THESIS

A PRELIMINARY COMPARISON OF THE ECONOMICS OF TWO WATER SUPPLY ALTERNATIVES FOR THE CITY OF FORT COLLINS

Submitted by

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ABSTRACT OF THESIS

A PRELIMINARY COMPARISON OF THE ECONOMICS OF TWO WATER SUPPLY ALTERNATIVES FOR THE CITY OF FORT COLLINS

It is the determination of this paper that the Joe Wright Project is more economical than the Installation of Water Meters as a water supply alternative for the city of Fort Collins.

Arriving at this conclusion required a brief review of the Joe Wright Project and an investigation of water meters and their effect on water consumption in Fort Collins. This required an examination of such local factors as population, housing and water consumption. It was also necessary to make various projections and assumptions to accomplish this end.

This report is intended as a preliminary study of the economics of these projects. The comparisons made here are based solely on a partial (in the sense that many side economic effects of the projects have not been considered) economic analysis. Therefore, financial considerations have been neglected. Specifically, this report compares the cost/AF of water produced or saved by the Joe Wright Project, the Joe Wright Project with one reuse and water meters with three different estimated water use reductions. Based on the analysis completed here, conclusions have been drawn in the hope that they will aid the City in its decision making process.

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INTRODUCTION

Fort Collins is a rapidly growing city located in Larimer County, Colorado. Currently it is the eighth largest city in the state. The rapid growth experienced in the last 20 years is evident from Figure 1. This recent growth coupled with the projected population growth made in this report (Table 1 and Appendix I), exhibits the need for the City to investigate future sources of raw water.

Presently, the city of Fort Collins has a more than adequate water supply to serve its current population of approximately 50,000 (including Colorado State University). In fact, the present supply is projected to be sufficient until the year 1996.[19] However, rapid population growth, increasing per capita consumption and limited availability of supplemental water sources have caused the city to investigate possible future water supply alternatives now.

At the outset of this project, three alternatives were to be considered. These included the Joe Wright Project, the Windy Gap Project, and the installation of water meters. However, since that time, the City has decided to develop the Joe Wright Project for city water and has transferred its rights in the Windy Gap Project will only be mentioned in the appendix. Therefore, the purpose of this report is to compare the Joe Wright Project with the installation of water meters in terms of their costs and water production or savings.

Because of the many factors influencing the outcome of an analysis such as this, many assumptions and qualifying conditions were necessary. Some of the more important of these have been listed here. First of all, the broad range of this study and difficulty in obtaining

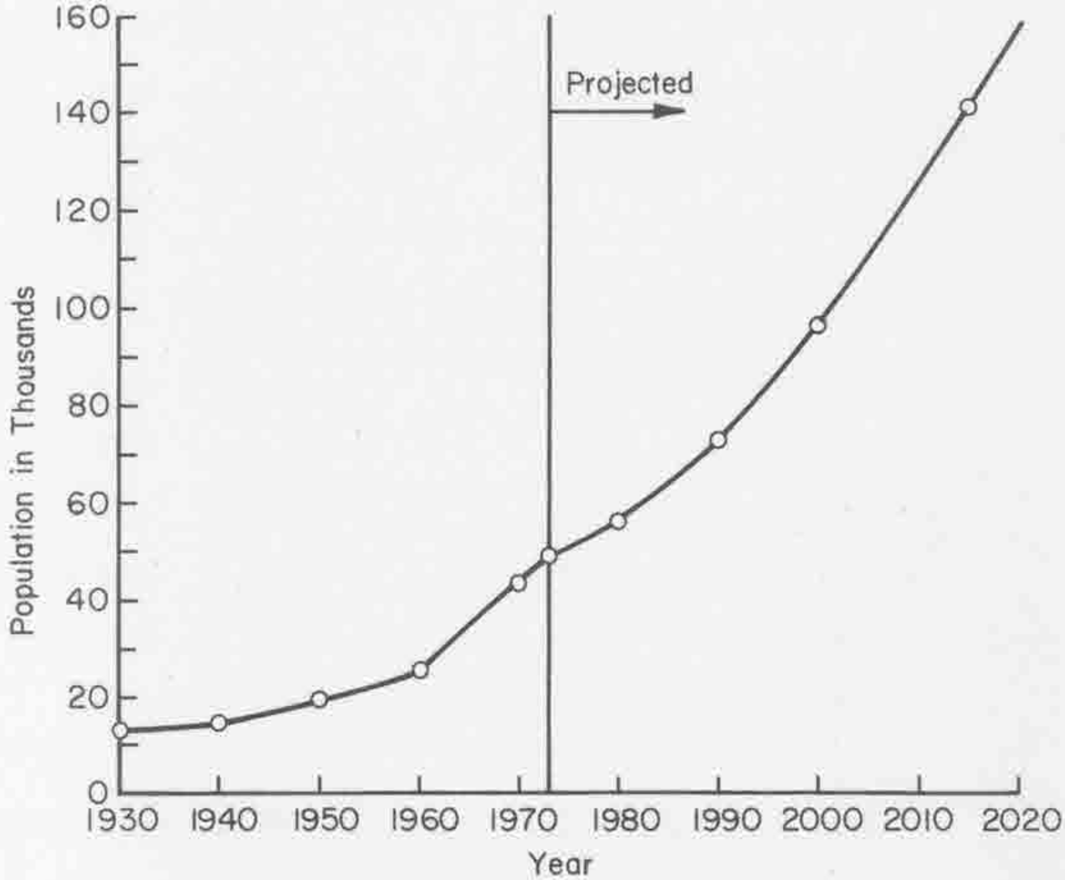


Figure 1. Population of Fort Collins, Colorado.

Table 1

Fort Collins Past and Projected Population[1]

Past

Year	Population[2]
1930	12,991
1940	14,308
1950	19,040
1960	25,027
1970	43,337

Projected

Year	Population
1980	56,000
1990	72,667
2000	96,000
2010	126,000
2020	158,000

[1] Projection made in Appendix I

[2] Population Includes Colorado State University Students

much of the data warrants the classification of this analysis as only a preliminary report. Furthermore, the investigation of water meters was done only in terms of examining them as a water supply alternative. Therefore, should the City seriously consider water meters in the future, an in depth analysis including metering experiments specifically for Fort Collins would be required.

Many qualifying assumptions were also necessary in order to complete the economic analysis. The most noteworthy of these is that this study was intended strictly as an economic analysis. Therefore, no financial aspects of these projects were considered. Additionally, secondary benefits such as savings in water treatment costs were not included. This also eliminated considering other effects of metering such as aesthetic values (no "environmental dollars" were considered). Costs for the Joe Wright Project were not given further investigation, even though these costs are a sensitive part of the economic analysis. Finally, all costs associated with metering are assumed to be paid by the City. In reality, this would probably not occur, since after the metering program was initiated, individual home owners would most likely pay for their own meters. However, this greatly simplified the analysis and would not appreciably affect the resultant cost in terms of dollars per acre-foot of water.

CHAPTER 1

PRESENT AND PROJECTED WATER SUPPLY NEEDS

A. Present Water Supply

The present total amount of raw water owned by the city of Fort Collins is 27,348.5 acre-feet (March 1974 figure). A breakdown of the sources of this water is given in Table 2. Basically, the majority of the Fort Collins usable municipal supply comes from a combination of water rights from the Colorado-Big Thompson Project, ditch and reservoir companies and direct flow rights on the Poudre River.

Specifically, the Poudre water rights amount to 15 cfs year-round and 4.93 cfs from April 15 to October 15 (Appendix X). The City lists its rights on the Poudre as averaging a yield of 8240 acre-feet. This is based on an average of the historical diversions that have been made at the City's water treatment plant No. 1. However, if one converts 15 cfs per year and 4.93 cfs for six months to acre-feet, a total of 12,643 acre-feet could possibly be obtained as an annual yield. One must be cautioned when using this figure, since it represents the total maximum possible yield of the City's rights on the Poudre. To obtain a truly reliable figure of the yield of these rights, a hydrologic study of the Poudre River would be necessary. However, according to the river commissioner, this would be a task requiring considerable time and effort, because of the difficulty in compiling the vast amount of data needed. Therefore, an assumption is made in order to arrive at a more representative figure for use in this report.

There is often not enough water in the river to permit diversion of all the Fort Collins' rights year round. Thus, according to the

Table 2

Raw Water Owned by Fort Collins--March 1974*

Source	Amount (AF)	Figure Used in This Report for Available Municipal Supply
Poudre River	8,240.0	11,016.0
Arthur Irrigation Co.	186.6	--
Northern Colo. Conservancy District	7,985.8	7,203.7
Larimer County No. 2	751.2	--
New Mercer Ditch Co.	360.8	--
Pleasant Valley & Lake Canal	3,725.9	--
Warren Reservoir	347.2	--
Water Supply & Storage	1,061.1	1,061.1
North Poudre Irrigation Co.	4,689.9	4,689.9
Total	27,348.5	23,970.7

*Source: Dept. of Public Works

river commissioner, the flow in winter is often so low that the City is not permitted to make a diversion of its lowest basin priority (basin priority No. 143; 4.50 cfs) and it is assumed that diversion of this priority is only permitted for half of the year. Therefore, converting the year-round rights (10.5 cfs/yr = 7602 AF/yr) and the six month rights (9.43 cfs/6 mo = 3414 AF/yr) gives a total yield of 11,016 AF/yr. This is the figure used in this report to represent the yield of the City's rights on the Poudre River.

A second portion of the City's water comes from stock owned in the Water Supply and Storage Company and the North Poudre Irrigation Company. This amounts to an annual figure of 5751 AF. However, water owned in these companies can only be used by exchange. The reason for this is that the point of diversion is downstream of water treatment plant No. 1 (WTP1). Therefore, in order to use this water at WTP1, it must be traded at some cost (the cost being water, i.e., 3 AF for 2 AF) for other water that can be utilized by WTP1.

A third major portion of the City's municipal water is obtained through contracted water produced by the Colorado-Big Thompson (CBT) Project. The project was originally designed to produce 310,000 AF/yr. However, because of shrinkage in the system and errors in hydrologic considerations on the western slope, the net production has historically averaged about 70 percent of the design figure or slightly over 200,000 AF/yr. When the project was developed, there were 310,000 units to be allotted among various users. The City owns 10,291 of these units. At 70 percent this amounts to 7204 AF/yr. The City uses a figure of 7985.5 AF/yr (which is based on a projected yield of 77.6 percent) in compiling the amount of water it owns. To be conservative, and based on a historical yield of 70 percent, the figure of 7204 AF/yr will be used in this report to represent the yield of the City's CBT shares.

The remaining water owned by the City from various other small sources amounts to 1646 AF. This water is not available for use in the City's municipal system because of unfavorable points of diversion.

It should be pointed out at this time that the total raw water supply of the City has been increasing year by year. This is shown in Figure 2 and Table 3. There are two reasons for this increase. One, the City will occasionally purchase additional water for various reasons. And two, as the City grows, it annexes more land. Much of this land has previously been used by agriculture, but is now becoming new housing developments. One of the prerequisites of annexation is the transfer of water rights to the City. Up to 3 AF per acre of land or the cash equivalent must be transferred before the land may be developed. Therefore, as the City grows in size, so does its raw water supply. The problem, however, is that the points of diversion are unusually unsatisfactory for use by the water treatment plants.

Based on the figures in column 3 of Table 2, it is assumed that the City's available municipal water supply amounts to 23,971 AF as of 1974.

B. Projected Consumption

A study done by McCall-Ellingson in 1972 used the figure of 23,314 AF as a firm estimate of the City's available municipal supply. They project that the City will need additional sources of water on line by 1996. This assumes a linear demand curve increasing by

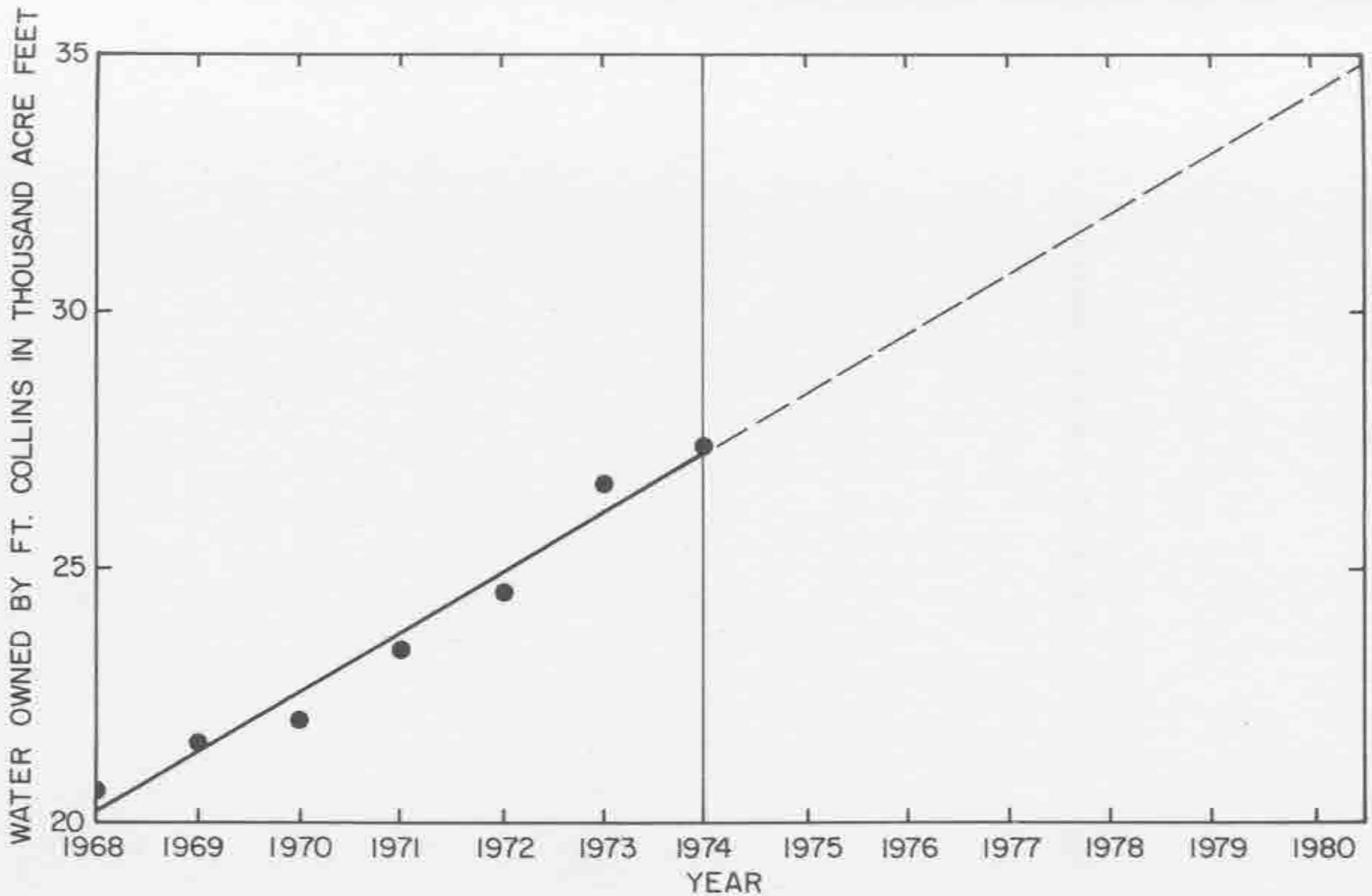


Figure 2. Projection of Increasing Fort Collins Raw Water Supply.

Table 3

Fort Collins Increasing Raw Water Supply*

(Through Purchase, Trade or Annexation)

Year	Amount (AF)
1968	20,630.7
1969	21,583.5
1970	22,081.0
1971	23,399.6
1972	24,536.8
1973	26,656.2
1974	27,348.5

*Source: Dept. of Public Works

486 AF/yr. A water consumption projection has been made in this report (Appendix II). The results are shown in Figure 3.

Using the population and water consumption projections made in this report (Appendixes I and II) the projected per capita consumption has been calculated and is listed in Table 4. Also listed is the estimated per capita consumption given by the Department of Public Works. These figures indicate a leveling off or decrease in the future per capita consumption. This decrease is probably caused by the growing popularity of apartment and condominium living over private homes. Data from the Fort Collins and Boulder (a city very similar to Fort Collins) Building Departments show that in recent years more apartment units than single family units have been built (Appendixes VIII and IX). Apartment dwellers use considerably less water than single or double family residences. A report done by Linaweaver states that the average annual apartment use for five study areas in the U.S. was 191 gallons per day per dwelling unit (gpd/du), while metered single and double family residence use in the west was 458 gpd/du (17). Therefore, if the present trend continues, per capita consumption should indeed decrease.

C. The Need to Supplement Present Supplies Now

With a present water supply adequate through 1996, why look for new supplies now? There are two basic arguments for this. First, the acquisition of additional water rights is not a simple thing. New sources of water for municipal development are very scarce and difficult to obtain. If water is available, it is often in the best interest of a municipality to develop this water for future use.

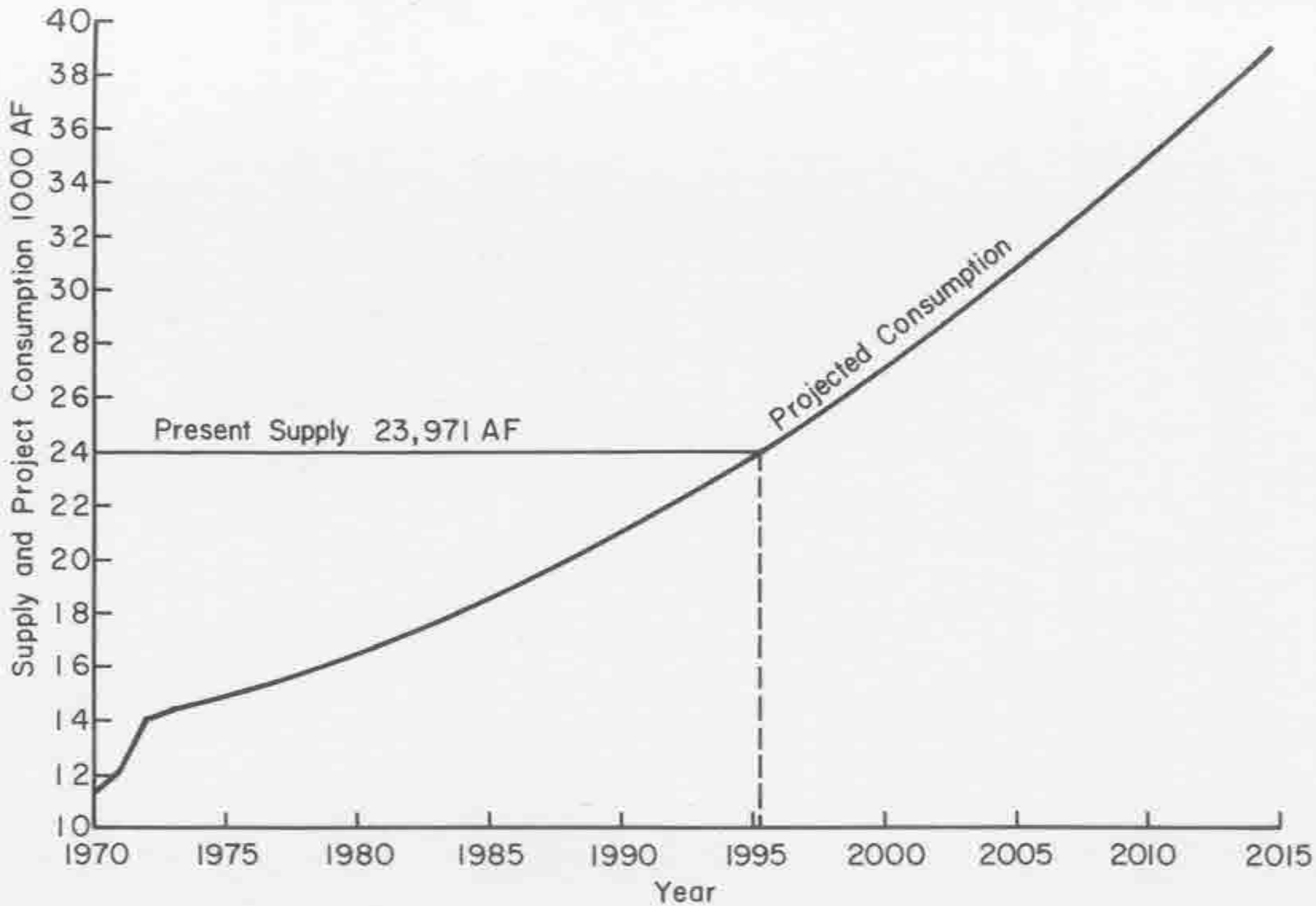


Figure 3. Projected Water Consumption for Fort Collins.

Table 4

Fort Collins Per Capita Consumption

Year	Per Capita Consumption Gal/Capita/Day	
1930	252	
1940	255	
1950	278	
1960	306	
1970	233	
1980	200[1]	262[2]
1990	180[1]	257[2]
2000	170[1]	251[2]
2010	---	252[2]

[1] From Fort Collins Dept. of Public Works

[2] From Projections of Population and Water Comsumption made in this report - Appendixes I and II

The City has acquired access to some additional water rights through the potential Windy Gap Project and the purchase of Joe Wright Reservoir. However, recent developments have caused the City to transfer its rights in Windy Gap to the Platte River Power Authority and choose Joe Wright as the project it intends to implement. In order to keep from forfeiting its rights in Joe Wright the City must use them or show due diligence in attempting to develop them. Up to this point the City has done this. A feasibility study has been done on the enlargement of Joe Wright Reservoir and the City is now in the process of having an environmental impact statement prepared. The next step would be actual design which would have to take place shortly after the impact statement is completed. Development of this project at this time will bring Joe Wright into use before it is actually needed. In other words, if the City wishes to assure its use of these supplies for future water, they must be developed now.

Secondly, demand for water in this area has been constantly increasing. This increase in demand has brought about an accompanying increase in the cost of obtaining water. If the City knows there will be a need for additional water in the future, and has access to water, it should make arrangements to develop it. Water rights not developed now are likely to be either in greater demand in the future and therefore at a higher cost or will undoubtedly be developed by someone else.

An additional reason should be included here. Recently, the capacity of the City's WTP1 was increased to 20 MGD (or 31 cfs). The City's water rights on the Poudre River amount to 19.93 cfs from April 15 to October 15. This is equivalent to 12.85 MGD. Thus, the river plant capacity (WTP1) is greater than the amount of water it can take from the river. To eliminate this problem, the City would either have to develop additional water supplies above WTP1 or it must acquire more water to transfer there (Figure 4 shows map of Fort Collins water system).

Thus, basically, the problem facing the city of Fort Collins is to somehow meet the future demand for water with an adequate supply. In other words it must be assured that the supply is always equal to or greater than the demand. There are two ways to accomplish this. One, the City can seek out new sources of supply that will always be greater than demand. Or two, the City can in some way regulate demand so that it does not exceed the supply, thereby delaying the need to develop additional supplies.

The first alternative to be discussed here is the Joe Wright Project. It provides an additional quantity of water (by storage) to meet demand. The second alternative, the installation of water meters, will reduce demand for water also reducing the amount of water needed to meet future consumption requirements. The purpose of this study is to compare these projects from an economic point of view. However, there are aspects of each that cannot be readily considered in terms of dollars and cents. An attempt will be made to mention some of these in addition to the economic advantages and disadvantages.

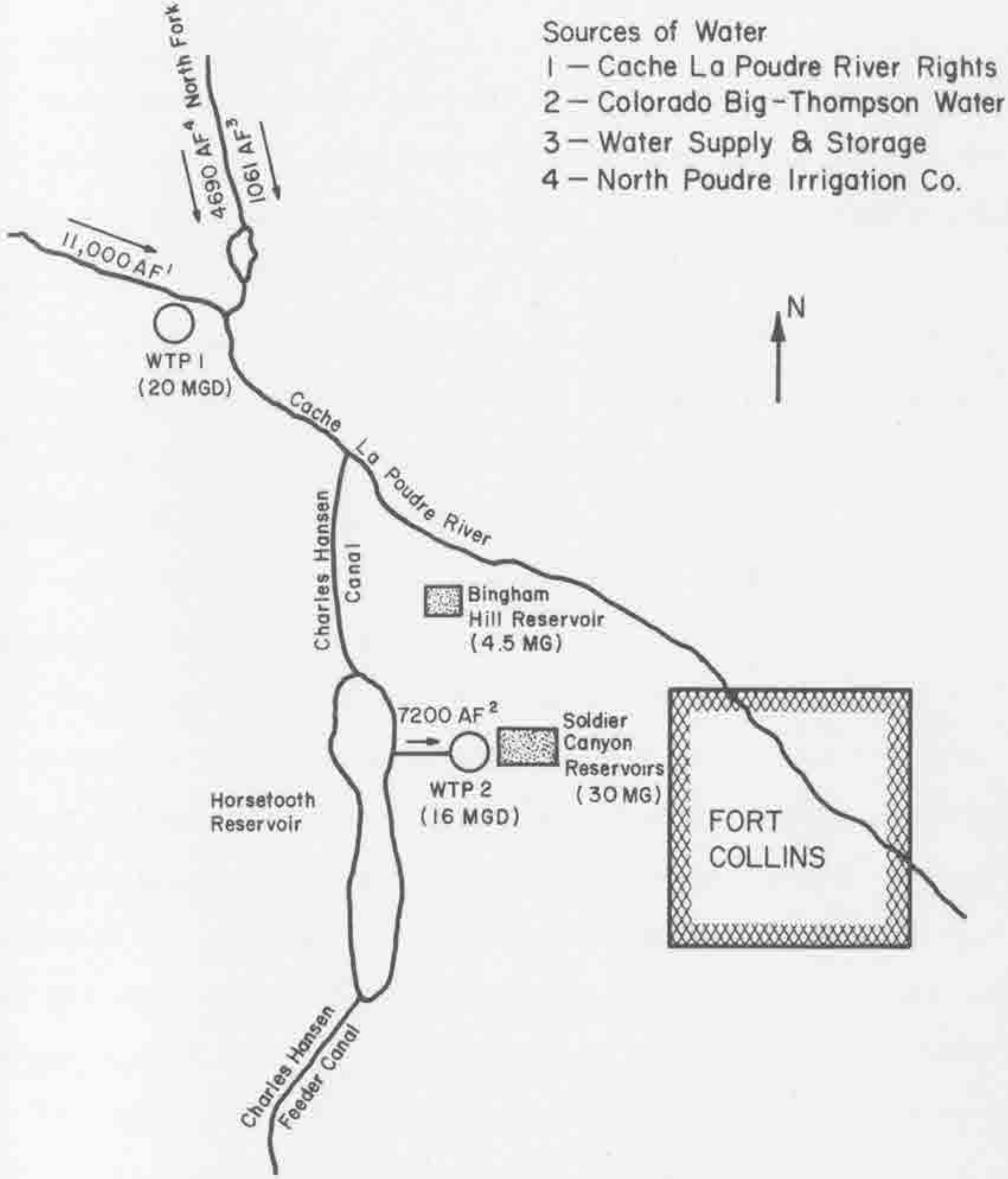


Figure 4. The Fort Collins Water System.

CHAPTER 2

THE JOE WRIGHT PROJECT

A. Project Description

The present Joe Wright Reservoir is located three miles northeast of Cameron Pass and 65 miles west of Fort Collins (Figure 5). It was acquired by the City in February of 1971. The present storage capacity, with repairs, is 800 AF.

The Joe Wright Project is simply an enlargement of the present Joe Wright Dam and Reservoir. There are three alternate plans given by McCall-Ellingson for this project (listed in Appendix V). The largest of the projects is considered the most favorable. The projected 1976 construction cost of the Joe Wright Project is $4,925,328 (see Appendix VII for the cost projection).

The implementation of this project would give the City more flexibility in its water system operation. At the present time, the city of Fort Collins has no high mountain storage. However, Joe Wright would give the City the option of storing water during times of high flow until it is needed. The net storage capacity created would be 6455 AF. This water would come from such sources as the Michigan and Cameron Ditches, the basin above Joe Wright and any additional water the City could obtain through purchase or exchange. Figure 6 shows the Fort Collins system with Joe Wright. The addition of this water to the Fort Collins system is projected to meet demand until 2005 (Figure 7).

B. Michigan Ditch Yield

The Michigan Ditch is presently owned by the City and a renovation is currently under way. Historically, diversions through it have

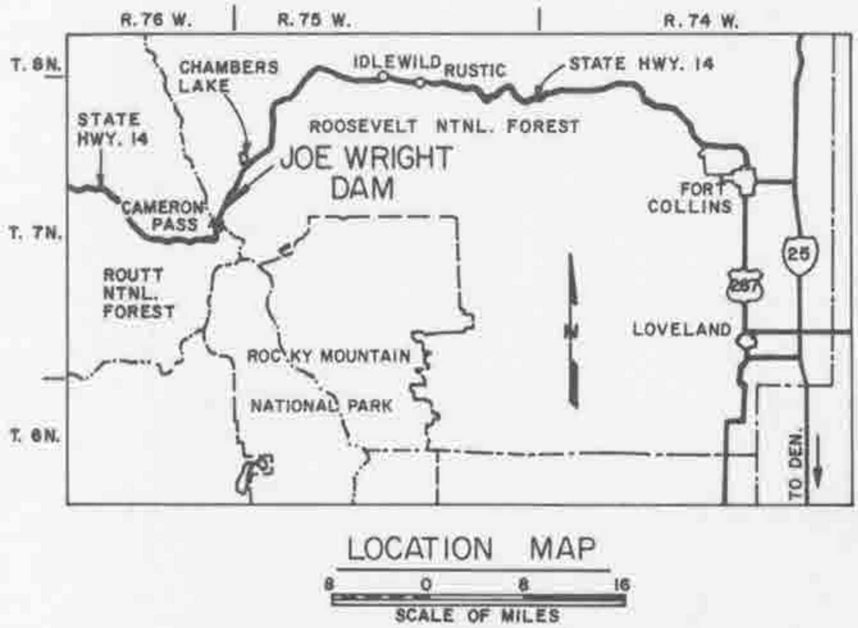


Figure 5. The location of Joe Wright Reservoir.

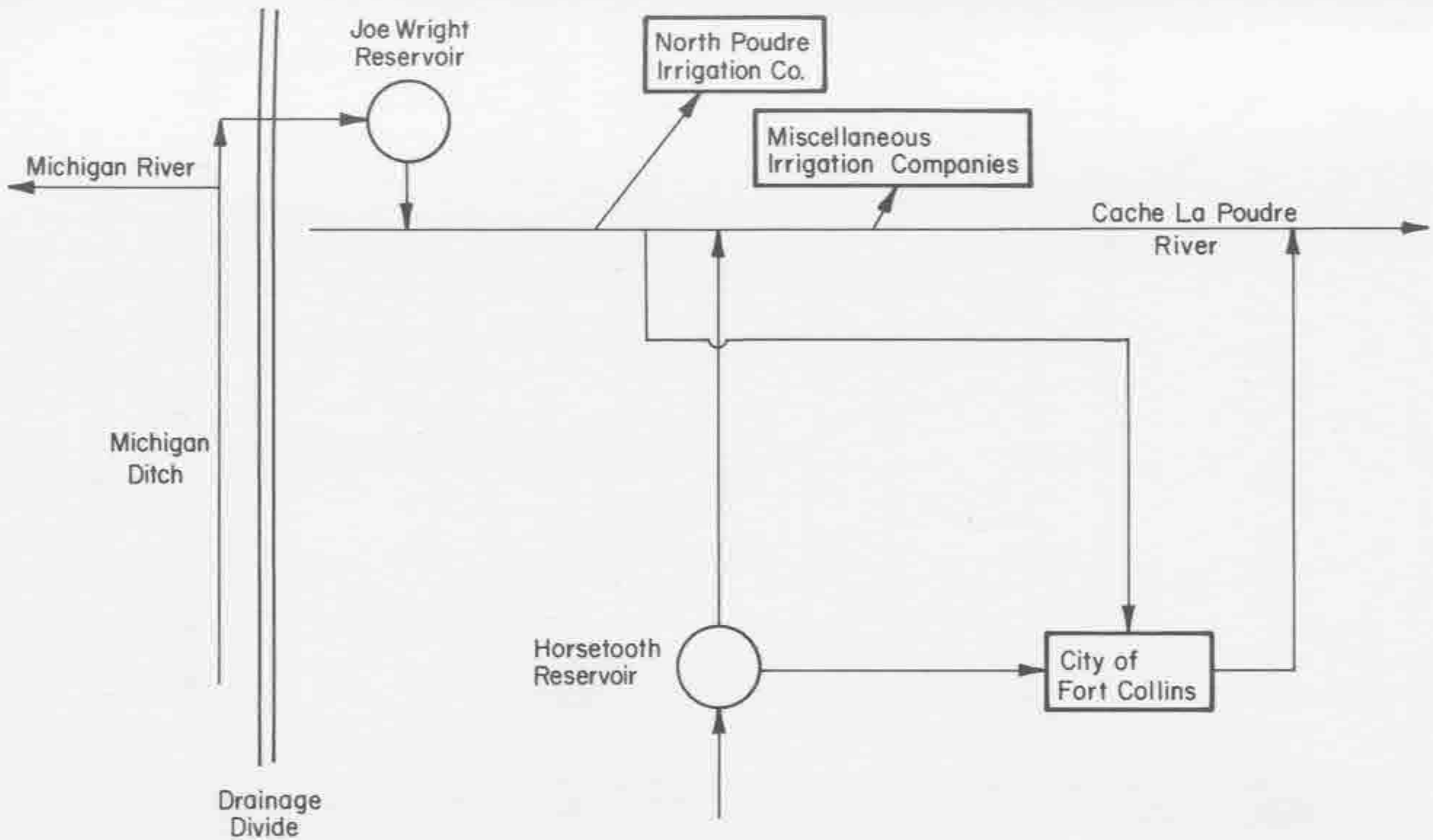


Figure 6. The Fort Collins Water System with Joe Wright.

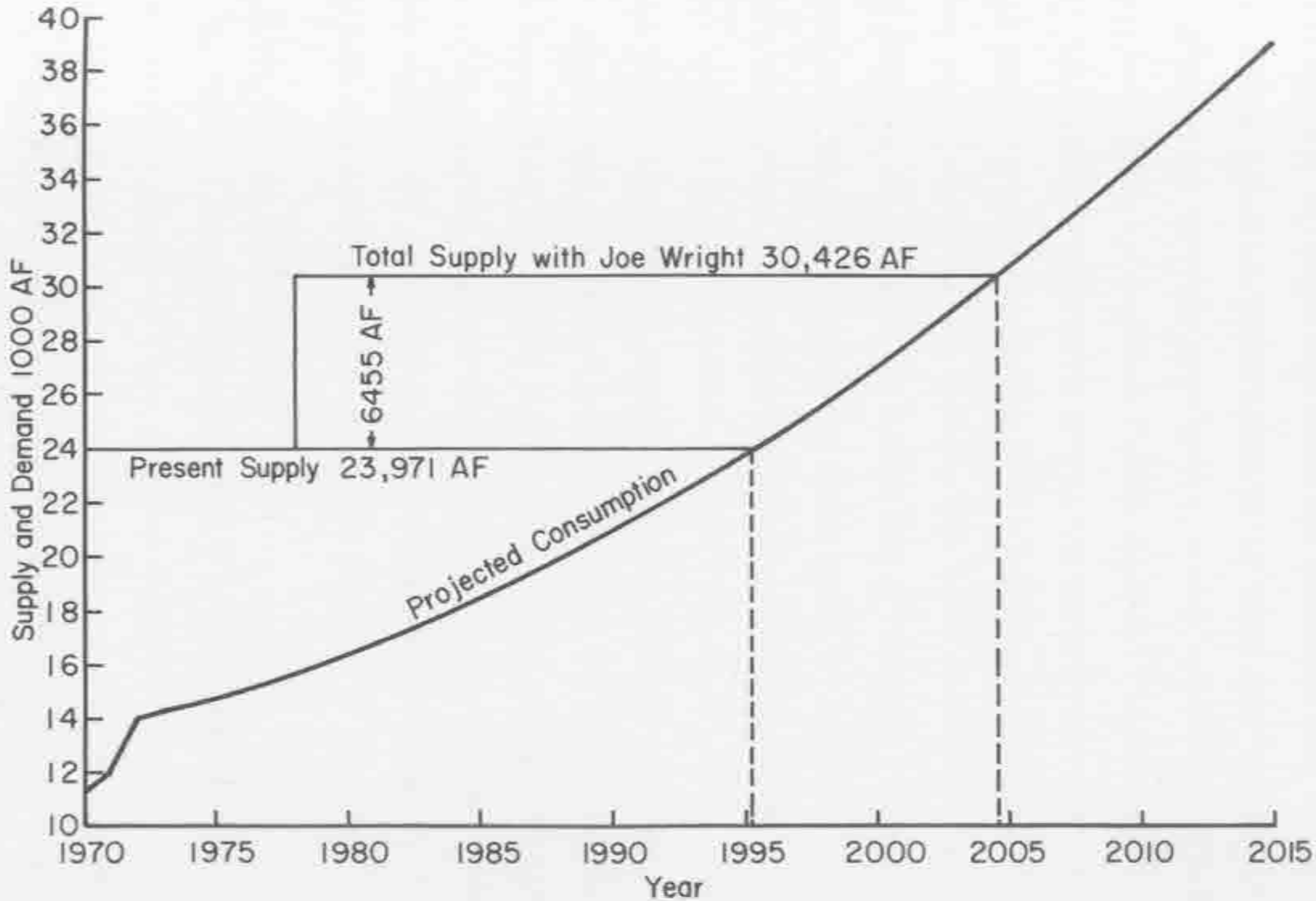


Figure 7. Water Supply and Consumption with Joe Wright.

averaged only 2467 AF. However, this includes diversions at times when the ditch was not maintained at its ultimate capacity. In a report to the City in 1972, Bittinger and Associates estimated that fully maintained and operated, the Michigan Ditch could yield 4500 AF/yr. Since this may not be fully practicable, a more conservative figure of 3000 AF/yr is given in the March-Fischer Report.[20] Diversions through the Michigan Ditch originate in the North Platte River Basin and are generally permitted during high flows from April through July. In other words, diversion can usually take place at times when the Poudre River is also flowing at a high rate. Therefore, unless it can be shown that the diverted Michigan Ditch water can be used, the Division Engineer of irrigation division No. 1 (which includes the Poudre) will not permit diversion. This is one of the major reasons why Joe Wright Reservoir is needed. With its storage capacity far up the Poudre Canyon, this water could be diverted and stored for use at a later date. There is a legal limitation restricting the amount of water being diverted from the North Platte River Basin. It states that no more than 60,000 AF may be diverted during any ten year period. Diversions must average no more than 6000 AF/yr.

C. Reuse for Joe Wright Water

The right to reuse certain water is a law of Colorado. Specifically, it gives the right to reuse any water that is foreign to the watershed where this water is used. Since the Joe Wright Project imports foreign water from the North Platte River Basin into the Poudre River Watershed, the law is applicable to this project and that imported water is eligible for reuse.

At this point in time the City is hoping for a ruling of 50 percent reuse. In other words if 4000 AF of foreign water is introduced into the system, 2000 of it will be eligible for reuse. Then 50 percent of that figure can be reused for extra 1000 AF, and so on. Therefore, assuming all the water produced by this project can be reused, the following table is obtained:

Table 5

Reuse of Joe Wright Water

Original Supply (AF)	6,455	
1 Reuse	3,228	
2 Reuses	1,614	Yield Per Reuse
3 Reuses	807	
4 Reuses	403	
--------	---	
∞Reuses	12,910	Total Available Yield

This reuse is possible via two techniques. The first is to physically transport water available to be reused by way of a pipeline from the sewage treatment plant back to the water treatment plant to be reintroduced into the City's water system. This technique would probably not be used because of its high cost. The second method is through transfer or exchange of water rights. This would involve trading the water available for reuse, that is leaving the sewage treatment plant to a downstream water user for water that could be diverted at one of the City's water treatment plants. This method is the one that would be most likely adopted by the City should it implement a reuse program.

Table 5 shows the significance of reusing water from this project. Theoretically an infinite number of reuses doubles the original supply. This report will consider only one reuse of the eligible supply. Since the limitation on importing water through the Michigan and Cameron Ditches is an average of 60,000 AF for any ten year period, the maximum amount available for actual reuse is 6000 AF/yr. Assuming one reuse, this could give Fort Collins the additional supply of 3000 AF/yr. This being the case, the Joe Wright Project could produce 9455 AF/yr (Figure 8). The economic analysis will consider this project both with and without reuse.

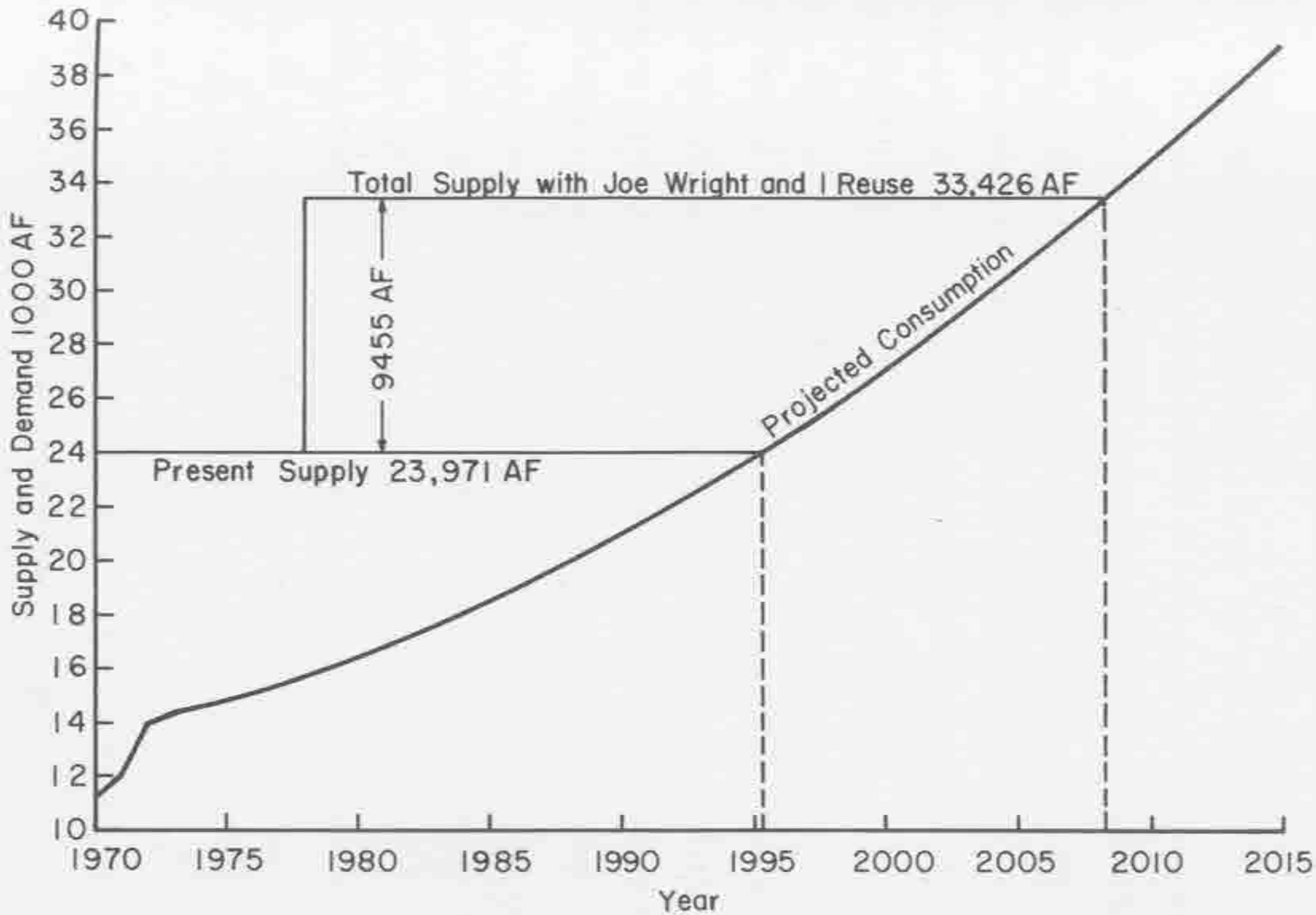


Figure 8. Water Supply and Consumption with Joe Wright and 1 Reuse.

CHAPTER 3

GENERAL LITERATURE REVIEW OF PREVIOUS METERING STUDIES

A. Reasons for Water Meters

The other alternative considered here is the installation of water meters. The immediate question to answer is why consider water meters at all? The literature proposes two ideas. One, selling water by measurement is the only fair and equitable way to sell water.[(5)] And, two, the installation of meters brings about a reduction in demand--a lower per capita consumptive use.[(13)]

First, let's examine the way people pay for water now. Currently the city of Fort Collins is about 10 percent metered (figure from Dept. of Public Works). This 10 percent includes some single family and duplex dwellings and all commercial, trailer and apartment dwellings. Additionally, all water service outside the City is metered resulting in approximately 20 percent of the total Fort Collins water service being metered. This means that the majority of the water users served by the City are charged for water under a flat rate system. This entitles the user to use as much water as he pleases with no additional charge. This charge is \$3.00/mo for single family and duplex dwellings, plus \$2.55/mo for lots ranging from 6000-9000 ft^2 in area. So, 80 percent of the water users in Fort Collins pay an amount similar to this and may use as much water as they please. The other 20 percent pay according to rates similar to these:

Table 6

Fort Collins Metered Rates

Monthly Usage (gal.)	Cost
First 2000	\$3.00/mo.
Over 2000	\$.24/1000 gal.

The simultaneous operation of these two rate structures could be considered by many as an inequitable system. However, the inequities within the flat rate system itself could be considered even greater. For instance, family 1 could consist of two older people living in an older home with a small yard (say 6000 ft^2 in area). Then consider family 2, a family of five with a larger lot (say 9000 ft^2), possibly two cars and a newer house with all the modern water consuming conveniences. Family 2 has more lawn to water and two cars to keep clean in addition to the extra domestic (in house) use. Yet the charge to both families is \$5.55/mo. Because these rates are averaged over all the water users to supply sufficient revenue to pay for the water produced, family 1 is in essence paying for some of the water family 2 uses. A similar comparison could be made between a metered account and a flat rate account, but because of the small number of metered accounts, this comparison is not significant at this time.

The second reason for the installation of water meters is the accompanying reduction in demand. The reduction in demand is not caused by metering per se, but rather is a function of a variable price that has been attached to metering which brings about a response from the consumer.(12) The drop in demand can bring about two main benefits. One, it eliminates (or postpones) the cost of expanding present facilities in terms of raw water supply and treatment. And secondly, in the long run it will result in lower peak to average demand ratios, meaning smaller systems can be designed and implemented.

Any of these benefits are a result of the price attached to water not of the meters themselves. "There is ample evidence that higher prices do moderate residential demands for water...results do support the proposition that an increase in relative price will be followed by a drop in quantity demanded."[5] Since it is this cost that changes demand, the type of pricing structure that is applied to metering is a point that deserves consideration at this time.

Three types of pricing systems will be mentioned here. They include a flat-rate system, a uniform pricing system, and a block-rate system.

A flat-rate system can be defined as one that charges a fixed fee for water services over some period of time, regardless of the quantity of water that is used. The main advantages of this system are that it is inexpensive and its application and administration are quite simple; the reason being that there are no meters to install, maintain, read, or bill. However, there are two major opposing views to a flat-rate system. The first is that some regard it as an unfair method of distributing the cost of supplying water. And secondly, it leads to inefficient and even wasteful use of water.

A uniform pricing system is one that charges the same price for each gallon of water no matter what quantity is used. It has an advantage in that it provides greater revenue as use increases (compared to flat-rate or declining block-rate pricing systems). The main disadvantages are that off-peak users subsidize peak users and that users living in high density areas subsidize users living in low density areas away from load centers. However, this system is not widely used in this country.

The third type of pricing system is block-rate price scheduling. This means that different rates are charged for quantities of water used, with the cost increasing or decreasing as more water is used. Declining block-rates are very popular in the United States at this time. Under this system, the cost per quantity of water that is used decreases as more and more water is used. This could be considered an illogical way to sell water. However, there are..."two reasons why water utilities can sell water in a declining block-rate when consumption is increased:

1- the savings involved in transporting large quantities of water to a single point, and

2- the better than average load factor of large water users, i.e., more uniform use of water."[(5)]

The increasing block-rate structure is not very popular in the United States at this time, but with the overall demand for water continually rising and the increasing difficulty of developing new supplies, some utilities have begun to give this alternative serious consideration.

In "Evaluation of the Use of Pricing as a Tool for Conserving Water,"[(5)] a rate structure is proposed that attempts to give rise to efficient use of water and at the same time also sell water in an equitable manner. The rate structure would consist of two parts. The first part is a "commodity cost" to cover the costs of producing water. The second is a "capacity cost" to meet the costs of developing the necessary capacity required by the demand. The proposed rate structure suggests using an increasing block-rate schedule to offset normal commodity costs and a seasonal peak load rate schedule to offset capacity costs. This amounts to a two part seasonal price structure whereby different rates are charged during the off-peak winter period than are charged during the summer peak period. The contention is that this would be a fair and equitable way to sell water and at the same time would promote an efficient use of water.

This short discussion on pricing water is necessary to give exposure to the types of pricing systems and to show the importance of the type of rate structure employed by a water utility. In terms of metering, since their purpose is usually to conserve water or make more efficient use of it, the rate structure chosen should be consistent with that purpose. This point deserves serious consideration when a city implements a universal metering program.

B. Water Consumption Reductions in Other Cities

Do meters result in a reduction in water consumption? This question is answered by examining some municipalities that have gone to universal metering. Here are three examples. In 1931, Elizabeth City, North Carolina distributed an average of 1,800,000 gal/day on a flat-rate basis. The installation of water meters reduced this figure to 300,000 gal/day; a reduction of 83 percent.(5) In 1957, Kingston, New York had an average water use of 5.47 MGD. After metering, water use dropped to 4.0 MGD; a drop of 27 percent.(5) And finally closer to home, universal metering at Boulder, Colorado resulted in annual use being reduced by 34 percent.(8) These examples can leave no doubt as to the effect metering has upon water consumption.

Of course it is true that there are other factors that may have influenced this reduction in demand. For instance, the installation of meters in Elizabeth City, North Carolina in 1931 occurred during the depression years. This would explain the extremely high figure; 83 percent. It does show, however, that pricing water causes a change in the use pattern, the degree of which probably depends on the financial position of the consumer. Therefore, meters may bring about differing degrees of response, depending on the influencing factors.

C. Some Characteristics of Metered Use from the Linaweaver Study of Residential Water Use

A study done for the U.S. Dept. of Housing and Urban Development, "A Study of Residential Water Use" gives the following data for residential water use:

Table 7

Summary of Residential Water Use

Type of Study Area	Mean of Annual Uses	Mean of Maximum Daily Uses	Mean of Peak Hourly Uses
	(gallons per day per dwelling unit)		
Metered public water and public sewers			
West (10 areas)	458	979	2,481
East (13 areas)	310	786	1,833
Flat-rate public water and public sewers			
(8 areas)	692	2,354	5,170

Source: "A Study of Residential Water Use," Reference (17), p. 12 (Entire table presented in Appendix XIV)

The conclusions to be drawn from this table are:

1. Flat-rate use is higher than metered-rate use.
2. Peak hourly use for flat-rate areas is twice as much as that of metered areas.
3. Water use in the West is higher than use in the East.

The reason for the differences in these figures is a result of the different amount of lawn sprinkling that is done. When residential use is divided into domestic (in house) use and sprinkling use, it is evident that sprinkling accounts for the difference. Table 8 shows domestic use. Note that the figures for flat-rate and metered-rate use in the West are nearly identical.

Table 8

Summary of Domestic (Household) Use

Type of Study Area	Mean of Annual Uses	Mean of Maximum Daily Uses	Mean of Peak Hourly Uses
	(gallons per day per dwelling unit)		
Metered public water and public sewers			
West (10 areas)	247	454	1,214
East (13 areas)	209	271	536
Flat-rate public water and public sewers			
(8 areas)	236	431	1,016

Source: "A Study of Residential Water Use", Reference (17), p. 19. (Entire table presented in Appendix XIV)

Table 9 compares sprinkling use for metered and flat-rate price systems. It shows the amount of use to be quite different. In fact, flat-rate use is at least double the metered use. Therefore, metering affects how much people sprinkle, but has little effect on their domestic use--their essential use of water. People will still take showers and use their dishwashers. Some may try to conserve the amount of water they use domestically. But even if they are successful, it may not amount to a significant quantity. It does, however, show that metering does result in an attempt to use water more efficiently.

Table 9

Summary of Sprinkling Use

Type of Study Area	Mean of Annual Uses	Mean of Maximum Daily Uses	Mean of Peak Hourly Uses
	(gallons per day per dwelling unit)		
Metered public water and public sewers			
West (10 areas)	186	707	2,076
East (13 areas)	80	556	1,534
Flat-rate public water and public sewers			
(8 areas)	420	2,083	4,812

Source: "A Study of Residential Water Use," Reference (17), p. 21. (Entire table presented in Appendix XIV)

If metering reduces sprinkling use, what are the consequences of this effect? Will people stop watering their lawns and let everything turn brown? This has not occurred to any great extent. However, it has been shown that some people will let parts of their lawn turn brown.

Table 10 shows the difference between actual lawn sprinkling and potential lawn sprinkling (or "ideal sprinkling"; see Appendix XV). Hanke has defined "ideal sprinkling" as the "amount of water that should be applied to a given yard to maintain its aesthetic quality, a green appearance."(13)

It is evident from Table 10 that in flat-rate areas, more water is applied than is actually needed. In fact, the quantity applied is 2 1/2 times greater than the quantity required. This excess water is lost from the City's water system through infiltration, runoff and evapotranspiration. Table 10 also shows that in the metered areas

Table 10

Comparison of Metered versus Flat-Rate Use

	Metered Areas (10)	Flat-Rate Areas (7)
	(inches of water)	
Annual		
Actual Lawn Sprinkling	14.0	39.4
Potential Sprinkling Requirements	22.5	14.8
Summer		
Actual Lawn Sprinkling	7.4	24.5
Potential Sprinkling Requirements	11.5	10.3

Source: "A Study of Residential Water Use," Reference (17), p. 50. (Entire table presented in Appendix XIV)

studied, actual sprinkling does not meet the potential sprinkling requirements. Thus, based on these figures, it appears that at least parts of the lawn do not receive sufficient water from sprinkling to maintain that aesthetic green appearance.

To determine the actual quantity of excess water lost in flat-rate areas, the potential evapotranspiration must be calculated. This has been determined for the study areas in Table 11.

Note that the flat-rate lawn sprinkling exceeds the potential lawn sprinkling requirements by 24.6 in. Additionally, the amount of water used for sprinkling exceeds the potential evapotranspiration by 14 in. per year. This excess is lost through infiltration and runoff. If 6229 sq ft is taken as an average value for irrigable area per dwelling unit in Fort Collins (this figure is an average of .140 acres per dwelling unit from Hanke's study of Boulder and .146 acres per

Table 11

Comparison of Actual Lawn Sprinkling and Potential Lawn Sprinkling Requirements

Type of Study Area	Annual	Summer (inches of water)	Maximum Day
Flat-rate public water and public sewers			
(8 areas)			
Potential Evapotranspiration	25.4	14.7	0.29
Potential Lawn Sprinkling Requirement	14.8	10.3	0.29
Lawn Sprinkling	39.4	24.5	0.51

dwelling unit from the Linaweaver report of eight areas under a flat-rate pricing system), this amounts to an excess of 54,366 gal per dwelling unit. In 1973 there were 9678 one and two family dwelling units in Fort Collins. Their loss amounts to 526.2 million gal per year (1615)! The installation of meters would result in a more efficient use of water and eliminate much of this loss.

D. Results of Metering in Boulder, Colorado

A paper by Hanke done in 1969 showed that universal metering in Boulder caused actual sprinkling to drop down to or below ideal sprinkling (Figures 9-11 are data from three metered routes in Boulder). This specifically shows that metering can bring about a more efficient use of water.

The next question to answer, and a very important one too, is that once demand had been reduced, will it remain at that level? "The majority of writers feel that the reduction is only temporary and that the original impact will wear off, with consumers eventually finding a

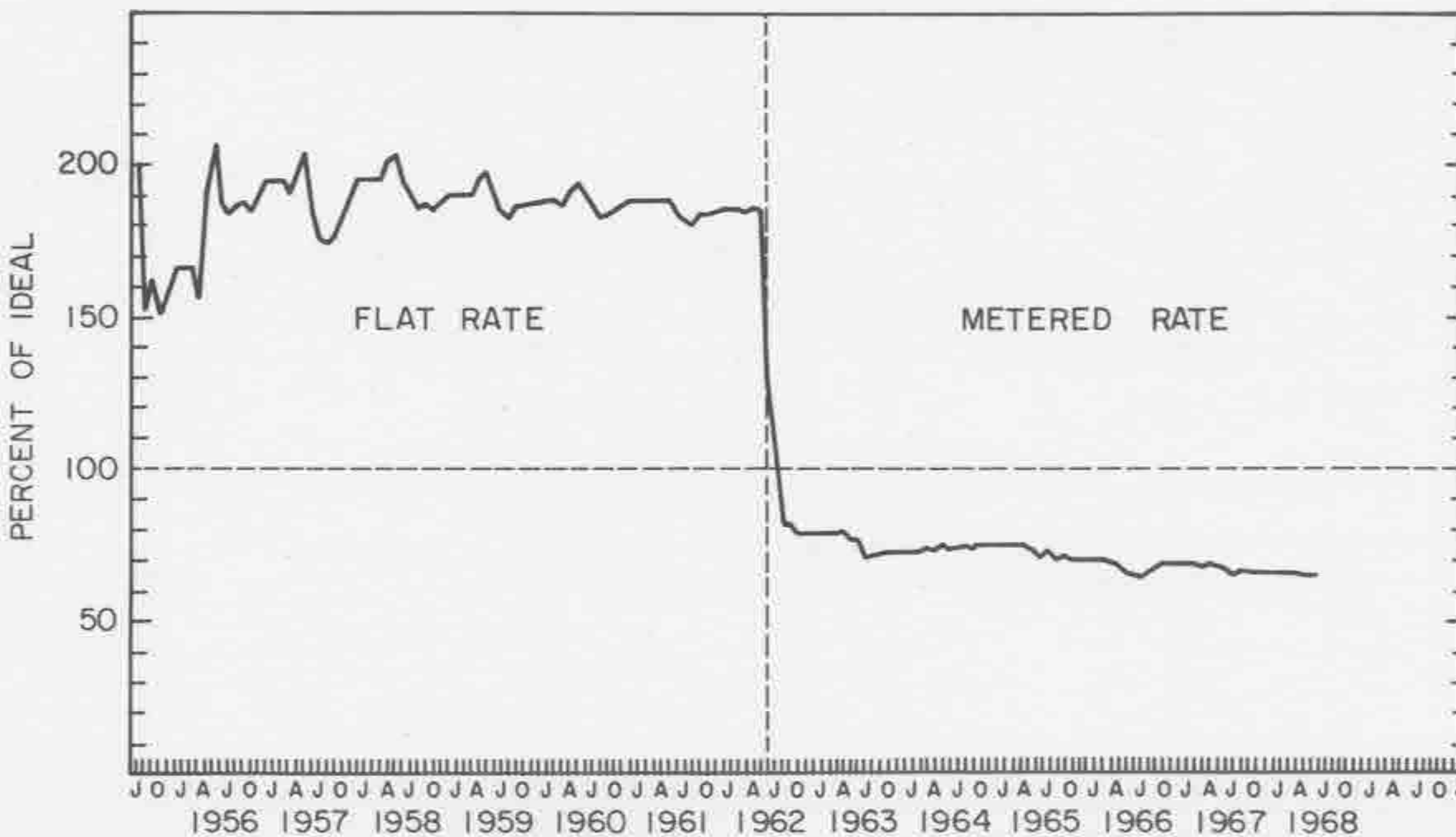


Figure 9. The Effect of Metering on Sprinkling at Boulder, Colorado.

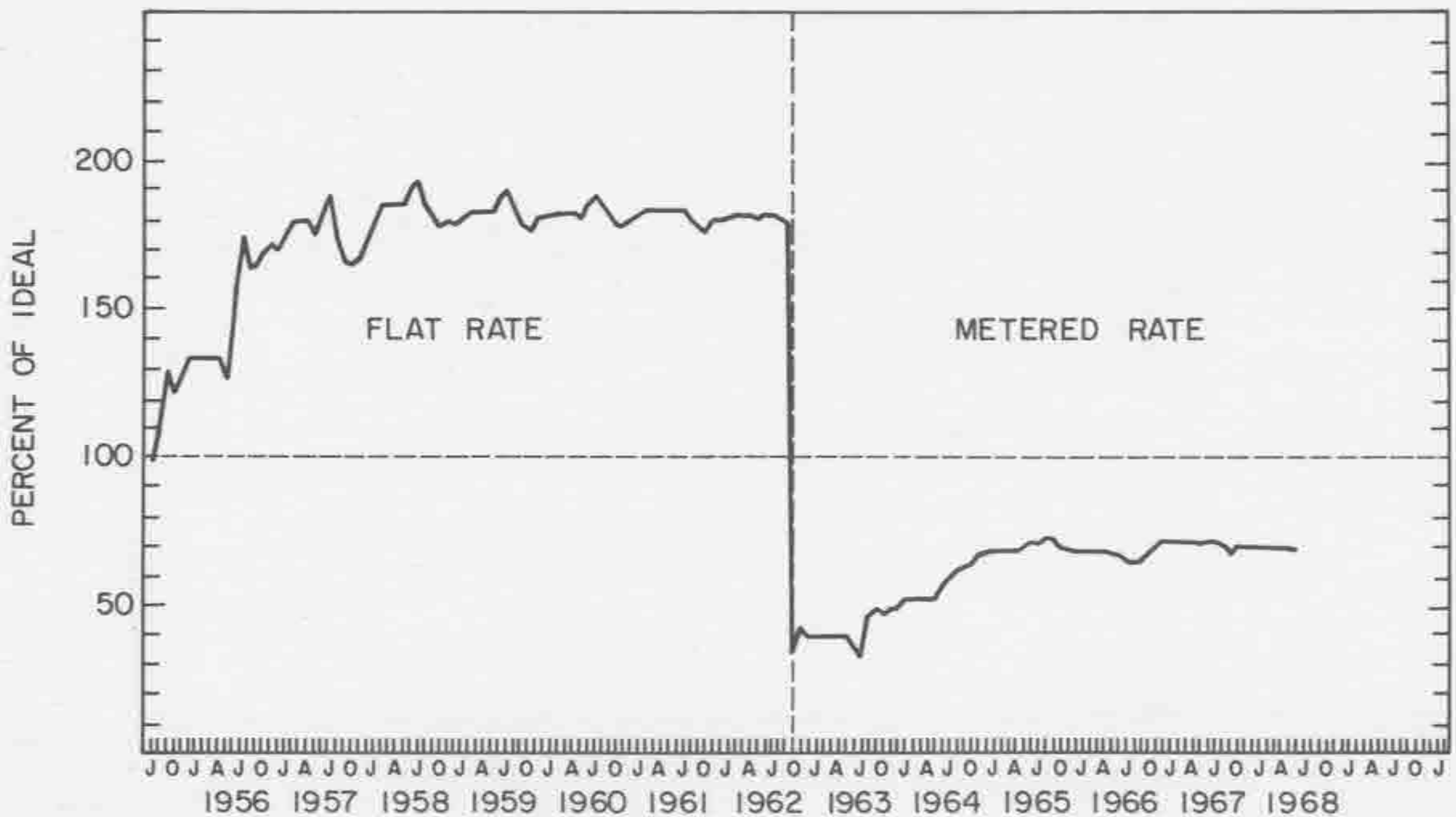


Figure 10. The Effect of Metering on Sprinkling at Boulder, Colorado.

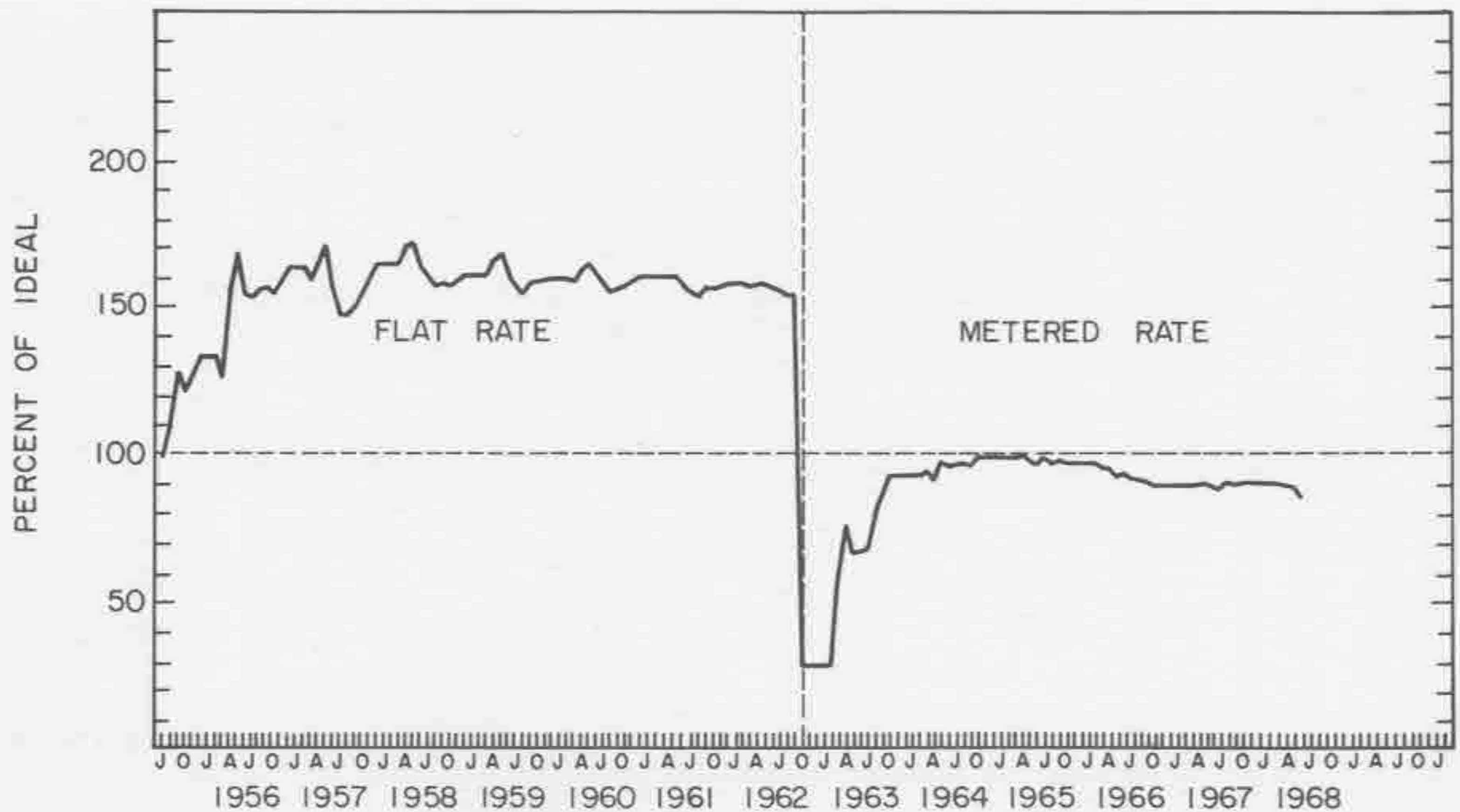


Figure 11. The Effect of Metering on Sprinkling at Boulder, Colorado.

new equilibrium between price and amount of water used."[5] However, Hanke states that per capita use can change over time being influenced by such things as changing tastes, increased incomes, population increases and alterations of habits.[13] He has given the curve in Figure 12 to indicate this. He contends that per capita use has been increasing regardless of the price structure. This increase may be attributed to such modern conveniences as dishwashers, garbage disposals, etc. These all use water and are bound to increase per capita consumption.

Referring to Figure 12:

Q_{fr} = consumption under a flat-rate system--the effective price of water equals 0

Q_m = consumption under a metered system--the effective price of water being P_m

In 1965 when the entire system became metered, demand was reduced from Q_{fr} to Q_m. This is represented by the line labeled D_{1965}. However, after three years the demand curve has shifted to the right (labeled C_{1968}). At this point demand has reached Q_{fr} again. The general conclusion often made at this time is that the effect of metering has worn off. But this is not the case! If the flat-rate had still existed, the demand would now be at Q'_{fr}!

Hanke considered Boulder data after metering for only six years until 1968. He concluded that demand drops to a lower level under metering and never returns to its original level under a flat-rate system. Figures 9 through 11 show his data collected for selected metered routes in Boulder. These figures show that sprinkling demand dropped to near or below the ideal use. Several routes recovered some

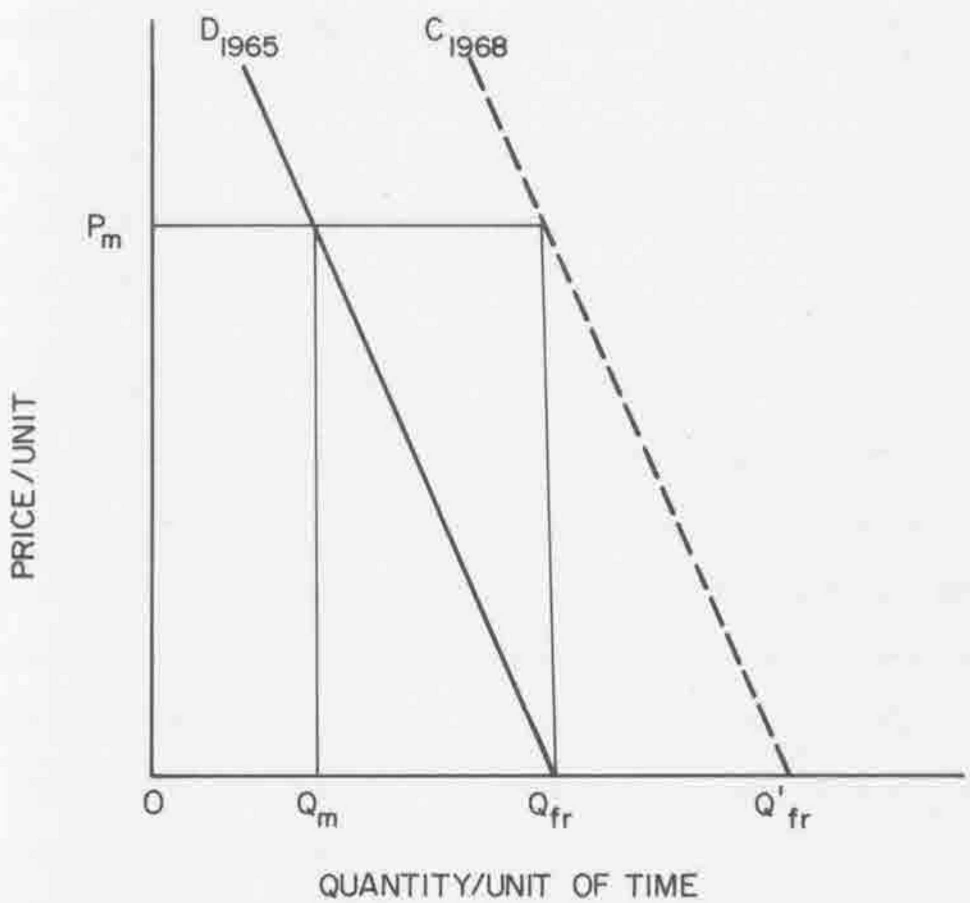


Figure 12. The Demand-Price Relationship of Water Consumption.

after an initial drop, but never to their original level. The reduction in sprinkling was the major factor accounting for his figure of 34 percent reduction in water use.

Hanke's study consisted of an in depth look at residential water use. So his figure of 34 percent is only applicable to residential use, not to the entire city's consumption. There are additional uses for water that are not affected by universal metering such as watering parks and golf courses, apartment use, street cleaning, etc. Therefore, one must be careful in applying this figure of 34 percent to the installation of meters in other areas. It is not a reduction to be applied to the total water system!

E. The Effect of Metering on Total Water Production at Boulder, Colorado

Examining the total water produced by the Boulder water treatment plant since 1953, one can see a significant drop after the introduction of meters (Figures 13 and 14). The reduction due to metering was greatest immediately after meters were installed, but the percent of reduction decreased after that. The average for the available data was approximately 24 percent. The slopes of the two lines are very similar, but the metered line is slightly steeper.

The decrease in percent reduction of water use has several possible explanations. One is that the total water consumption for the city is increasing, even though sprinkling use has remained fairly constant. This increase in water use combined with a constant sprinkling reduction would result in a smaller percent reduction in total water use year by year.

Another reason is that the population density of Boulder is increasing. This means an increase in condominium and apartment

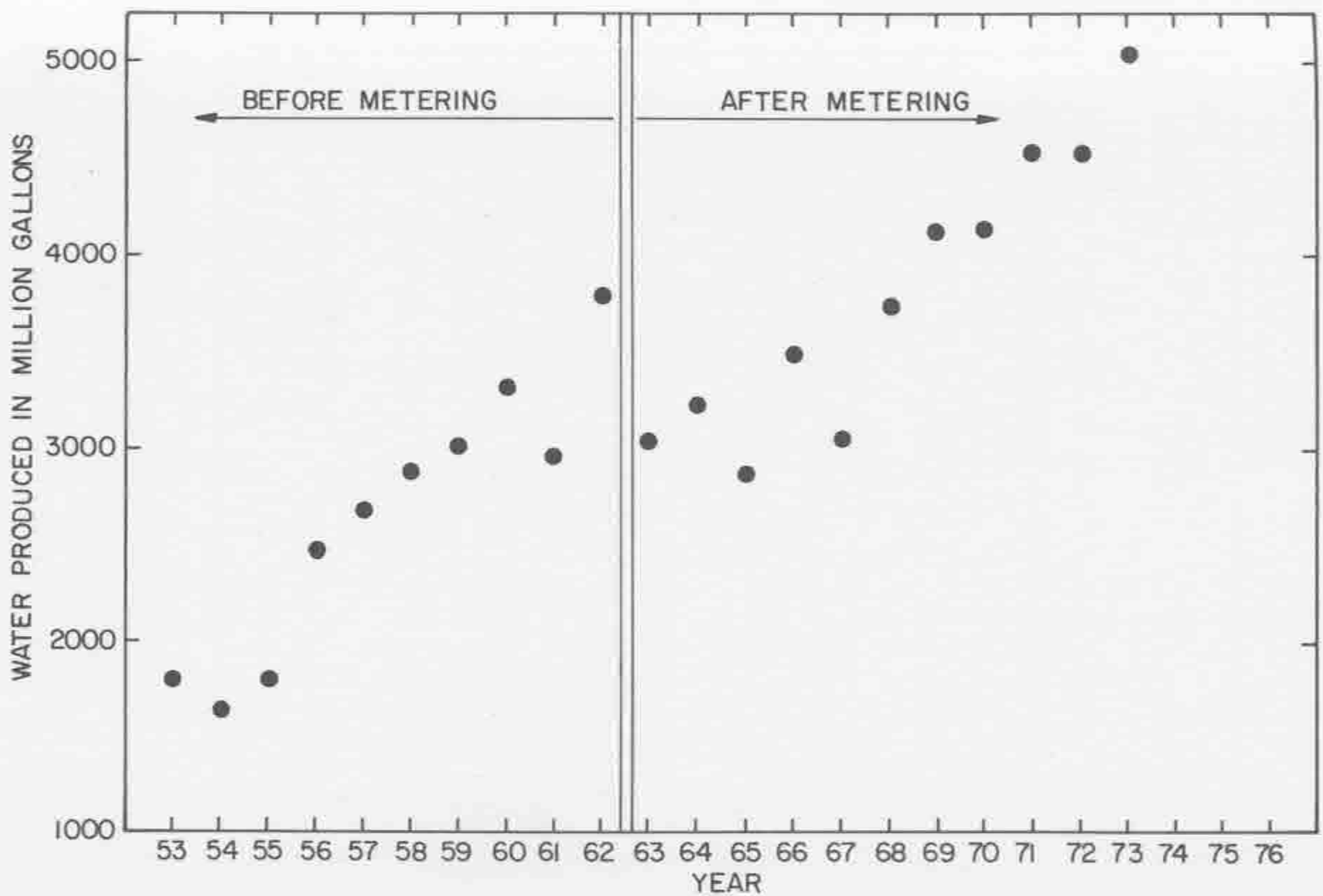


Figure 13. Total Water Consumption at Boulder, Colorado.

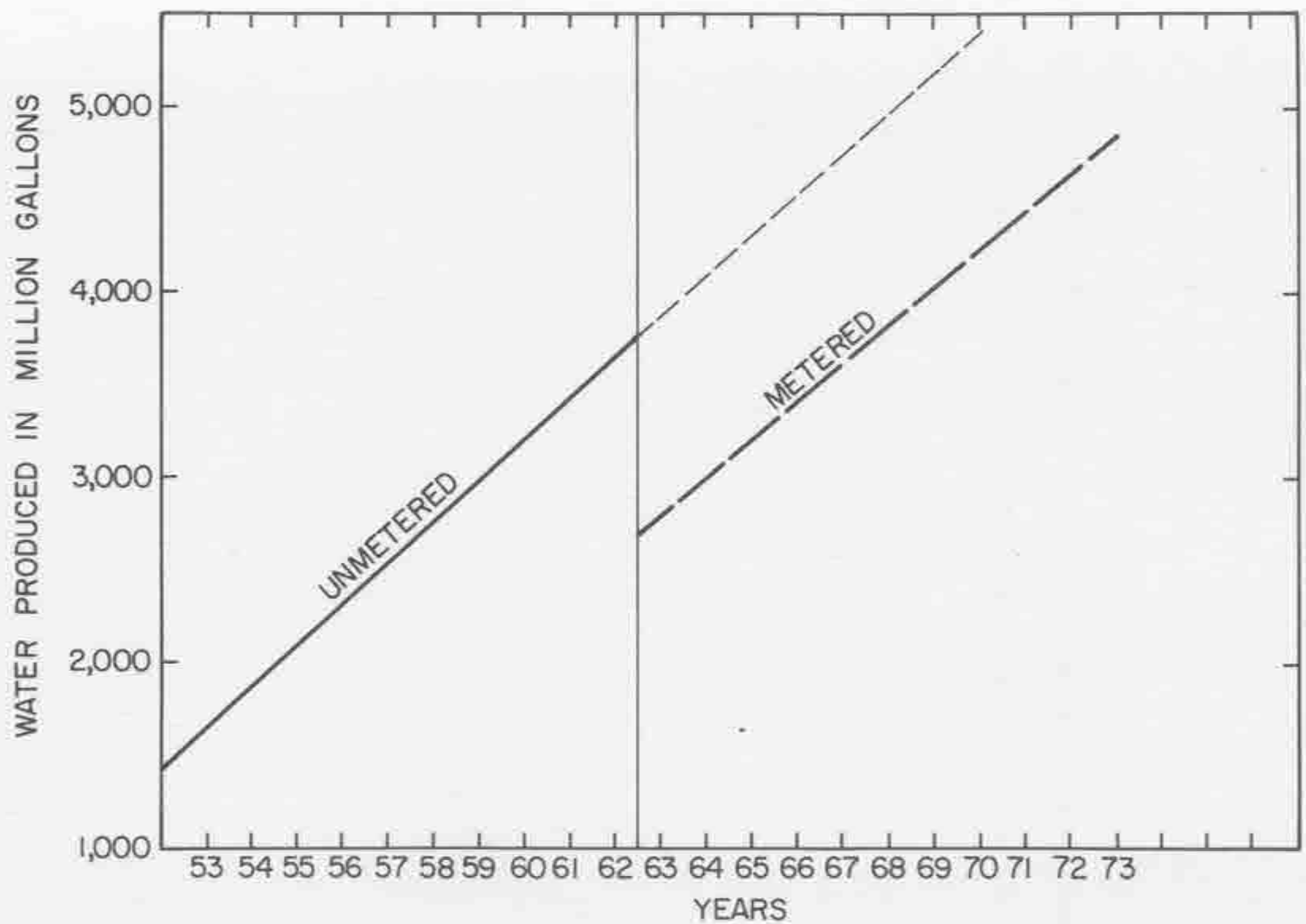


Figure 14. Least Square Fit to Boulder Data before and after Metering.

dwellings. The addition of these dwelling units would increase the water consumption. However, since sprinkling use would be nearly nonexistent, metering would have little effect. Hence an increase in consumptive use without any accompanying reduction.

Of course a third explanation is that people are becoming accustomed to the price of water and their conservation tactics are becoming more relaxed. Undoubtedly this has happened some. However, the extent cannot be readily determined. The effect in this case is probably not significant enough to warrant the conclusion that the effect of metering will wear off after a number of years. Figure 15 shows that the reduction has leveled off and can probably be considered to remain at that level.

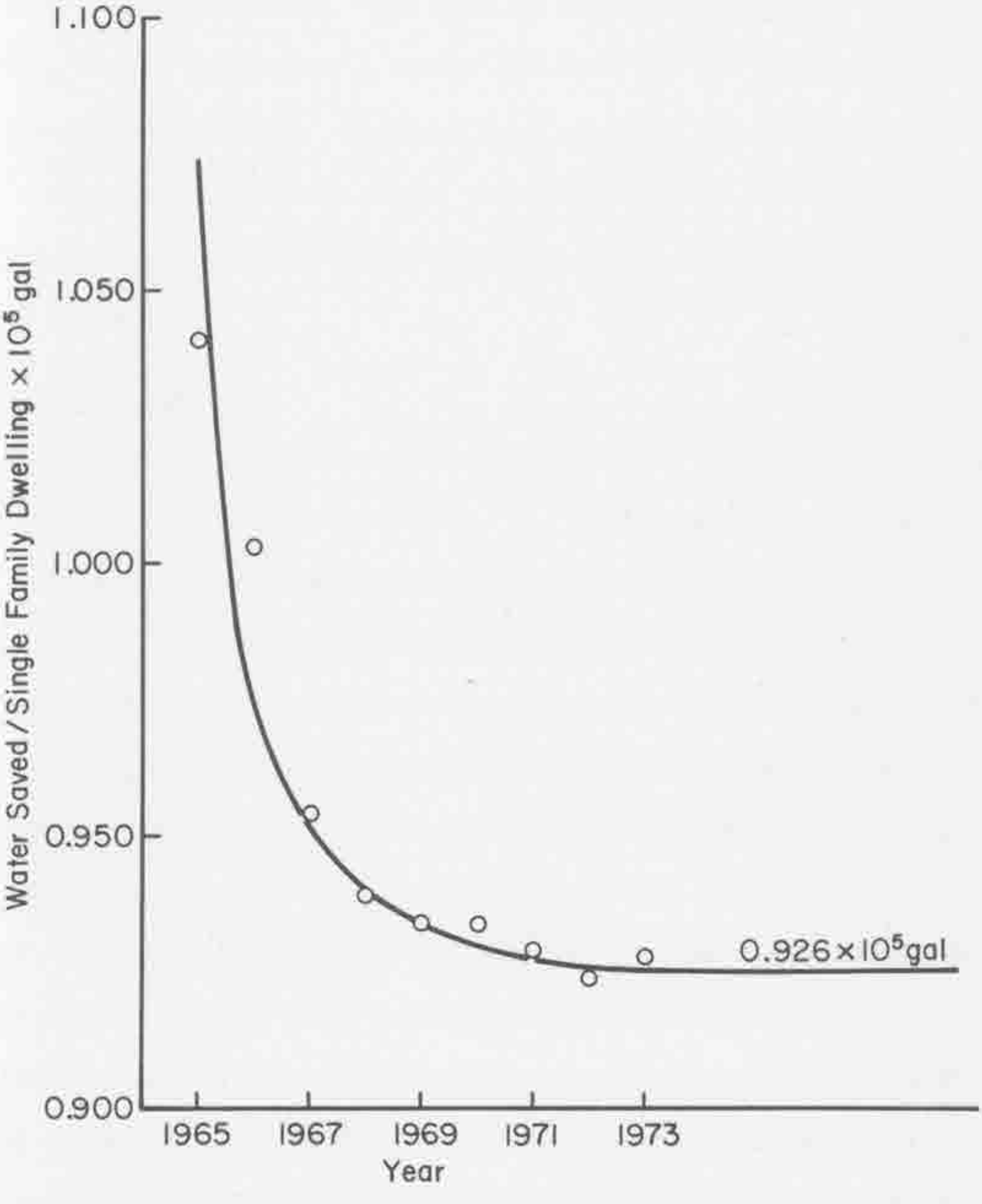


Figure 15. Water Reduction per Dwelling Unit at Boulder.

CHAPTER 4

SOME SPECIFIC REDUCTION FIGURES AND THEIR QUALIFYING ASSUMPTIONS

Chapter 3 was intended as a general review of some findings of previous metering studies. The results listed therein show that metering indeed does cause a change in water use for the particular areas that were studied. However, none of these figures carry their necessary assumptions with them. This section will list some findings of others regarding metering, but including the assumptions they were forced to make.

A. Hanke's Results

The study by Hanke concluded that there was a substantial reduction in residential use due to metering.[13] Specifically, he indicated that domestic use was reduced from about 300 to 200 gpd/du and that sprinkling use was reduced by 230 gpd/du.[4] However his study contained various limitations and assumptions. First of all he states that the only readily available data was the total monthly water delivered to the system. His flat-rate use calculations are based on an average for the entire city after subtracting estimated system losses, while his metered data is calculated for only 14 metered routes in the city. The flat-rate consumption was based on subtracting all metered uses and estimated system losses from the total water produced making the assumption that flat-rate use is the remaining quantity. Any errors made in estimating system losses directly affect the value for flat-rate use.

Therefore, Hanke's reductions should be used with care. His metered data is good compared to other studies, but his flat-rate data is much less precise.

B. Green's Results

A study made by Green in 1972 considered the feasibility of universal metering for Denver.[11] Using the same areas as those in "A Study of Residential Water Use" by Linaweaver[17] he obtained the following data:

Table 12

Residential Use in Denver (gpd/du)

Area	Unmetered	Metered	Difference	% Difference	% of Total that was Metered
3rd & Jasmine	1,127	916	211	19	27.6
11th & Jasmine	520	452	68	13	1.7
5th & Tennyson	643	448	195	30	2.4

Master meters were used to record water use for the areas in question. Flat-rate use was determined by subtracting any metered uses and estimated system losses for the area. For the small metered areas studied, this loss was estimated at 1 percent. Should this estimate be low, it would greatly affect the flat-rate results. However, supposing that Green's assumptions are true, Table 12 gives a range of use reduction from 13 to 30 percent. This again confirms a reduction due to metering but gives no concrete results to apply to other areas because of the limited areas studied. The major limitation of this study is the small number of metered residences in the study area. Table 12 also gives the percent of the total residences that were metered in each area. Also, the study compared only a few specific areas in a very large and diversified city. Additionally, the areas studied were of middle and upper income. No low income areas were included.

C. Bryson's Results

Bryson completed a report in 1973 entitled "Water Metering Experiments for the Flat-Rate Denver Residences."[4] The object of his study was to plan some metering experiments that would give some reliable figures for water savings resulting from metering. He did however do one experiment that gives some reductions in water use that probably have more significance than previous studies. His approach was better than others before him, yet it was still necessary to make assumptions that also limited the results of others. His approach consisted of a random sampling of 1000 residences in the Denver area. His conclusion was that metering could effect a savings of 190 gpd/du. This result is based on calculating flat-rate use by the same residual method used in previous studies. System losses were estimated as 6 percent by the Denver Water Board. Bryson also made his calculations assuming a 10 percent loss. This lowered his water use reduction figure to 155 gpd/du. Another limitation arises from the value chosen for the irrigable area per dwelling unit. Bryson assumed that the water use reductions were the result of decreased lawn irrigation. Therefore the water saved due to metering was converted to a depth of water applied to an average irrigable area per dwelling unit. If the average area assumed was too small, the estimated water use reduction would be larger than it should be. Another assumption made is that domestic use in winter equals domestic use in summer. Some believe that domestic use increases in summer. Should this be the case, the amount of water saved by metering would be lower. Another limitation to consider is that a large number of one and two family residences are rented, with the owner paying the water bill. If these were metered in the future, and the owner still paid for the water, it is likely that the renters would not change their water use habits unless the owner insisted that they pay the water bill. Finally, it is interesting to make note of what Bryson calls the "Full Experiment." This analysis would be the largest and of course the most expensive. Bryson states that it would compare flat-rate and metered residences with a minimum amount of assumptions and with a maximum sample size. The accuracy is estimated at 30 gpd/du. With the accuracy for the "Full Experiment" one can only wonder how accurate his figure of 190 gpd/du was.

CHAPTER 5

THE EFFECT OF METERING ON WATER CONSUMPTION IN FORT COLLINS

A. Application of Reductions from other Areas to Fort Collins

The determination of the effects of metering on total consumption in Fort Collins can only be accomplished after a good estimate of the size of the reduction has been made. The best way to find the reduction is to do some type of study comparing metered and flat-rate use in Fort Collins itself. If the experiment was well designed it would give a figure of water savings that would be truly representative of the savings resulting from universal metering. Unfortunately, no study of this type has been made or is planned for the City. Additionally, current water consumption records of various users are not readily available. Therefore, in order to determine the amount of water that could be saved, figures from other areas must be applied to Fort Collins. The disadvantage of this procedure is that any figure chosen has been determined in another area with different physical, social and economic characteristics. Many studies have been done on metering in Denver and Boulder, but even these results cannot be considered truly representative of what would happen in Fort Collins.

The effect of metering here in Fort Collins has been examined using three different figures of reduction. The first two, 190 gpd/du and 155 gpd/du were determined by Bryson in his study of Denver. The second, 254 gpd/du has been determined in Appendix XIII from total water consumption in Boulder. The figure determined here is quite a bit higher than Bryson's figures and may include additional savings resulting from the correction of leaks in the system that were detected once meters were installed.

B. Similarities of Boulder and Fort Collins

Any reductions found at Boulder (provided they are reliable) should give the best estimate of reductions in Fort Collins. Black and Veatch conclude that reductions should be comparable since the cities are so similar and since present day Fort Collins parallels Boulder at the time it installed meters.[(2)] Table 13 shows the similarity of Boulder in 1963 (when it installed meters) to Fort Collins in 1973.

Table 13

Fort Collins-Boulder Similarities

	Boulder 1963	Fort Collins 1973
Population	46,113	48,823
Occupied Single Family Units	9,798	9,768[1]
Occupied Apartment Units	4,834	5,710

[1]Includes 2 family units

C. Determination of the Reduction at Boulder and Application to Fort Collins

The method of determining the reduction due to metering at Boulder used in this report is contained in Appendix XIII but is also mentioned briefly here. Lines were fitted to the total consumption data from before and after metering. Figure 13 has already shown these lines. The reduction is taken as the difference between these lines. The reduction is assumed to be due entirely to the reduction in residential use (one family dwelling units). This thereby assumes other uses and system losses to remain constant before and after metering. However as

Table 14

Possible Water Saved by Metering in Fort Collins (AF)

	Reduction		
	254 gpd/du	190 gpd/du	155 gpd/du
1976	0	0	0
1977	313	234	191
1978	627	469	382
1979	640	703	573
1980	1253	937	765
1981	1566	1172	956
1982	1880	1406	1147
1983	2193	1640	1338
1984	2506	1875	1529
1985	2819	2109	1720
1986	3483	2605	2125
1987	3546	2653	2164
1988	3612	2702	2204
1989	3680	2753	2246
1990	3751	2806	2289
1991	3825	2861	2334
1992	3901	2918	2381
1993	3980	2977	2429
1994	4062	3038	2478
1995	4146	3101	2530
1996	4232	3166	2583
1997	4321	3233	2637
1998	4413	3301	2693
1999	4508	3372	2751
2000	4605	3444	2810
2001	4704	3519	2871
2002	4806	3595	2933
2003	4911	3674	2997
2004	5019	3754	3063
2005	5129	3836	3130
2006	5241	3921	3198
2007	5357	4007	3269
2008	5474	4095	3341
2009	5595	4185	3414
2010	5718	4277	3489
2011	5843	4371	3566
2012	5972	4467	3644
2013	6103	4565	3724

mentioned before, metering showed that there were large system losses, much of which were soon eliminated. By plotting the average reduction per dwelling unit versus time (Figure 15), it is hoped that any system loss corrections have been eliminated from the reduction figure. The curve seems to level off after time. It is assumed that this decrease in water savings per dwelling unit is due to the correction of leaks (although some may also be attributed to the effect of metering wearing off to an extent). The value at which the curve is assumed to level off is 0.0926 MG/du or 254 gpd/du.

D. Possible Water Saved in Fort Collins Using These Reductions

To estimate the water saved by metering in Fort Collins, the projected number of one and two family dwelling units has been multiplied by figures of 155 gpd/du, 190 gpd/du and 254 gpd/du in Table 14. The number of one and two family units was determined in Appendix II. Water savings are listed from 1977 on. This assumes that installation of the first meters would begin in 1976. It also assumed that the City would install its own meters, resulting in a ten year installation program (Boulder had it done in two years). Table 15 gives the average water (total water saved per time period divided by that time period) saved per year for different time periods.

Table 15

Averaged Water Saved (AF)

Reduction	254 gpd/du	190 gpd/du	155 gpd/du
First 10 yr	877	658	535
First 20 yr	2194	1641	1339
First 30 yr	2953	2209	1802
First 40 yr	3601	2694	2197

E. Possible Effects of Metering on Water Revenue

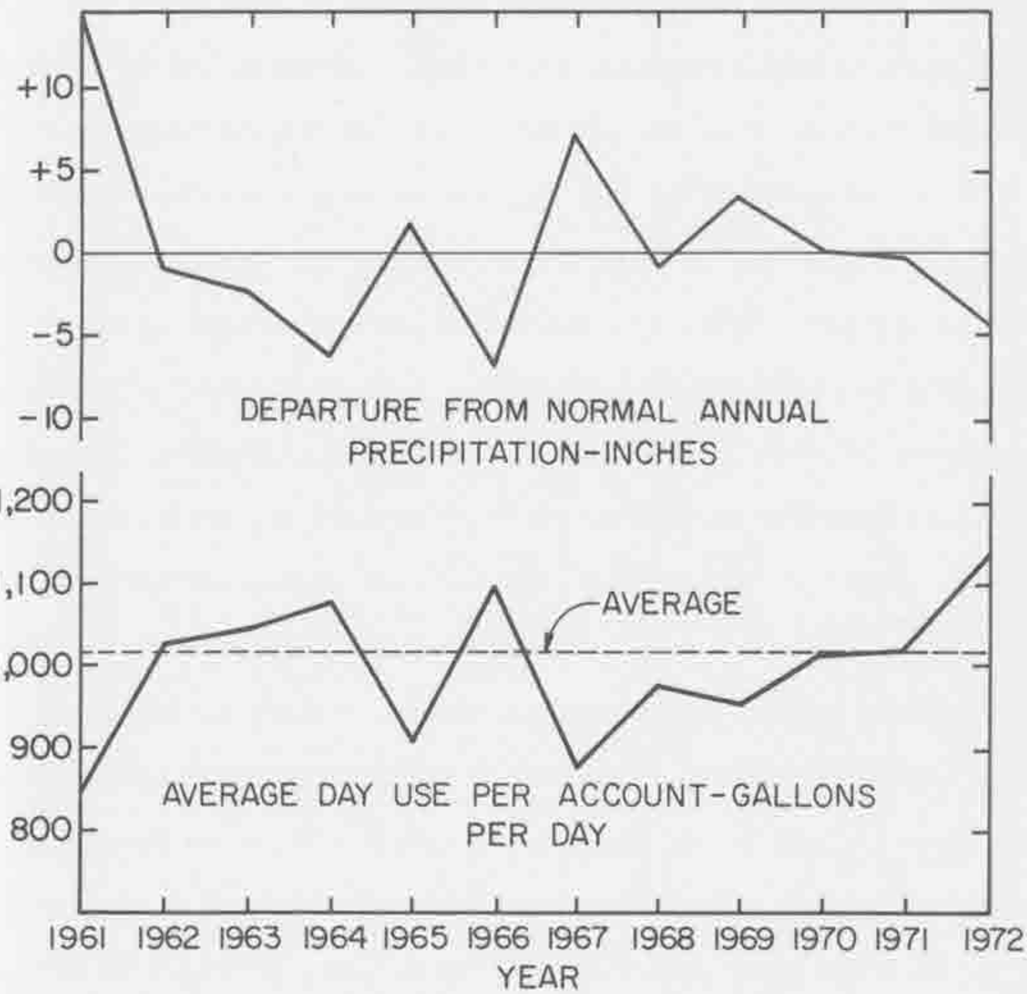
There is an additional effect of metering that deserves attention here. This is the effect that metering and precipitation have on the flow of revenue to the water utility.

The amount of precipitation an area receives determines the amount of sprinkling that is done. Figure 16 shows how departures from normal precipitation result in changes in average day water use.[2] This phenomenon is an important point to take into account when meters are being considered. Under a flat-rate system, the City is guaranteed a fixed amount of revenue no matter how much water is used. Under a metered system, should an extremely wet summer occur, water use will be much lower than normal. Hence the resulting revenue from the sale of this water will also be lower than normal.

Denver has a policy such that water rates acquire a sufficient revenue reserve to compensate for two consecutive very wet summers. At the present time they estimate that a very wet summer could cost them $2.5 million (Denver is not entirely metered at this time and that figure would be higher with universal metering). So if the city of Fort Collins should decide to install meters, the rate structure must have some reserve built into it to meet the possibility of a very wet summer.

F. Some Qualifications for Applying These Reductions to Fort Collins

The significance of applying these reduction figures to Fort Collins probably could be questioned. However, it seems that these are the most applicable. The total savings for the City is dependent on the individual reduction per dwelling unit and the actual number of one and two family dwelling units. So the figures for total water



Source: Black & Veatch Report (2)

Figure 16. Precipitation versus Water Consumption at Fort Collins.

savings determined here depend on the assumptions of reduction and housing projections as being valid. Any reductions found in Boulder should be more applicable to Fort Collins than any found in Denver since Boulder is so similar to Fort Collins. Hanke's study indicated a domestic reduction due to metering whereas Bryson's study of Denver did not. This reduction in domestic use amounted to 100 gpd/du (a total reduction of 215 gpd/du). If the domestic reduction is indeed a true effect of metering, it can be assumed also to apply to Fort Collins. This would indicate a greater savings for Boulder than Denver and explain why Hanke's results and those found in this report are higher.

Bryson's figures for reduction use an average irrigable area/du of 5400 ft^2. Hanke estimated an average irrigable area of 6200 ft^2/du for Boulder indicating larger lots than Denver. If it is assumed that Fort Collins lots are similar to those in Boulder and that similar sprinkling habits exist, the reduction here should be higher than Bryson's estimated 190 gpd/du for Denver.

All previous studies include an estimate of system losses. The values chosen are very critical to the water use reduction calculations. In the Bryson study, the Denver Water Board listed their system losses at 6 percent. Many believe this figure is low for a flat-rate system the size of Denver's (some 90,000 single family dwelling units). A state report done for the southeastern New York area, listed distribution leakage in major cities with universal metering from 2 to 16 percent.(28) The average for six cities was 7 percent. Other sources state that the mean loss of unaccounted water was 11 percent.(24) No mention was made as to whether the areas studied were metered or flat-rate. The fact that Bryson included a reduction figure assuming a 10 percent system loss indicates that he was not entirely convinced that the 6 percent figure was valid.

Finally, the results found here should give an indication of the possible water savings due to metering. Table 15 has shown that the amount of reduction makes a significant difference in the total water savings for the City. If a more accurate determination for Fort Collins is necessary, the only solution is for the City to conduct a metering experiment itself.

G. Costs Associated with Universal Metering

The cost of universal metering is quite high. A 1974 price quoted by the water department estimates each meter, materials and installation to cost \$350. This however is not the only cost associated with metering. Such costs as reading, billing, maintenance and the cost of adding additional meters to new homes must be considered. These costs will be discussed in greater detail later in this report.

Assuming a ten year installation program by the City, this would require an initial capital investment to purchase the estimated number of meters needed in 1985. It is projected that there will be 12,662 one and two family dwelling units in Fort Collins in 1985. Subtracting the estimated number of already metered homes in 1973 (10% of 10,187) leaves an estimated 11,643 one and two family homes requiring meters in 1985. Purchasing these meters at the outset of the installation program would require an initial investment of \$1,455,375.

CHAPTER 6

EXCESS WATER CREATED BY IMPLEMENTATION OF JOE WRIGHT OR WATER METERS IN THE NEAR FUTURE

Since the present Fort Collins water supply is sufficient to meet demands until 1996, the addition of one of these projects would result in a surplus of water for nearly 20 years. This surplus amounts to as much as 6455 AF for Joe Wright and 4146 AF for water meters using a reduction figure of 254 gpd/du. When reuse is considered this amounts to even more with Joe Wright. The City is confident that this water would not be wasted, but rented or leased on the open market probably to potential downstream users. Of course the leasing price of this water (to agricultural users for irrigation) would not be as high as the cost of developing these new sources. However, if reuse is considered, the cost of development would be more competitive with the current price of water. The possibility of multiple reuse of water produced by Joe Wright could be considered in this analysis. However, because of the many variables concerning reuse such as the amount eligible for reuse, the number of reuses and the legal aspects, this report will consider the Joe Wright Project with only one reuse.

Tables 17-21 show the yearly excess water for these projects. They also show the return that is generated from the rental of this excess water. The City believes it can rent or lease this excess water at $7.00/AF. Also evident from the tables is the year in which the new supplies are exhausted by demand. Table 16 summarizes these years.

Table 16

Year Supplies of These Projects are Exhausted

Project	Year Additional Supply is Needed
Joe Wright	2005
Joe Wright (1 Reuse)	2009
Water Meters 254 gpd/du	2003
Water Meters 190 gpd/du	2001
Water Meters 155 gpd/du	2000

Table 17

Joe Wright Excess Water

	Excess Water (AF)	Return
1976		
1977		
1978	6455	$45,185
1979	6455	45,185
1980	6455	45,185
1981	6455	45,185
1982	6455	45,185
1983	6455	45,185
1984	6455	45,185
1985	6455	45,185
1986	6455	45,185
1987	6455	45,185
1988	6455	45,185
1989	6455	45,185
1990	6455	45,185
1991	6455	45,185
1992	6455	45,185
1993	6455	45,185
1994	6455	45,185
1995	6455	45,185
1996	6023	42,160
1997	5388	37,714
1998	4736	33,154
1999	4069	28,480
2000	3384	23,691
2001	2684	18,788
2002	1967	13,771
2003	1234	8,640
2004	485	3,394
2005		
2006		
2007		
2008		
2009		
2010		
2011		
2012		
2013		

Table 18

Joe Wright Excess Water With One Reuse

	Excess Water (AF)	Return
1976		
1977		
1978	9455	$66,185
1979	9455	66,185
1980	9455	66,185
1981	9455	66,185
1982	9455	66,185
1983	9455	66,185
1984	9455	66,185
1985	9455	66,185
1986	9455	66,185
1987	9455	66,185
1988	9455	66,185
1989	9455	66,185
1990	9455	66,185
1991	9455	66,185
1992	9455	66,185
1993	9455	66,185
1994	9455	66,185
1995	9455	66,185
1996	9023	63,160
1997	8388	58,714
1998	7736	54,154
1999	7069	49,480
2000	6384	44,691
2001	5684	39,788
2002	4697	34,771
2003	4234	29,640
2004	3485	24,394
2005	2719	19,034
2006	1937	13,559
2007	1139	7,971
2008	324	2,268
2009		
2010		
2011		
2012		
2013		

Table 19

Excess Water from Meters (Reduction = 254 gpd/du)

	Excess Water (AF)	Return
1976		
1977	313	$ 2,193
1978	627	4,386
1979	940	6,578
1980	1253	8,771
1981	1566	10,964
1982	1880	13,157
1983	2193	15,350
1984	2506	17,543
1985	2819	19,735
1986	3483	24,381
1987	3546	24,823
1988	3612	25,284
1989	3680	25,763
1990	3751	26,260
1991	3825	26,776
1992	3901	27,309
1993	3980	27,861
1994	4062	28,431
1995	4146	29,019
1996	3800	26,600
1997	3254	22,779
1998	2694	18,861
1999	2121	14,848
2001	933	6,533
2002	319	2,231
2003		
2004		
2005		
2006		
2007		
2008		
2009		
2010		
2011		
2012		
2013		

Table 20

Excess Water from Meters (Reduction = 190 gpd/du)

	Excess Water (AF)	Return
1976	234	$ 1,640
1978	469	3,281
1979	703	4,421
1980	937	6,561
1981	1172	8,201
1982	1406	9,842
1983	1640	11,482
1984	1875	13,122
1985	2109	14,763
1986	2605	18,238
1987	2653	18,569
1988	2702	18,913
1989	2753	19,272
1990	2806	19,643
1991	2861	20,029
1992	2918	20,428
1993	2977	20,841
1994	3038	21,267
1995	3101	21,707
1996	2734	19,135
1997	2165	15,157
1998	1582	11,077
1999	985	6,898
2000	374	2,617
2001	--	--

Table 21

Excess Water from Meters (Reduction = 155 gpd/du)

	Excess Water (AF)	Return
1976	191	$ 1,338
1978	382	2,676
1979	573	4,014
1980	765	5,353
1981	956	6,691
1982	1147	8,029
1983	1338	9,367
1984	1529	10,705
1985	1720	12,043
1986	2125	14,878
1987	2164	15,148
1988	2204	15,429
1989	2246	15,722
1990	2289	16,055
1991	2334	16,339
1992	2381	16,665
1993	2429	17,002
1994	2478	17,349
1995	2530	17,708
1996	2150	15,053
1997	1570	10,988
1998	974	6,821
1999	364	2,550
2000	--	--

CHAPTER 7

ECONOMIC EVALUATION OF JOE WRIGHT AND WATER METERS

A. Interest Rate and Discount Rate

A valid economic comparison of these projects requires that both projects be evaluated in the same manner. Therefore they must be considered over the same time span and using the same discount rate. The comparison will take place assuming construction to begin in 1976. It is also assumed that Joe Wright will be completed in two years and the installation of water meters in ten years. The period of construction could vary slightly during the actual implementation of these projects, but the time spans chosen here are adequate for this study.

The interest rate to finance the bonds has been chosen as 6 percent based on the fact that the city recently (early 1974) sold bolds at 6 1/4 percent. Additionally, with interest rates being at record highs at the present time it seems logical to assume that they will remain at present levels or decrease rather than going even higher. The life of bonds sold to finance these projects would probably be 20 years since that is the life most used by the City. Bond retirement would take place through twenty equal annual payments. However, these conditions could also vary with the actual implementation of these projects.

The next point to consider is the discount rate. James and Lee define discount rate as "the expression of the time value of capital used in equivalence calculations comparing alternatives".[16] Unfortunately there are many different viewpoints concerning the selection of the appropriate discount rate. One opinion (Grant and Ireson) is that the rate selected should be greater than the bare cost of borrowed money. They generally have used rates from 5 to 8 percent for their economic comparisons of public works projects.[10] Because of the many opinions concerning discount rate, a specific value was not chosen for this study. Rather, the comparisons were made using three discount rates of 3, 6 and 10 percent.

B. Type of Economic Comparison

The method of comparison chosen here is net present worth. The final comparisons will be in terms of 1974 dollars per acre-foot of water saved or produced and per acre-foot of water used (based on the projected consumption). The comparisons have been made over a 40 year period.

The quantities of water produced by each of these projects are all consumed within approximately 30 years. Ideally when the supply is exhausted, the cost of developing additional water should be included in the analysis. However, since this occurs so far in the future, any cost involved would be discounted some 25 years back to 1974. Additionally, the supplies generated by each of these projects are exhausted at nearly the same time. Therefore, the consideration of such costs at that time would not significantly affect the conclusions drawn here. However, rather than completely neglect this point, any additional water supply that may be needed is assumed to be purchased at \$7.00/AF.

C. Effect of Price Changes

An error common to many economic analyses is that an attempt is made to account for changes in costs and benefits. Price changes are often introduced as a consideration. Grant and Ireson define two types of price changes in an economic comparison. "One is a change in the general level of prices; that is really a change in the purchasing power of the monetary unit. The other is differential price change; the prices of some goods and services rise with reference to the general price level, while the prices of other goods and services are falling with reference to the general level".[10] This analysis is comparing two projects. The first type of price change (inflation) affects both projects in the same way (they are both increasing in cost). The second type of price change is also applicable in that the cost of constructing, collecting and impounding reservoirs (Joe Wright) is increasing faster than the costs of a project such as water meters (from Appendix VIII to the Handy-Whitman Index).

The first type of price change (inflation) can be handled with little difficulty. Hirschliefer, DeHaven and Milliman state that lenders in the capital market insist on interest rates to cover any anticipated depreciation of the dollar due to inflation and that .. "it would, of course, be a crude error to inflate future revenues in proportion to the price levels expected to govern in those periods and then to weigh these inflated revenues against costs measured in today's dollars. The entire comparison of costs and revenues should be calculated using dollars of constant purchasing power of some convenient period, usually the present period".[14] Therefore the point to be made is that since estimates of price changes in the future are mere speculation and that any increase in prices due to inflation is offset by an accompanying depreciation of the dollar, the current prices should be used throughout the period of the analysis.

The second type of price change is difficult to account for in this analysis. The Handy-Whitman Cost Index indicates that the costs of collecting and impounding reservoirs are increasing faster than costs associated with water meters. If this is truly the case, the costs used in this analysis should reflect it. However, because of the uncertainty involved in this type of projection and possible water meter cost changes, any differential increases in costs have been neglected.

All other costs are assumed to increase at the annual inflation rate and therefore can be neglected. Grant and Ireson state that "it is sufficient to base estimates of future cash flow on the prices in effect at zero date"...(1974 in this case) ... "provided it is forecast that all prices will move up and down at the same rate".[10] In other words any price changes will affect both projects in a similar manner.

D. The Economics of Joe Wright

The costs of the Joe Wright Project include the initial capital investment and the annual maintenance costs. Costs used in this report have been obtained from the McCall-Ellingson Report.[19] They estimate a 1974-1975 total project cost of $4,632,000. This includes some $262,000 for financing during construction. Since this is an economic analysis, financing costs have been neglected. This results in an estimated 1974-1975 project cost of $4,370,300 (For financial considerations possibly of interest to the City, the 1974 cost has been projected in Appendix VI to a 1976 cost of $4,925,328. If this cost is valid and bonds were sold for that amount, the bond retirement would take place through 20 equal annual payments of $429,390; for comparison only, if the 1976 cost had increased to $6,000,000, the annual payment would be $523,080.).

The economic analysis has been kept as simple as possible. After the initial capital outlay, the only other costs are those of maintenance taken as $4,800/yr. Any excess water produced by Joe Wright is assumed to be leased at $7.00/AF. The annual difference between the maintenance costs and the return from this excess water has been discounted to 1974 present worth. The total present worth of the costs for various discount rates have been divided by the water produced and used to determine the cost of water per acre-foot.

Additionally, Joe Wright has been considered with one reuse. All costs are assumed the same, but the yield is assumed to be 9455 AF/yr.

E. <u>The Economics of Water Meters</u>

The installation of water meters is assumed to take place over a ten year period beginning in 1976. This is based on the fact that the City would prefer to handle the installation itself rather than assign the work to an independent contractor, resulting in a long period of time to complete installation. If 11,643 meters are required in 1985, the initial capital cost is $1,455,375. This is based on a cost of $125.00 for meters and materials and $225.00 for labor and installation. This analysis also assumes that the City would pay for meters just as it would pay for any other water supply alternative.

Determination of the other costs associated with meters is not an easy task. Since universal metering would be a new experience for any of the City's departments involved, the costs used here are best estimates acquired through conversations with the appropriate people in the Departments of Water, Public Works and Public Utilities.

Should the City seriously consider universal metering, it should design and implement its own program of data collecting to determine actual figures for water use reduction in Fort Collins.

The costs associated with metering in Fort Collins are listed in Table 22. These are costs required in addition to costs that may apply to the current flat-rate system.

Table 22

Estimated Meter Costs for Fort Collins

Cost of Meters and Materials	$125.00/meter
Cost of Installation	225.00/meter
Cost of Maintenance	4.05/meter/yr
Cost of Reading and Billing	5.52/meter/yr (Monthly billing)

Table 23 shows costs determined by Green in his study of the feasibility of universal metering for Denver in 1972.

Table 23

Estimated Metering Costs for Denver

Initial Meter Costs	$285.00/meter installation
Meter Reading Costs	2.76/meter/yr (bi-monthly billing)
Meter Maintenance Costs	1.71/meter/yr

Comparing these tables shows that there is a large discrepancy between the maintenance costs. Fort Collins has a very thorough maintenance program. The author is unaware of the type of program in Denver. Other costs are quite similar.

The cost of meters is based on a pit installation and attempts to include all costs of labor, materials, and machinery. The maintenance costs are estimated from conversations with people from the Water Department and the Department of Public Works. They estimate a cost of $4.05/meter/yr and could give no explanation as to why Denver's cost was so much lower. Reading and billing costs are estimated by assuming a cost of 40 cents for reading and 6 cents for costs associated with customer service, processing and billing. This results in a total cost of 46 cents per meter per bill or $5.52/meter/yr. Again, this is not the total cost of reading and billing, but rather the additional cost of metering over and above the flat-rate costs.

F. 1974 Present Worths of the Joe Wright and Water Meter Projects

Tables 24 and 25 give the results of the economic analysis. It is obvious that the Joe Wright Project has a lower cost/AF than any of the metering projects no matter which discount rate is used. At a discount rate of 6 percent, the cost to save 1 AF of water by metering (reduction = 254 gpd/du) is slightly more than twice as much the cost of producing 1 AF of water by the Joe Wright Project. Also, consideration of Joe Wright with one reuse increases the yield by 50 percent at one third less cost.

These tables also show the sensitivity of the analysis to the value of the discount rate. Since Joe Wright has a high initial capital investment and low annual costs afterward, the value of the discount rate has a very insignificant effect. However, water meters have high annual costs that increase as time goes on. Therefore, high discount rates make it appear more favorable.

Table 24

Costs per Acre-Foot of Water Produced or Saved 1974-2013

	Discount Rate	Joe Wright	Joe Wright 1 Reuse	Water Meters (254 gpd/du)	Water Meters (190 gpd/du)	Water Meters (155 gpd/du)
1974 Present Worth	3%	$3,872,198	$3,452,627	$8,181,894	$8,307,946	$8,376,881
Water Produced (AF)		232,380	340,380	144,035	107,743	87,895
Cost/AF		16.66	10.14	56.81	77.11	95.31
1974 Present Worth	6%	3,994,903	3,737,105	5,637,057	5,705,977	5,743,667
Water Produced (AF)		232,380	340,380	144,035	107,743	87,895
Cost/AF		17.19	10.98	39.41	52.96	65.35
1974 Present Worth	10%	4,113,287	3,960,615	4,041,457	4,076,634	4,095,872
Water Produced (AF)		232,380	340,380	144,035	107,743	87,895
Cost/AF		17.70	11.64	28.06	37.84	46.60

Table 25

Costs per Acre-Foot of Water Used 1974-2013

	Discount Rate	Joe Wright	Joe Wright 1 Reuse	Water Meters (254 gpd/du)	Water Meters (190 gpd/du)	Water Meters (155 gpd/du)
1974 Present Worth	3%	$3,872,198	$3,452,627	$8,181,894	$8,307,946	$8,376,881
Water Produced (AF)		86,221	107,102	77,296	60,942	51,056
Cost/AF		44.91	32.24	93.67	120.88	145.63
1974 Present Worth	6%	3,994,903	3,737,105	5,637,057	5,705,977	5,743,667
Water Produced (AF)		86,221	107,102	77,296	60,942	51,056
Cost/AF		46.33	34.89	66.24	85.14	102.37
1974 Present Worth	10%	4,113,287	3,960,615	4,041,457	4,076,634	4,095,872
Water Produced (AF)		86,221	107,102	77,296	60,942	51,056
Cost/AF		47.71	36.98	48.84	62.53	46.35

An inadequacy of this analysis should be mentioned at this time. The comparisons have been made over a 40 yr span. Yet the supplies generated by these projects are able to meet demand for less than one quarter of that time. For this reason Table 25 was included. It gives costs in terms of the water actually used (beginning in 1995). Under these circumstances and a discount rate of 10 percent, water meters (254 gpd/du) are comparable in cost to the Joe Wright Project (but only at this high discount rate). Also Joe Wright has a finite yield. On the other hand, water meters will continue to save water as long as new homes are built with lawns to water. So the water saved by metering will continue to increase with time while the yield from Joe Wright remains fixed.

Given these present worth cost figures, an analysis was done to determine what the price of each meter and its installation would have to be reduced to in order to make the cost of producing water through metering equal to that of Joe Wright. Examining costs in terms of water that is produced, at a 10 percent discount rate and a reduction of 254 gpd/du, the cost of meters and installation would have to be approximately $218, or $132 less than the present estimated cost. However, in terms of water that is actually used to meet demand (assuming additional supplies are developed as they are needed), under the same conditions (a 10 percent discount rate and reduction of 254 gpd/du), the required cost is $340. Only $10 less than the current estimated cost. The reason that meters are able to compare favorably to Joe Wright in this case results from the fact that the costs have been determined using the water that is acutally used rather than produced. Under this condition, the large return that could be obtained from 20 yr of excess Joe Wright water is lost.

At all other reductions and discount rates, the necessary cost of meters is unrealistically low. Table 26 shows the results of this analysis. The significance of these figures rests on which discount rate is considered applicable and whether the projects are compared in terms of total water produced or water actually used.

Table 26

The Required Cost of Meters Necessary to Make the Cost/AF of Water Saved Comparable with Joe Wright

Discount Rate	254 gpd/du Joe Wright	254 gpd/du With 1-Reuse	190 gpd/du Joe Wright	190 gpd/du With 1-Reuse
	In Terms of Water Produced or Saved			
3%	$ 24.27	$-38.91	$-24.89	$-72.15
6%	121.38	44.06	61.49	3.65
10%	217.82	123.81	144.84	74.52
	In Terms of Water Used			
3%	$ 96.38	$ 30.49	$ 38.49	$-13.47
6%	216.91	140.47	145.46	85.19
10%	340.44	251.10	252.61	182.17

G. The Effect of Incorrect Population Projection on the Analysis

A population projection was made in this report because the author felt that the projections given by the City seemed unrealistic. However, even with a lower projected population, as given in this report, the water consumption projections are quite similar (the Department of Public Works projections are given in Appendix III). Therefore, in the event that the projections made in this report are questioned, an analysis was done using the population and water consumption projections given by the Department of Public Works. The costs using these figures are shown below in Table 27.

Table 27

Costs Using the Department of Public Works Population and Water Consumption Projections

Discount Rate	Joe Wright $/AF	Water Meters $/AF 254 gpd/du	190 gpd/du	155 gpd/du
3%	16.35	49.55	67.40	83.41
6%	17.08	35.37	47.92	59.17
10%	17.53	26.13	35.25	43.43

The results show that Joe Wright is still less expensive in cost/AF.

H. Considerations of These Projects Not Included in the Economic Analysis

It has been shown here that economically Joe Wright is more favorable than water meters. Yet this is not to say that water meters should never be considered by Fort Collins. In a paper to the Denver Water Board, J. E. Flack states that the Benefit-Cost Ratios for metering are near 1.00 depending on the amount of reduction (these Benefit-Cost Analyses include deferral of costs of distribution and treatment investments not considered here). He also states that metering has a more significant impact on treatment plant investments rather than raw water supply investments.[9] Also in this day of energy and resource conservation, metering would lead to a more efficient use of water. None of these additional impacts have been considered in the economic analysis. This report only considered the economics of developing an additional water supply.

There are additional effects caused by metering that result in changes in behavior or are difficult to assign monetary value to. For instance, Bryson has estimated that universal metering could bring about an average reduction of 10 percent in average lawn, garden, and shrub area. Hanke's study also investigated some behavior modifications due to metering. He found that universal metering resulted in such changes as watching sprinklers more carefully, permitting yards to turn brown periodically, watering at night, and reducing the size of the yards watered. These are by no means major effects, but nontheless should be considered in a metering program.

There are also aspects of the Joe Wright Project not discussed here. The main advantage is the flexibility of the Fort Collins system with its own high mountain storage and the resulting efficient use of the Michigan Ditch and Water Treatment Plant No. 1.

CHAPTER 8

CONCLUSIONS: JOE WRIGHT OR WATER METERS

The purpose of this report was not to make a strong recommendation as to which project the City should build (The City has already decided to build Joe Wright). Rather this report was intended to be informative on the effects of water meters on demand in Fort Collins and to give a comparison of two possible water supply alternatives in general economic terms.

The analysis done on Joe Wright is basically the product of the McCall-Ellingson Report on the Feasibility of Joe Wright Dam. Their general format for comparison was followed with little further investigation of the subject. It was their costs that were projected and used in the economic analysis.

The analysis of water meters is based on many different sources and opinions. Various assumptions were necessary and many of these are very critical to the outcome of the analysis. The basic assumption made was that reductions obtained in Denver and Boulder are directly applicable to Fort Collins. Using three different values for the water savings per dwelling unit shows how much the cost/AF varies. It seems logical to assume that any reduction in Fort Collins would not exceed the figure of 254 gpd/du. The other reduction figures used in the analysis are more conservative, but have been obtained for Denver, a large city, very different from Fort Collins. Also, changing the predicted number of one and two family dwelling units for Fort Collins could significantly alter the results of this analysis. Should the trend toward apartments become more pronounced, the number of one and two family residences built in the future correspondingly would be reduced. This would result in less water being saved. Therefore, should the City seriously consider metering, it should be noted that this report only examines the feasibility of metering as a water supply alternative.

Finally, this report has compared the Joe Wright Project and water meters in an economic sense with the interest of increasing the Fort Collins water supply. Based on the results found here, this report cannot recommend universal metering as a favorable water supply alternative for the city of Fort Collins. It is the final conclusion of this analysis that the Joe Wright Project is economically more feasible than water meters.

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APPENDIXES

APPENDIX I

Population Projection

Population Projection

Various figures of projected population have been given for the City of Fort Collins. The City Planning Department has given a figure called "Financial Base Projection" of water service population served. Their figure for the year 2000 is 150,668. The Department of Public Works has listed a projection of 133,000 as the expected population of Fort Collins for the year 2000. A projection of 96,000 people for the City by 2000 has been made by the author and is the projection to be used in this report.

It is obvious from the table below that the growth of Fort Collins has followed the growth of Colorado State University. Since there is little industry in the Fort Collins area, the growth of the City can be attributed to the growth of the University.

Year	CSU Enrollment	Fort Collins (including CSU)
1920	950	9,705
1930	1,502	12,991
1940	2,057	14,308
1950	4,103	19,040
1960	6,131	25,027
1970	17,045	43,337
1973	18,360[1]	48,829

[1]CSU enrollment for fall quarter 1973

It seems that many of the projections that have been made have been based on the total population of Fort Collins including CSU. Since the enrollment of CSU nearly tripled from 1960 to 1970, a projection using these figures could give quite high results. If the University was free to grow, this would be a valid approach. This is not the case. The State Board of Agriculture has set a ceiling of 20,000 students for CSU for the year 1985. Therefore, limiting the growth of the University would also tend to limit the growth of Fort Collins. This is the basis for the population projection made here.

The procedure followed was to separate CSU enrollment from the City population. The City population was then projected geometrically (Figure I-1) using the greatest ten year growth span which was 1960 to 1970. This gave the following results:

Year	Population
1980	37,000
1990	51,000
2000	71,000
2015	116,000

The CSU enrollment was not predicted since it is controlled. However, it was assumed that the State Board would raise the ceiling on enrollment to 25,000 for the year 2000. Therefore, assuming a linear increase up to this ceiling, the following enrollment figures for CSU are obtained:

Year	Population
1980	19,000
1990	21,667
2000	25,000

Combining these with the previous Fort Collins predictions results in the following population projections:

Year	Fort Collins Population (including CSU)	
1970	43,337	(actual)
1980	56,000	(projected)
1990	72,667	(projected)
2000	96,000	(projected)
2015	141,000	(projected)

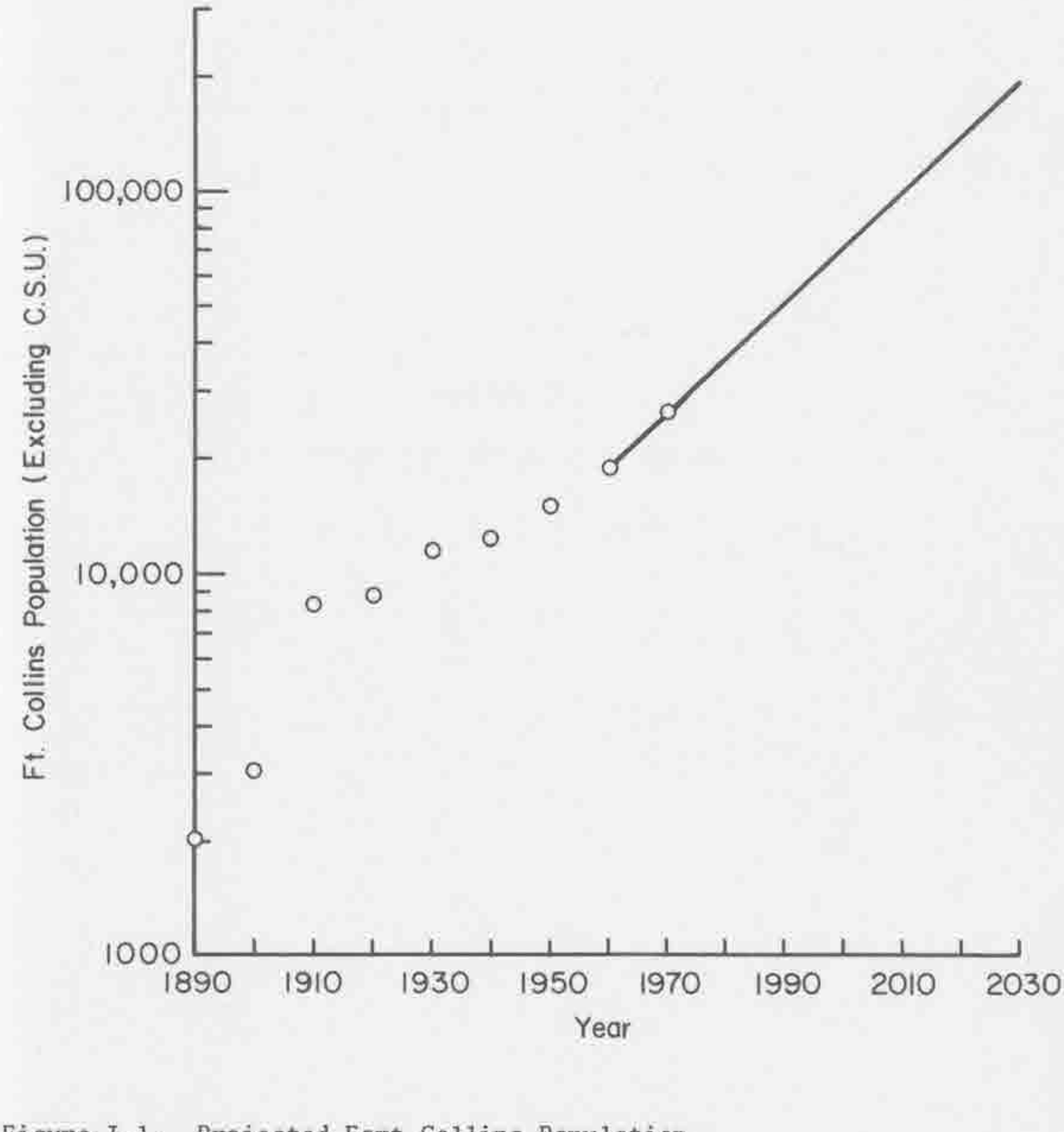

Figure I-1. Projected Fort Collins Population.

APPENDIX II

Water Consumption Projection

Water Consumption Projection

The water consumption of a city is dependent on such things as population, housing characteristics and the economic base. The projection made in this report has been based on population and its distribution in various forms of housing. This approach can be considered valid since the majority of water use is residential and water use by industry is insignificant. The economic base of the region is agriculture (water for agricultural use in the region is not supplied by the City).

Water consumption by the city of Fort Collins will be based on a simple model that assumes varying quantities of water use depending on the type of user. Three different types of water users will be considered here. These are one and two family units, apartment units and CSU campus units (other uses such as commercial, industrial, public, street cleaning, etc. will be added on to these residential uses).

Unfortunately, specific numbers for each of these housing units are not available. Therefore certain assumptions must be made to arrive at these figures. Reports by the U.S. Census Bureau give the following data:

City of Fort Collins-1970		Units
Total Housing Units		13,844
One Unit Structures		7,864
	Difference	5,980

The difference in these two figures is assumed to be the number of apartment units in Fort Collins. It is also assumed that these one unit structures are all single family dwelling units.

The number of two family units was estimated in the following manner. Data was obtained from the City Building Department which showed the number of new one and two family homes built in the past 13 yr. It was found that of the total one and two family units built, 13 percent were two family units. So with 7864 single family units in Fort Collins in 1970, it was assumed that there were also 1193 two family units that had been accounted for as apartment units.

This results in a total of 9039 one and two family units in 1970 and leaves 4805 as apartment units. But of the 13,844 total housing units, only 13,106 were occupied. With a 5 percent vacancy in 1970 there were 8587 occupied one and two family units and 4565 occupied apartment units.

The year 1973 will be used as the base year for the water consumption projections. The population in housing units is given for 1970 as 37,180. The total population of Fort Collins increased from 43,337 in 1970 to 48,829 in 1973 or an increase of 14.8 percent. Applying a similar increase to the population in housing gives 42,683 people living in housing units in Fort Collins in 1973. The difference between this figure and the 1973 population (48,829 - 42,683 = 6146) is assumed to be the population living in CSU campus housing which was not accounted for in the census report. These 6146 people are assumed to live in 3073 units. Results are summarized in the following table:

Type of Dwelling	Total Units	Occupied Units
1 and 2 family	9039	8587
Apartment	4565	4565
CSU housing	3073	3073

The above table includes those units completed as of 1970. So, additional units built in 1970, 1971, and 1972 must be added to them. The Building Department lists 1148 new one and two family units built during these years (Appendix VIII). There was also the addition of 1206 new apartment units during those same years. Adding these new units to the census count for 1970 results in the following:

Type of Unit	No. of Units	95% Occupied
1 and 2 family	10,187	9678
Apartment	6011	5710
CSU Housing	3073	3073

The next step is to determine the density (persons/dwelling unit) for each type of dwelling such that the resulting population is nearly the same as the actual population in 1973. Unfortunately exact population densities for Fort Collins are not available. Therefore densities were determined by adjusting densities given in the 1970 U.S. Census Report and by the Boulder Planning Department.

Type of Unit	Fort Collins[1] Densities	Boulder Densities	Adjusted Densities	Occupied Units	Population
1 and 2 family	3.2	3.4	3.25	9678	31,454
Apartment	2.5	2.1	2.10	5710	11,991
CSU Housing	--	--	1.75	3073	5,378
					48,823

[1]Densities are 3.2 for owned housing units and 2.5 for rented housing units from 1970 Census Report.

The density for CSU is listed as 1.75 instead of 2.0. This assumes that the dormitories are filled only three-fourths of the year but are still used to some extent during the summer months. This results in a population of 5378 in CSU housing rather than a possible 6146 if the density were 2.0. The difference in these figures is small and should not significantly influence the results. The reason for using the lower figure is that later it will be assumed that a maximum of 6100 will be living in CSU housing.

Estimating Water Consumption for Each Type of Unit

The Linaweaver study gives figures for average water consumption per dwelling unit (Appendix XIV). Also given are the densities per dwelling unit for the areas of their study. From these two figures, the water consumption in gallons per capita per day can be determined for each type of unit. Using these figures, an estimate of yearly water consumption for each type of unit can be found (multiply number of units x density x gpcd x 365). This is shown below.

Type of Unit	No. of Units	Density	gpcd	Water Consumption (MG)
1 and 2 family	9678	3.25	182.0	2146.9
Apartment	5710	2.10	73.5	321.7
CSU Housing	3073	1.75	73.5	144.3
				2612.9 MG

It should be noted that the water consumption figure for one and two family units is based on a flat-rate system of paying for water. Fort Collins is approximately 10 percent metered at this time. However this 10 percent is considered as being flat-rate also.

The figure of 2612.6 MG is only the water consumption for the types of units mentioned. It does not include such things as street cleaning, commercial and industrial use, system losses and use outside the city limits. These uses will be accounted by adjusting the gpcd values for each unit.

In 1973 the total water produced by the Fort Collins treatment plants was 4678.7 MG (Appendix III). The water consumption not attributed to the individual uses already determined is 2065.8 MG, which when divided by the population and 365 is equivalent to 11.9 gpcd. Adding this figure to the use for each type of unit gives the following results:

Type of Unit	Water Use gpcd	Additional Use gpcd	Total Use gpcd
1 and 2 family	187.0	115.9	302.9
Apartment	73.5	115.9	189.4
CSU Housing	73.5	115.9	189.4

Future water consumption will be estimated using the above values for water consumption and the predicted future population values. The predicted population figures will be distributed among the various types of dwelling units:

$$(N+F)D_f + (2N + A)D_a + 6100 = P_{\text{Fort Collins}}$$

where N is the number of new one and two family units built since 1972 that are occupied

F is the number of occupied one and two family units in 1973

D_f is the density of one and two family units

2N is the number of new apartment units built since 1972 that are occupied

A is the number of occupied apartment units in 1973

D_a is the density of apartment units

6100 is the population estimated to live in CSU housing

$P_{\text{Fort Collins}}$ is the predicted population of Fort Collins (including CSU)

In other words, this states that the number of occupied one and two family units times their density, plus the number of occupied apartment units times their density, plus 6100, is equal to the total population of Fort Collins.

Various assumptions were made to make this model usable. First, the densities which were determined previously are assumed to remain constant with time. Second, a value of 6100 is taken to be the population living in CSU housing. This is based on the fact that there is space for approximately 5350 students in residence halls on campus plus some married housing off campus. The housing office estimates that during any year, 5000-6000 students reside in CSU housing. They also state that the University has no long range plans for additional spaces. In 1970, the population of Fort Collins was 43,337 with 37,180 of these listed as living in housing units. The difference in these figures is 6157. With this information and keeping in mind that the trend has been more toward off campus living, the figure of 6100 was chosen here to represent the number of students living in CSU housing.

Finally, it is assumed that the number of new apartment units will increase twice as fast as the number of new one and two family units. Data was obtained from the Boulder and Fort Collins Building Departments to justify this assumption (Appendixes VIII and IX). Data for Fort Collins shows that the number of new one and two family units and the number of apartment units built over the last 15 yr was nearly identical. If Fort Collins in 1973 is assumed to be at a similar stage of growth as Boulder was in 1963, we would expect Fort Collins to follow the same basic trends. In Boulder, the period from 1964-1973 saw multi-family units nearly double one and two family units.

Consideration of the present state of the economy, the trend toward apartment and condominium living, and the experience of Boulder tend to justify the assumption that new multi-family units will double the number of new one and two family units.

PREDICTION OF FUTURE WATER CONSUMPTION

1985

$$(N + 9678)\ 3.25 + (2N + 5710)\ 2.10 + 6100 = 63{,}000$$

$$N = 1806;\ 2N = 3612$$

Type of Unit	No. of Occupied Units	Density	Water Use gpcd	Total Water Use MG/yr
1 and 2 family	11,484	3.25	302.9	4126.4
Apartment	9,322	2.10	189.4	1353.3
CSU housing	6,100		189.4	435.5
				5975.0

2000

$$(N + 9678)\ 3.25 + (2N + 5710)\ 2.10 + 6100 = 96{,}000$$

$$N = 6234;\ 2N = 12{,}471$$

Type of Unit	No. of Occupied Units	Density	Water Use gpcd	Total Water Use MG/yr
1 and 2 family	15,912	3.25	302.9	5717.4
Apartment	18,181	2.10	189.4	2639.4
CSU housing	6,100		189.4	435.5
				8859.6

2015

$$(N + 9678)\ 3.25 + (2N + 5710)\ 2.10 + 6100 = 141{,}000$$

$$N = 12{,}276;\ 2N = 24{,}552$$

Type of Unit	No. of Occupied Units	Density	Water Use gpcd	Total Water Use MG/yr
1 and 2 family	21,954	3.25	302.9	7888.4
Apartment	30,262	2.10	189.4	4393.3
CSU housing	6,100		189.4	435.5
				12,777.1

APPENDIX III

Total Water Consumption
City of Fort Collins, Colorado

Total Water Consumption
City of Fort Collins, Colorado
(MG)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1925	34.0	28.0	31.0	66.0	64.0	57.0	70.0	55.0	48.0	44.0	46.5	40.0	583.0
1926	31.0	28.0	31.0	35.0	65.0	82.0	89.0	96.0	93.5	92.0	60.5	67.0	770.0
1927	69.5	40.5	63.7	67.0	138.5	119.7	158.0	100.8	138.8	113.7	87.0	91.7	1103.0
1928				96.5	101.2	87.0	147.7	150.0	124.5	111.7	77.5	88.5	1231.0
1929	76.2	83.8	87.2	91.8	119.2	154.0	178.5	148.5	81.5	95.8	82.0	80.0	1278.0
1930	74.0	77.5	69.8	101.2	102.8	172.8	179.0	115.8	102.2	76.0	64.2	60.8	1196.0
1931	60.7	50.5	58.8	79.0	103.5	144.8	205.2	162.0	123.2	80.8	68.5	61.5	1198.0
1932	53.2	51.0	58.5	109.5	133.5	141.5	183.8	134.2	116.8	78.5	59.2	57.5	1177.2
1933	54.2	56.2	57.2	72.2	87.2	172.0	182.3	116.5	88.2	91.5	65.8	60.5	1104.0
1934	55.2	51.2	54.8	80.0	144.8	160.2	202.8	151.0	101.5	76.0	60.0	64.0	1200.8
1935	67.5	62.0	63.2	82.0	74.2	117.8	179.0	201.5	104.5	94.7	76.7	73.3	1196.5
1936	66.5	68.5	69.5	99.0	143.8	156.0	207.0	155.2	114.5	68.0	62.5	63.0	1274.5
1937	64.2	59.2	56.8	55.5	121.5	114.2	169.5	202.5	138.2	86.2	70.5	64.5	1203.0
1938	62.0	56.0	63.7	56.5	83.2	108.2	201.5	213.5	85.5	78.5	63.0	66.7	1138.5
1939	62.0	59.0	62.0	76.2	154.8	192.2	255.2	193.5	150.2	113.0	77.0	73.0	1468.2
1940	54.2	50.7	55.2	99.7	152.0	216.5	212.0	199.0	100.0	70.7	66.5	55.5	1332.25

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1941	49.0	49.0	54.2	57.0	87.5	148.2	182.0	123.7	90.5	57.7	56.0	54.2	1006.2
1942	55.0	49.0	54.2	64.5	112.5	116.2	225.0	164.5	119.2	107.0	67.5	64.7	1199.5
1943	56.7	51.0	56.7	98.7	81.0	141.7	225.5	196.0	138.7	77.7	56.5	58.5	1282.2
1944	60.2	51.0	54.5	56.5	108.0	155.2	165.8	235.5	146.0	97.0	72.0	66.5	1691.0
1945	62.5	57.5	73.5	64.5	144.5	133.5	224.5	115.5	149.0	85.0	75.0	71.0	1256.0
1946	69.8	67.5	105.5	177.5	128.0	208.0	218.0	201.5	98.5	108.0	88.2	78.0	1546.5
1947	87.2	82.3	90.5	108.0	143.0	128.5	244.0	256.0	195.5	146.0	126.0	122.5	1729.5
1948	99.2	109.5	129.0	172.8	202.5	181.0	264.5	222.0	178.5	137.5	114.0	104.5	1915.0
1949	102.5	98.0	106.5	142.5	175.0	185.5	231.0	251.5	179.5	141.0	142.5	129.0	1884.5
1950	123.0	105.0	135.5	163.0	148.5	228.0	230.5	239.0	132.5	170.5	129.0	126.0	1930.5
1951	124.0	112.0	126.0	144.0	182.5	173.0	249.0	174.5	164.0	129.5	103.0	110.0	1791.5
1952	105.0	105.5	124.0	136.0	184.0	230.0	236.0	241.0	208.0	154.0	108.5	109.0	1941.0
1953	112.5	103.0	134.2	112.5	192.0	220.5	272.5	261.0	215.0	164.0	119.5	109.5	2016.3
1954	106.0	105.0	124.0	210.5	223.5	266.0	255.5	216.5	198.5	156.5	137.0	123.5	2122.5
1955	123.0	112.0	135.0	200.0	222.0	210.0	276.0	194.5	179.0	142.0	121.0	93.0	2007.5
1956	108.5	110.5	119.5	144.5	174.5	300.5	267.0	195.5	223.0	161.0	113.5	114.0	2032.0
1957	108.5	103.5	128.0	128.5	123.5	224.0	285.0	188.5	177.5	137.0	112.0	101.0	1717.0
1958	110.0	98.0	106.0	110.5	152.0	241.5	242.0	288.0	220.5	165.0	105.0	113.0	1951.5
1959	93.0	87.0	90.0	118.5	161.0	300.0	341.5	318.5	234.0	130.5	103.0	99.0	2076.0
1960	108.5	101.5	113.0	185.5	257.0	364.0	412.5	442.5	337.5	220.0	136.0	121.5	2799.5
1961	133.0	114.5	128.5	162.0	182.5	272.0	347.5	311.5	181.0	128.0	108.5	120.0	2189.0

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1962	134.0	122.5	137.0	206.5	261.5	326.5	387.0	435.5	325.5	220.5	160.0	136.5	2753.0
1963	139.5	128.0	151.5	259.5	371.0	365.5	401.8	279.0	246.5	218.5	155.0	151.3	2867.1
1964	151.0	143.0	149.5	189.5	365.0	365.5	480.2	385.5	326.5	241.0	178.5	146.5	3112.7
1965	161.5	135.0	161.0	204.5	298.5	233.0	366.5	412.5	247.0	203.0	173.5	156.5	2752.5
1966	164.0	150.0	212.5	255.5	445.0	290.0	519.5	415.0	320.0	279.5	201.0	166.5	3418.5
1967	169.0	154.5	194.0	253.5	250.8	189.1	318.2	455.3	270.0	226.0	175.0	175.0	2830.4
1968	192.0	175.5	178.0	237.5	312.0	455.0	457.3	365.9	359.3	250.0	177.0	166.5	3326.0
1969	175.0	157.5	184.5	292.0	343.9	300.4	494.8	477.4	364.3	177.1	185.2	180.0	3332.4
1970	195.0	203.5	204.5	201.5	431.8	480.0	508.5	519.8	346.9	208.0	192.0	177.0	3668.5
1971	190.5	170.0	209.5	240.0	247.1	591.2	597.2	657.4	331.6	255.0	231.0	205.5	3926.0
1972	222.9	228.5	211.4	333.9	507.5	578.0	643.3	555.4	352.9	305.7	287.0	227.0	4564.4
1973	239.0	221.5	248.7	247.4	450.0	722.3	626.1	719.5	420.2	335.6	235.5	213.0	4678.7

Year	Population	Consumption AF	Consumption MG	GPCD[1]
1930	11,489	3,670	1,196.0	285.0
1940	12,251	4,089	1,332.25	297.9
1950	14,937	5,925	1,930.5	354.1
1960	25,027	8,591	2,799.5	306.5
1970	43,098	11,258	3,668.5	233.2
1980	71,000	15,958	5,200	200.6
1990	101,000	20,562	6,700	181.7
2000	133,000	25,165	8,200	168.9

[1]GPCD = gallons per capita per day

APPENDIX IV

The Windy Gap Project

The Windy Gap Project

The Windy Gap Project proposes the diversion of western slope water to be used east of the Continental Divide. If developed, it will serve basically six eastern slope cities: Boulder, Estes Park, Fort Collins, Greeley, Longmont and Loveland. The estimated average gross annual yield would be approximately 54,000 AF. After shrinkage losses this would result in a net yield of 48,600 AF/yr. Assuming the city of Fort Collins takes its full share, this amounts to one-sixth of the total or 8100 AF/yr.

The proposed project has three alternate plans. The costs of these ranging from $3,822,000 to $17,000,000 (These are 1974 costs.). The individual aspects of each alternate plan is contained in Appendix V. The largest plan here which is considered the most favorable and most likely to be implemented will be discussed here.

The project as proposed by the NCWCD consists of the construction of various facilities on the western slope to divert Colorado River water during high flows into the CBT system for conveyance to the east side of the divide. The CBT system currently transports water across the Continental Divide through the Adams Tunnel. The tunnel has a capacity of about 400,000 AF/yr. At the present time only slightly over 50 percent of that capacity is being utilized. Therefore even with the 50,000 AF produced by Windy Gap coming in through the tunnel, there would still be a reserve capacity in the tunnel in excess of 100,000 AF for possible future diversions.

The addition of nearly 50,000 AF to the CBT system will mean an increase of up to 20 percent more power generation. The Northern Colorado Water Conservancy District receives no payment for this power generation because of legal restrictions that require power revenue to be used to pay off the remaining CBT debt. However, the result of this additional power and revenue is that the Bureau of Reclamation will probably give the NCWCD a very favorable rate on electrical use for pumping on the western slope.

The facilities to be constructed include the following (Figure IV-1).

a) A diversion dam and 300 cfs capacity pumping plant on the Colorado River below its confluence with the Fraser River.

b) A conduit system of 300 cfs capacity to transport diverted water to a pumping plant (Jasper Pumping Plant No. 1) on Willow Creek below proposed Jasper Reservoir site.

c) A storage reservoir (Jasper Reservoir) of 23,000 AF capacity located on Willow Creek downstream of existing Willow Creek Reservoir.

d) A pumping plant (Jasper Pumping Plant No. 2) and conduit system to physically introduce Windy Gap water into the CBT system at Willow Creek Reservoir.

e) A conduit system from Jasper Pumping Plant No. 1 to the toe of Granby Dam so that a portion of the Windy Gap water can be exchanged into the CBT system through replacing the releases of water at the toe of Granby Dam to satisfy downstream fish and irrigation requirements. This method of introduction into the CBT system saves the cost of physically pumping that quantity of water into the CBT project.

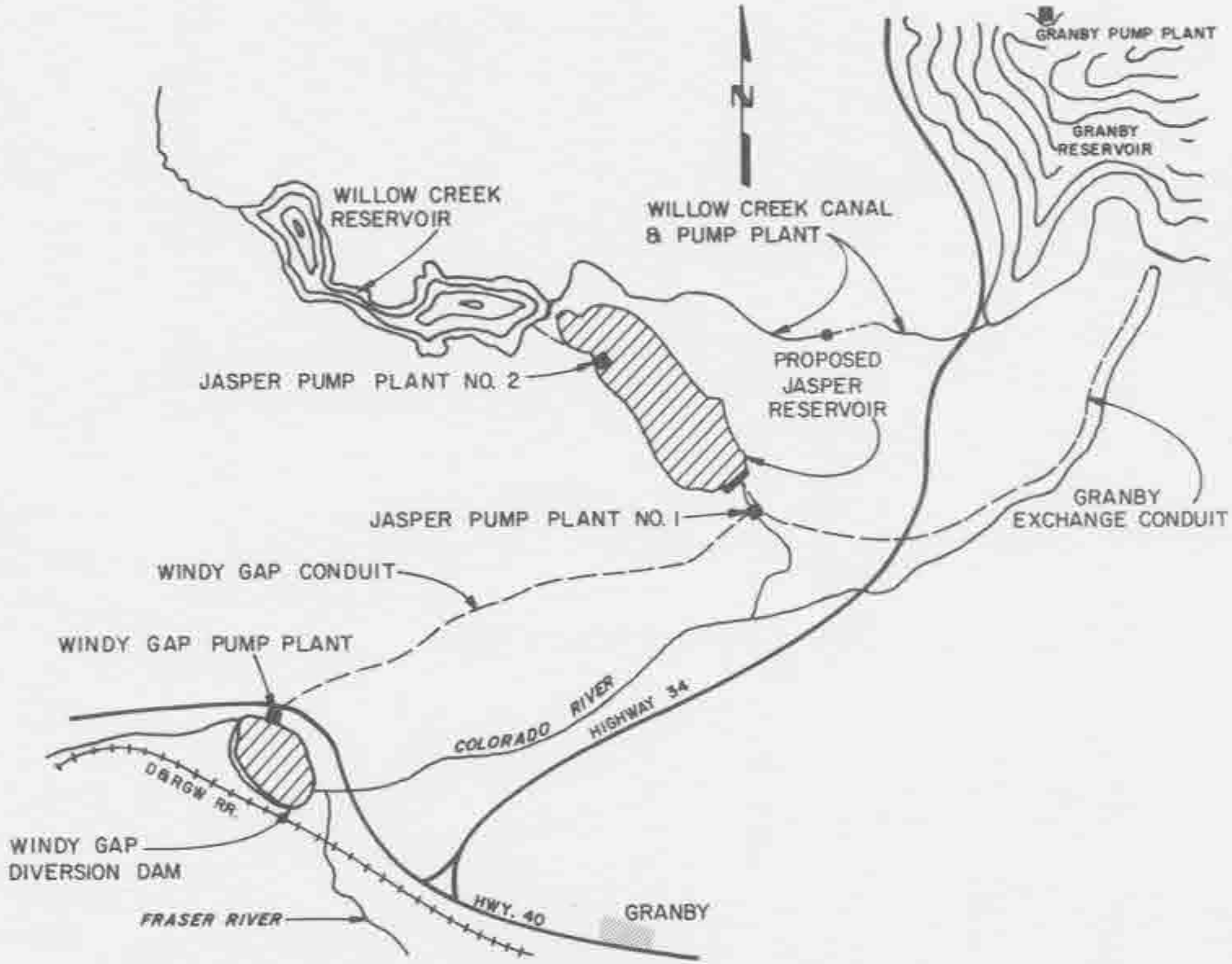

Figure IV-1. The Windy Gap Project.

APPENDIX V

Alternate Plans for Windy Gap and Joe Wright

Alternate Plans for Windy Gap[1]

Alternate A

Alternate A includes the following facilities:

a) A diversion dam and 300 cfs capacity pumping plant located on the Colorado River below its confluence with the Fraser River.

b) A conduit system of 300 cfs capacity to transport the diverted water to a pumping plant (Jasper Pumping Plant No. 1) located on Willow Creek below the proposed Jasper Reservoir site.

c) A storage reservoir (Jasper Reservoir) of 23,000 acre-foot capacity to be located on Willow Creek downstream of the existing Willow Creek Reservoir.

d) A pumping plant (Jasper Pumping Plant No. 2) and conduit system to physically introduce Windy Gap water into the CBT system at Willow Creek Reservoir.

e) A conduit system from Jasper Pumping Plant No. 1 to the toe of Granby Dam so that a portion of the Windy Gap water can be exchanged into the CBT system through replacing the releases of water at the toe of the Granby Dam to satisfy downstream fish and irrigation requirements. This method of introduction into the CBT system would save the cost of physically pumping that quantity of the water into the CBT Project.

Alternate A is felt to be the most favorable of the plans. A conservative estimate of its gross annual yield is 54,000 acre-feet. The estimated cost of construction in 1974 is $17,000,000.

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[1]From NCWCD Report.

Alternate B

This concept involves facilities needed to fully develop the exchange potential of the fish and irrigation releases from Granby Reservoir. This concept would involve the following physical facilities:

a) A diversion dam at Windy Gap.

b) A pumping plant and conduit to Jasper Reservoir with a capacity of 175 cfs.

c) A pumping plant at Jasper Reservoir.

d) Jasper Reservoir with a capacity of only 11,000 acre-feet.

e) A conduit from Jasper Reservoir to the toe of Granby Dam with a capacity of 75 cfs.

Alternate B is expected to produce an average deliverable net yield of 24,433 acre-feet. The estimated cost of construction in 1974 is $11,404,000.

Alternate C

This concept involves a minimal development which could utilize direct diversion from Windy Gap to the toe of Granby Reservoir for fish release exchange during periods of the year when such diversions could be made without replacement downstream. This concept would consist of the following physical facilities:

a) A diversion channel system at Windy Gap.

b) A 75 cfs capacity pump and conduit to the toe of Granby Dam.

This plan would produce an average deliverable yield of 11,974 acre-feet per year at an estimated 1974 cost of $3,822,000.

Alternate Plans for Joe Wright[2]

JOE WRIGHT DAM

HIGH DAM - 125 FEET HIGH

Dam

Type:	Earthfill
Crest El.	9,980.0
Max. W.S. El.	9,976.3
Nor. W.S. El.	9,967.0
Conserv. Stor. W.S. El.	9,893.0
Min. W.S. El.	9,862.0
Conservation Storage	755 AF
Municipal Storage	6,795 AF
Flood Surcharge Storage (Above Elev. 9,970.0)	1,250 AF

Service Spillway

Max. Cap.	
Uncontrolled	235 C.F.S.
Controlled	175 C.F.S.

Emergency Spillway

Max. Cap.	5.910 C.F.S.
Gates:	None

Outlet Works

Cap. 250 C.F.S. at W.S. El. 9,877.0
Cap. 300 C.F.S. at W.S. El. 9,882.0

HIGH DAM - 125 FEET HIGH Alternate

Dam

Type:	Earthfill
Crest El.	9,980.0
Max. W.S. El.	9,976.0
Nor. W.S. El.	9,965.0
Conserv. Stor. W.S. El.	9,893.0
Conservation Storage	755 AF
Municipal Storage	6,590 AF
Flood Surcharge Storage (Above Elev. 9,964.0)	2,020 AF

Spillway

Max. Cap.	2,900 C.F.S.
Gates	None

Outlet Works

Cap. 250 C.F.S. at W.S. El. 9,888.0
Cap. 300 C.F.S. at W.S. El. 9,911.0

The estimated 1974 cost of the high dam is $4,632,300.

JOE WRIGHT DAM

MIDDLE DAM - 105 FEET HIGH

Dam

Type:	Earthfill
Crest El.	9,960.0
Max. W.S. El.	9,956.2
Nor. W.S. El.	9,947.0
Conserv. Stor. W.S. El.	9,885.0
Min. W.S. El.	9,862.0
Conservation Storage	410 AF
Municipal Storage	4,320 AF
Flood Surcharge Storage (Above Elev. 9,949.8)	810 AF

Service Spillway

Max. Cap.	
Uncontrolled	235 C.F.S.
Controlled	175 C.F.S.

Emergency Spillway

Max. Cap.	6,000 C.F.S.
Gates:	None

Outlet Works

Cap. 250 C.F.S. at W.S. El. 9,877.0
Cap. 300 C.F.S. at W.S. El. 9,882.0

Estimated 1976 cost of the Middle Dam alternative is $3,534,900.

[2] From McCall-Ellingson Report.

JOE WRIGHT DAM

LOW DAM - 85 FEET HIGH

Dam		Service Spillway	
Type:	Earthfill	Max. Cap.	
Crest El.	9,940.0	Uncontrolled	280 C.F.S.
Max. W.S. El.	9,936.0	Controlled	175 C.F.S.
Nor. W.S. El.	9,925.0	Emergency Spillway	
Conserv. Stor. W.S. El.	9,883.0	Max. Cap.	11,250 C.F.S.
Min. W.S. El.	9,860.0	Gates:	None
Conservation Storage	380 AF		
Municipal Storage	2,200 AF	Outlet Works	
Flood Surcharge Storage	730 AF	Cap. 250 C.F.S. at W.S. El. 9,875.0	
(Above Elev. 9,928.0)		Cap. 300 C.F.S. at W.S. El. 9,880.0	

The estimated 1974 cost of this dam is $2,629,800.

APPENDIX VI

Cost Projections

Cost Projections

The cost projections made here are not a necessary part of the economic analysis. However they are of significant interest in financial considerations. The projections made here are based on the "Handy-Whitman Index of Water Utility Construction Costs" (Appendix VII). The "Handy-Whitman Index" is appropriate since it lists specific categories for "collecting and impounding reservoirs" (Joe Wright), "meters," and "meter installation." The recent trends of these costs are plotted in Figures VI-1, VI-2 and VI-3.

Considering the recent rise in inflation, the validity of these figures may be somewhat questionable. However they do give some indication of future costs.

Table VI-1

Joe Wright Cost Projections

	Jan. 1974	Jan. 1976	% Increase
Cost Index	284	320	12.7

Joe Wright Jan. 1974 Cost	$4,370,300
12.7% Increase	555,028
	$4,925,328

Table VI-2

Meter Cost Projections

	July 1974	Jan. 1974	% Increase
Meter Cost Index	204	205	0.5
Installation Cost Index	313	335	7.0

Meter Cost July 1974	$125.00
0.5% Increase	.63
	$125.63
Installation Cost	
July 1974	$225.00
7% Increase	15.75
	$240.75
Total Cost January 1976	$366.38

These projections are based on July 1974 estimated costs of $125.00 for meters and materials and $225.00 for labor, machinery and installation. Again these costs may also be low due to recent inflation.

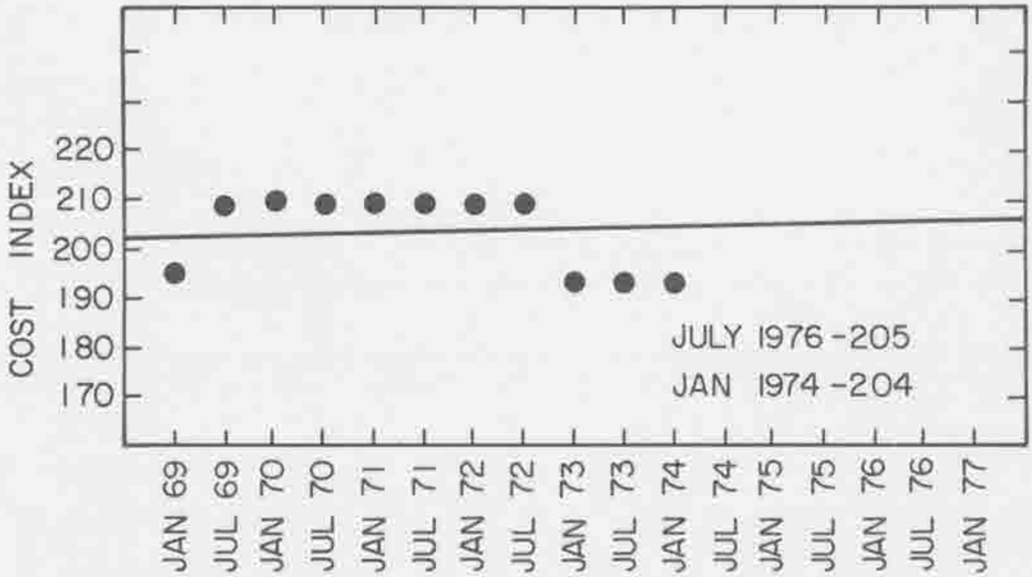

Figure VI-1. Meter Cost Projections.

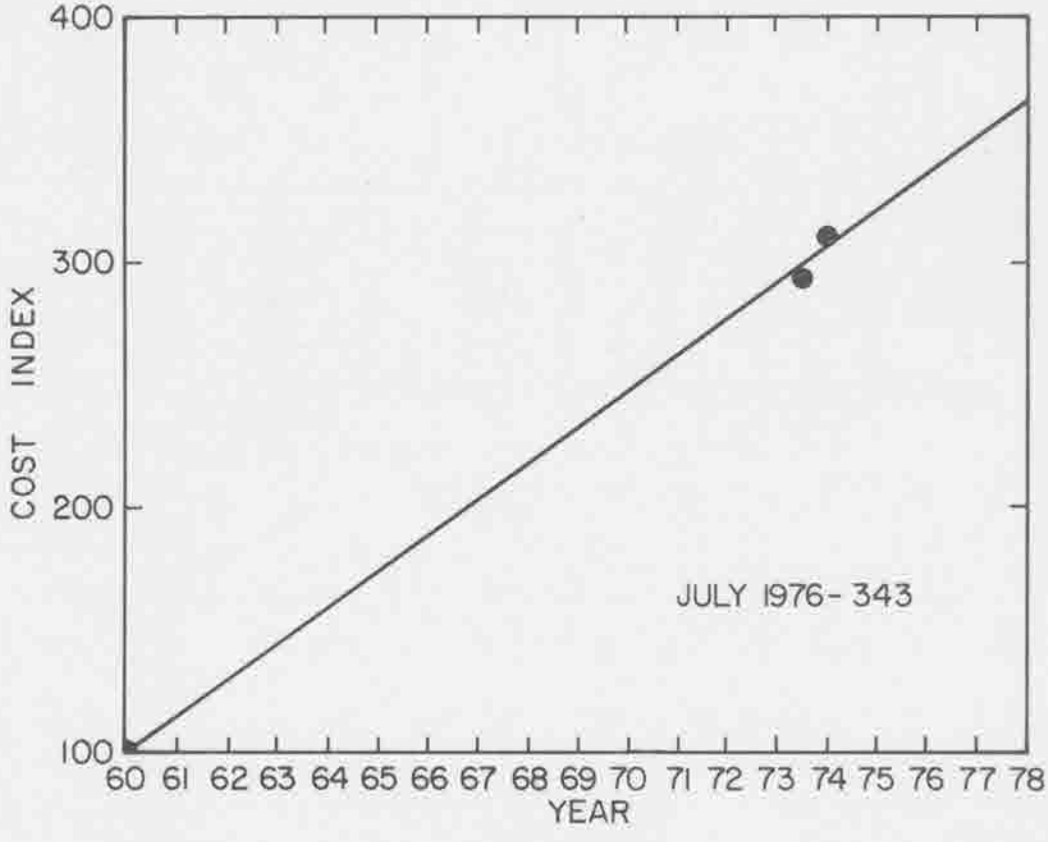

Figure VI-2. Meter Installation Cost Projections.

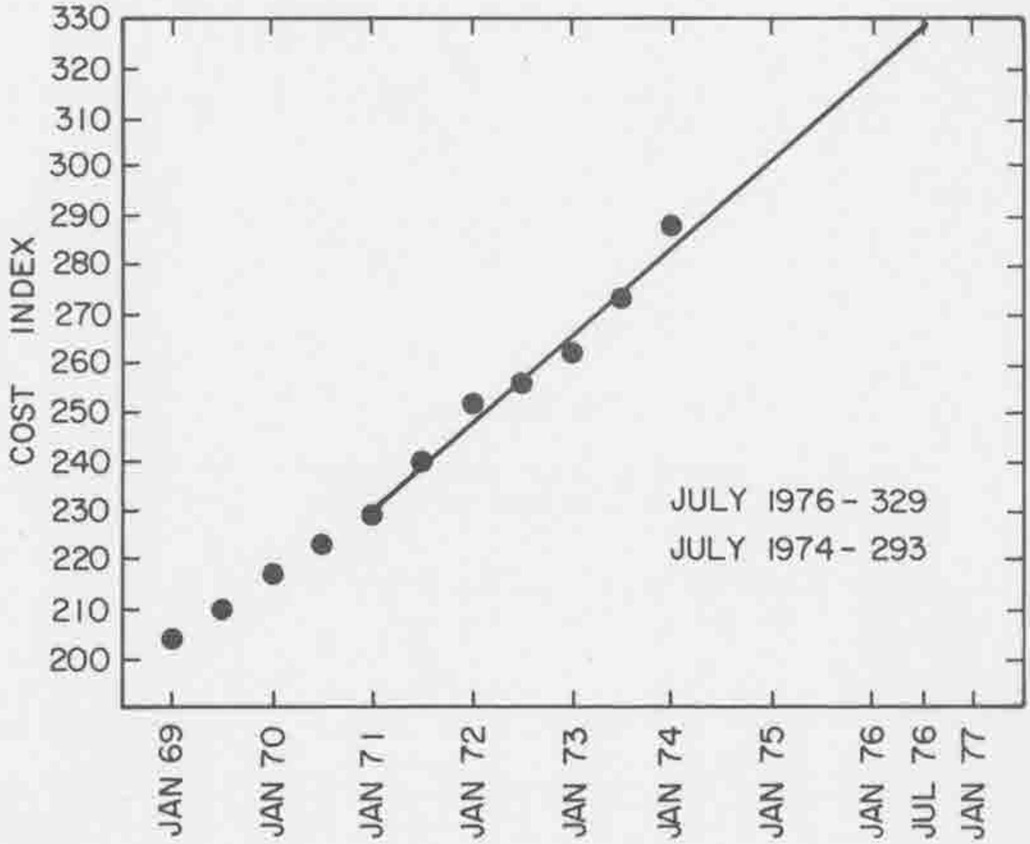

Figure VI-3. Projection of Costs of Collecting and Impounding Reservoirs.

APPENDIX VII

Handy-Whitman Index of Water
Utility Construction Costs

Trends of Construction Costs - Plateau Division

Classes of Construction, Material, Equipment and Labor Elements	Cost Index Numbers											
	1969		1970		1971		1972		1973		1974	
	Jan. 1	July 1	Jan. 1	July 1	Jan. 1	July 1	Jan. 1	July 1	Jan. 1	July 1	Jan. 1	July 1
Collecting and Impounding Reservoirs	204	210	217	223	229	240	252	256	262	273		288
Meters	195	209	209	209	209	209	209	209	193	193		193
Meter Installations										293		310

Source: From Bulletion No. 33 and preliminary release of Bulletin No. 35 of the Handy-Whitman Index of Water Utility Construction Costs, compiled and published by Whitman, Requardt and Associates, Engineering Consultants, Baltimore, Maryland.

APPENDIX VIII

Number of New One and Two Family and Apartment
Unit Building Permits, Fort Collins, 1961-1973

Below is a table summarizing new building starts of one and two family and apartment units (1961-1973) from the city of Fort Collins Building Department.

Year	1 and 2 Family Units	Apartment Units[1]
1973	707	1301
1972	925	658
1971	718	407
1970	344	290
1969	228	307
1968	269	484
1967	288	266
1966	201	101
1965	392	826
1964	393[2]	428
1963	315[2]	129
1962	261[2]	28
1961	263[2]	25
Totals	5304[3]	5250

[1] Includes triplex, fourplex and larger units

[2] Number of two family units estimated for these years

[3] Of this total, 13 percent are two family units

The above totals show that the number of new units of each type built in Fort Collins since 1960 have been nearly identical. A plot of the cumulative number of units (Figure VIII-1) shows that both types have followed similar paths.

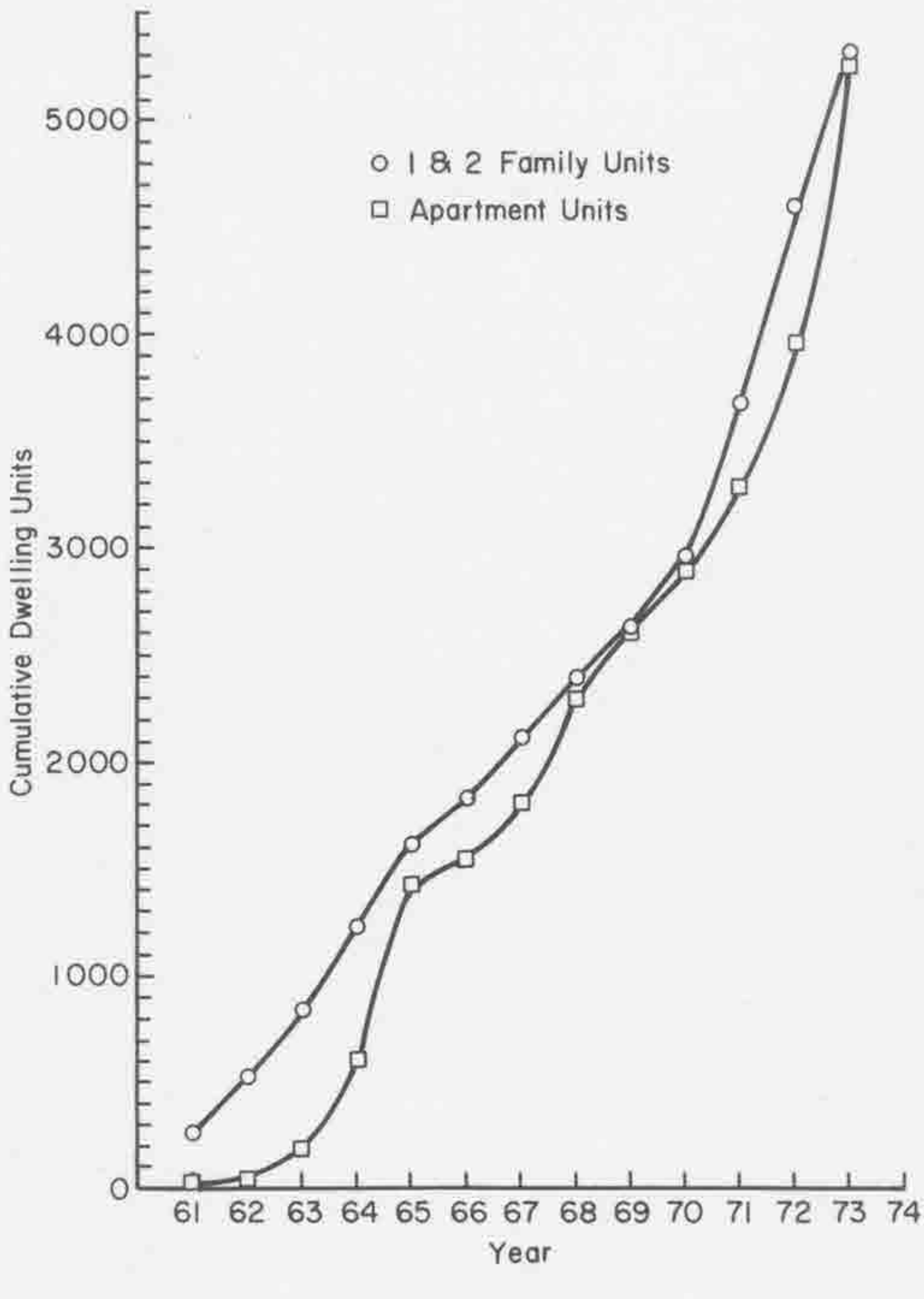

Figure VIII-1. Housing in Fort Collins.

APPENDIX IX

Boulder Housing and Population Data

Table IX-1

Revised Population Estimates
City of Boulder, 1960 through 1972

	Total Population	Increase	% Increase	Components of Total: SF	MF	Group
1960 Census	37,718					
4/1/61	40,780	3,062	8.1	28,152	7,148	5,480
4/1/62	43,942	3,162	7.8	29,811	8,001	5,680
4/1/63	46,113	2,171	4.9	31,562	8,671	5,880
4/1/64	49,544	3,431	7.4	33,313	10,151	6,080
4/1/65	51,307	1,763	3.6	34,432	10,595	6,280
4/1/66	53,548	2,241	4.4	36,305	10,763	6,480
4/1/67	56,929	3,381	6.3	38,287	11,962	6,680
4/1/68	61,009	4,080	7.2	40,861	13,268	6,880
1/1/69	63,729	2,720	4.5	42,109	14,540	7,080
1/1/70	66,391	2,662	4.2	42,949	16,162	7,280
1970 Census	66,870	1,390	2.1			
1/1/71	67,781			43,585	16,916	7,280
1/1/72	69,864	2,083	3.1	44,421	18,163	7,280
1/1/73	73,923	4,059	5.8	45,315	21,328	7,280
1/1/74	75,395	1,427	1.9	45,733	22,382	7,280

Group occupancy figures are interpolated on a straight-line basis from 1960 Census to 1970 Census and then estimated to continue at a constant level.

/City of Boulder
Revised 1/73

Table IX-2

Single Family Dwelling Units--City of Boulder

	Permits Issued	+	Units Annexed	-	Demolitions	=	Total Units	Vacancies	Occupied Units	x 3.4 =	Population	Increase	% Increase
1960 Census							8134						
1/1-12/31/60	581	+	14	-	4		8725	445	8280		4/1/61 28152	1659	5.9%
1/1-12/31/61	491	+	4	-	20		9200	432	8768		4/1/62 29811	1751	5.9
1/1-12/31/62	523	+	7	-	30		9700	417	9283		4/1/63 31562	1751	5.5
1/1-12/31/63	496	+	20	-	20		10196	398	9798		4/1/64 33313	1119	3.3
1/1-12/31/64	320	+	3	-	25		10494	367	10127		4/1/65 34432	1873	5.4
1/1-12/31/65	540	+	6	-	20		11020	342	10678		4/1/66 36305	1982	5.5
1/1-12/31/66	583	+	10	-	40		11573	312	11261		4/1/67 38287	2574	6.7
1/1-12/31/67	629	+	119	-	20		12301	283	12018		4/1/68 40861	1248	3.1
1/1/68-9/30/68	332	+	5	-	26		12612	227	12385		1/1/69 42109	840	2.0
10/1/68-9/30/69	217	+	1	-	19		12811	179	12632		1/1/70 42949	636	1.5
10/1/69 - 9/30/70	203	+	1	-	14		13001	182	12819		1/1/71 43585	836	1.9
10/1/70 - 9/30/71	281	+	2	-	33		13251	186	13065		1/1/72 44421	894	2.0
10/1/71-9/30/72	293	+	2	-	29		13517	189	13328		1/1/73 45315	418	.9
10/1/72 - 9/30/73	154	+	5	-	34		13642	191	13451		1/1/74 45733		

A three-month lag time is estimated from issuance of a building permit until occupancy.

Vacancy rate is estimated to descend on a straight-line basis from 5.5% in 1960 Census to 1.4% in 1970 Census and remain constant thereafter.

City of Boulder Planning Office

Table IX-3

Multi-Family Dwelling Units--City of Boulder

	Permits Issued	+ Units Annexed	- Demoli-tions	= Total Units	Vacan-cies	Occupied Units x 2.1 =	Population	Increase	% Increase
1960 Census				3403					
1/1-12/31/60	195			3598	194	3404	4/1/61 7148		
1/1-12/31/61	424			4022	212	3810	4/1/62 8001	853	11.9
1/1-12/31/62	317	+ 14		4533	224	4129	4/1/63 8671	670	8.4
1/1-12/31/63	736			5089	255	4834	4/1/64 10151	1480	17.1
1/1-12/31/64	216			5305	260	5045	4/1/65 10595	444	4.4
1/1-12/31/65	77			5382	257	5125	4/1/66 10763	168	1.6
1/1-12/31/66	396	+ 200	- 4	5974	278	5696	4/1/67 11962	1199	11.1
1/1-12/31/67	573	+ 72	-	6619	301	6318	4/1/68 13268	1306	10.9
1/1-9/30/68	625			7244	320	6924	1/1/69 14540	1272	9.6
10/1/68 - 9/30/69	805		- 7	8042	346	7696	1/1/70 16162	1622	11.2
10/1/69 - 9/30/70	379		- 4	8417	362	8055	1/1/71 16916	754	4.7
10/1/70 - 9/30/71	655		- 34	9038	389	8649	1/1/72 18163	1247	7.4
10/1/71 - 9/30/72	1582		- 8	10612	456	10156	1/1/73 21328	3165	17.4
10/1/72 - 9/30/73	689		- 164	11137	479	10658	1/1/74 22382	1054	4.9

A three-month time lag is estimated from issuance of building permit until occupancy. Since 1968 the actual occupancy date of large apartment complexes was used instead of the three-month lag time date, because many of these complexes had a longer construction period.

Vacancy rate is estimated to descend on a straight-line basis from 5.5% in 1960 Census to 4.3% in 1970 Census and remain constant thereafter.

City of Boulder Planning Office
Revised 1/73.

University of Colorado Enrollment (Boulder Campus)

Year	Total Enrollment (Fall Semester)	Full-Time Students*
1954	8,204	
1955	9,051	
1956	9,835	
1957	10,331	
1958	10,341	
1959	10,495	
1960	11,006	
1961	11,651	
1962	12,266	
1963	12,538	
1964	13,380	
1965	14,693	
1966	15,681	
1967	16,877	
1968	18,217	17,171
1969	18,962	17,537
1970	21,482	20,393
1971	21,171	20,444
1972	22,053	19,121

*Full-time student totals not available 1954-1967

Boulder Building Permits--From Boulder Building Department

Year	Single Family	Two Family	Multi-Family (all in units)
1973	204	6	628
1972	250	8	786
1971	358	14	1919
1970	231	-	807
1969	165	7	495
1968	429	15	976
1967	629	6	567
1966	583	10	387
1965	540	12	65
1964	320	8	133
1963	496	8	503
1962	523	28	289
1961	491	42	382
1960	581	30	163
1959	427	26	36
1958	398	6	140
1957	340	26	120
1956	451	32	110
1955	558	26	28
1954	371	52	54
	8300	362	8588

	1 & 2 Family	Multi-Family
1969-1973	1243	4365
1964-1973	3795	6763

APPENDIX X

Fort Collins Cache La Poudre River Rights

Fort Collins Cache La Poudre River Rights

Water Right	Quantity (cfs)	Basin Rank	Date
Fort Collins Pipeline	2.65	14	6/1/1860
Fort Collins Pipeline	0.85	14	6/1/1860
Fort Collins Pipeline	2.16[1]	56	3/1/1862
City of Fort Collins Pl.	7.00	58	3/15/1862
City of Fort Collins Pl.	2.78[1]	129	9/15/1864
Fort Collins City Pl.	0.50	143	5/1/1865
Fort Collins Pipeline	4.00	143	5/1/1865

[1]Diversion period limited to April 15 to October 15 of each year without replacement. From October 15 to April 15 of next year, water may be diverted on these rights provided it is replaced with an equal amount of water from sources other than waters which are naturally tributary to the Cache La Poudre River.(6)

APPENDIX XI

Boulder Water Consumption
(1953-1973)

Boulder Water Consumption 1953-1973
In Million Gallons

Source: Boulder Water Treatment Plant

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1953	86.8	61.0	89.5	104.2	157.4	230.1	273.6	176.1	203.0	109.7	106.2	95.0	1796.1
1954	75.3	83.8	73.7	157.4	167.3	245.4	200.5	200.2	159.0	86.2	86.9	82.9	1638.6
1955	82.5	85.8	82.8	109.3	107.7	112.5	319.3	300.3	244.4	183.8	96.5	82.5	1805.4
1956	111.3	96.3	105.1	141.1	242.0	364.1	404.6	325.9	320.5	210.5	130.1	119.8	2575.3
1957	116.7	115.1	134.0	129.3	156.0	289.3	447.9	377.0	288.2	287.4	183.8	149.5	2672.2
1958	144.9	130.8	144.9	148.8	206.4	356.2	408.8	443.6	350.3	248.0	155.1	140.7	2878.7
1959	144.1	134.1	151.9	158.0	256.6	436.2	487.3	414.3	372.9	181.6	146.1	134.4	3017.5
1960	118.8	113.4	131.8	215.3	305.8	449.6	489.6	462.2	389.4	271.1	191.3	181.0	3319.3
1961	161.2	143.3	161.1	183.8	219.3	288.1	473.6	414.6	278.6	240.4	202.3	187.1	2953.4
1962	180.6	179.7	199.0	253.1	423.6	394.0	546.2	528.6	397.3	244.3	226.2	217.1	3789.7
1963	174.8	145.2	158.7	270.0	308.1	348.7	461.9	323.0	284.5	254.1	173.1	152.9	3055.0
1964	152.6	143.6	151.3	183.0	405.4	335.4	495.0	416.5	386.5	255.0	169.8	153.5	3227.6
1965	147.5	136.8	151.4	199.2	263.7	312.3	455.2	380.2	250.3	201.0	197.8	163.7	2859.1
1966	155.0	139.9	172.2	218.8	414.8	408.1	580.3	509.2	294.3	252.5	171.9	178.0	3496.0
1967	177.9	175.5	203.5	255.7	273.9	217.8	340.2	486.5	292.1	249.0	202.5	192.3	3066.7
1968	197.2	182.1	217.4	223.6	325.5	506.2	593.5	398.1	403.5	274.1	214.1	201.0	3736.3
1969	207.6	211.0	228.9	312.6	411.5	358.7	583.8	631.7	458.2	267.2	228.8	216.7	4116.7
1970	213.9	227.1	230.7	233.0	450.8	473.6	579.6	629.2	388.2	248.2	246.4	239.6	4160.3
1971	232.0	223.0	243.0	294.8	325.9	646.3	632.9	748.9	401.2	289.6	256.5	235.1	4529.2
1972	248.2	233.5	316.6	306.8	477.2	568.7	507.6	554.4	425.9	355.3	257.7	245.3	4502.2
1973	265.2	254.0	279.1	274.8	393.9	706.8	711.1	773.9	466.8	368.3	280.8	269.9	5044.6

APPENDIX XII

Water Consumption Reduction Metering
Boulder, Colorado

Least square lines were fit to the Boulder water consumption data contained in Appendix XI. 1958 to 1962 is considered unmetered.

Equations

Without Meters $Y = 3634 + 222\ X$ (1953 = 1)

With Meters $Y = 2573 + 205\ X$ (1963 = 1)

where X = the year in question

Y = the predicted consumption (MG)

Year	Water Consumption Without Meters (MG)	Water Consumption With Meters (MG)	Water Saved	% Saved
1963	3856	2778	1078	28.0
1967	4744	3598	1146	24.2
1972	5854	4623	1231	21.0
1977	6964	5648	1316	18.9

APPENDIX XIII

Application of Boulder Water Consumption to Fort Collins

The basic assumption made here is that the total reduction in water consumption at Boulder is the direct result of the reduction in use by single family dwelling units. This gives a value of savings per day per dwelling unit that can be applied to dwelling units in Fort Collins. The water saved per dwelling unit at Boulder is listed in Table XIII-1.

Figure XIII-1 shows a plot of water saved per dwelling unit versus time. A curve was drawn through the points and values were taken from it in an attempt to neglect changes in water use due to precipitation variations. These values are shown in Table XIII-2.

Table XIII-1

Water Savings Per Single Family Dwelling Unit at Boulder

Year	Consumption Without Meters (MG)	Consumption With Meters (MG)	Water Saved	Occupied Single Family Units	Water Saved Per Unit (MG)
1965	4300	3188	1112	10678	0.1041
1966	4522	3393	1129	11261	0.1003
1967	4744	3598	1146	12018	0.0954
1968	4966	3803	1163	12385	0.0939
1969	5188	4008	1180	12632	0.0934
1970	5410	4213	1197	12819	0.0934
1971	5632	4418	1214	13065	0.0929
1972	5854	4623	1231	13328	0.0924
1973	6076	4828	1248	13451	0.0928

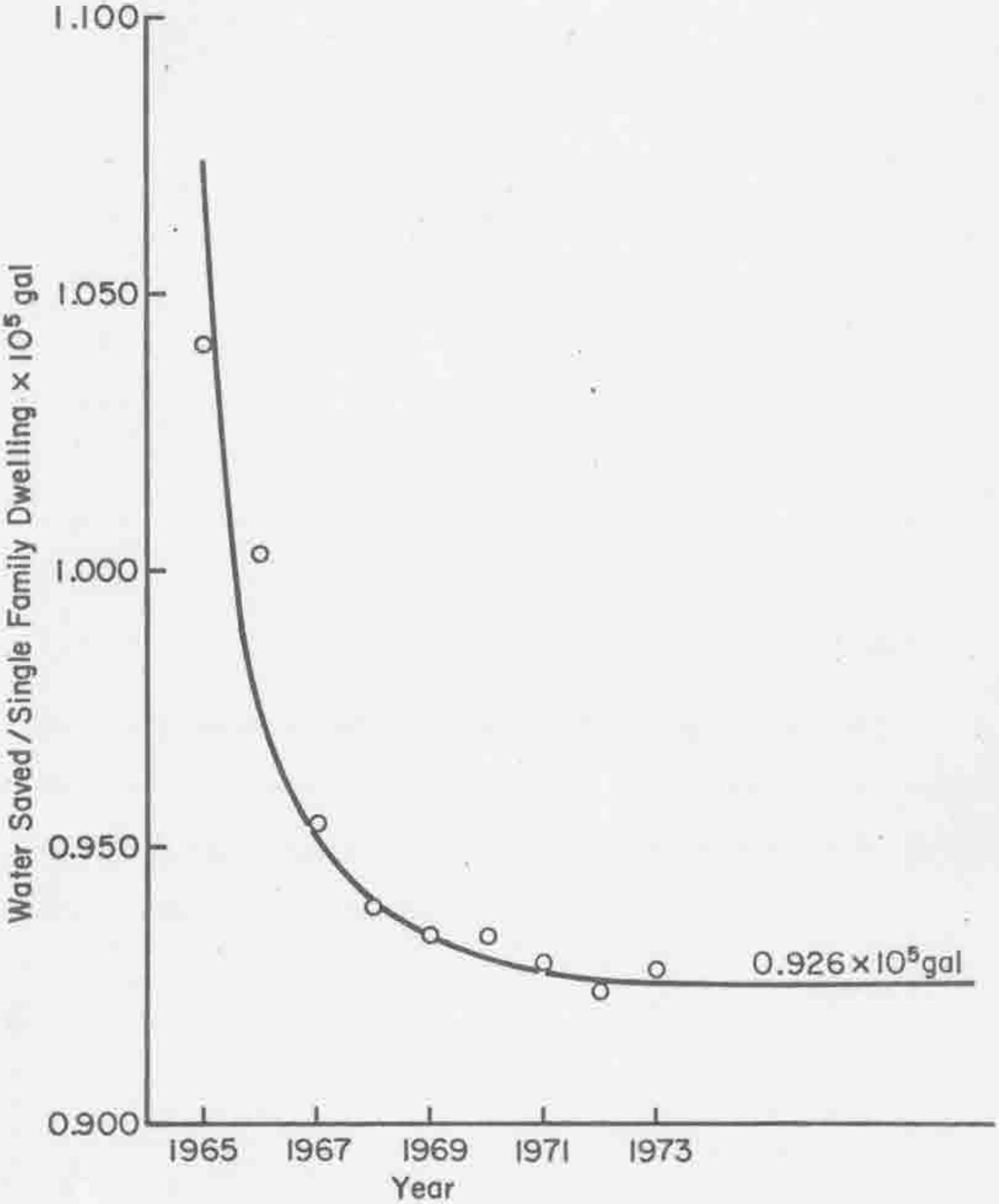

Figure XIII-1. Water Saved per Dwelling Unit at Boulder.

Table XIII-2

Water Saved Per Day Per Dwelling Unit

Year	Water Saved Per Day Per Dwelling Unit (MG)	Water Saved Per Day Per Dwelling Unit (MG)
1965	0.1070	293
1966	0.0975	267
1967	0.0954	261
1968	0.0940	257
1969	0.0934	256
1970	0.0930	255
1971	0.0927	254
1972	0.0926	254
1973	0.0926	254

The graph seems to level off at 0.0926 MG/du or 254 gpd/du. Therefore the estimated Fort Collins water reduction will be determined by multiplying that figure by the number of one and two family dwelling units (which has been determined in Appendix II).

APPENDIX XIV

Tables of Residential Water Use from Linaweaver Report
(Reference 13)

Table XIV-1

Characteristics of Study Areas

Type of Study Area	Number of Dwelling Units (2)	Average Market Value (dollars) (3)	Population Density (persons per dwelling) (4)	Housing Density (dwellings per acre) (5)	Irrigable Area (acres per dwelling) (6)	Annual Precipitation (inches) (7)
Metered public water and public sewers						
West (10 areas)						
Minimum	63	13,200	2.7	1.28	0.079	7.09
Mean	158	24,400	3.8	3.61	0.205	14.9
Maximum	295	42,400	4.5	6.14	0.582	27.2
East (13 areas)						
Minimum	124	9,500	3.4	1.32	0.406	29.2
Mean	235	18,500	4.1	4.16	0.183	39.0
Maximum	410	35,300	4.9	9.35	0.595	48.7
Metered public water and septic tanks						
(5 areas)						
Minimum	44	19,700	3.1	0.94	0.243	30.4
Mean	174	27,600	4.1	1.66	0.516	43.3
Maximum	307	36,000	4.9	2.73	0.868	47.5
Flat-rate public water and public sewers						
(8 areas)						
Minimum	91	11,100	2.7	2.75	0.094	14.1
Mean	184	19,100	3.7	3.99	0.146	14.7
Maximum	326	53,500	4.7	4.98	0.191	16.3
Apartment areas						
(5 areas)						
Minimum	34	6,500	1.8	23.4		10.4
Mean	789	9,200	2.6	36.2		28.5
Maximum	2,373	15,200	3.0	50.0		43.5
All 41 study areas						
Minimum	34	6,500	1.8	0.94	0.046	7.09
Mean	267	20,000	3.8	7.6	0.227	27.6
Maximum	2,373	53,500	4.9	50.0	0.868	48.7

Table XIV-2

Summary of Residential Water Use

Type of Study Area	Mean of Annual Uses	Mean of Maximum Daily Uses	Mean of Peak Hourly Uses
	(gallons per day per dwelling unit)		
(1)	(2)	(3)	(4)
Metered public water and public sewers			
West (10 areas)	458	979	2,481
East (13 areas)	310	786	1,833
Metered public water and septic tanks			
(5 areas)	245	726	1,835
Flat-rate public water and public sewers			
(8 areas)	692	2,354	5,170
Apartment Areas			
(5 areas)	191	368	960
All 41 study areas	398	1,096	2,572

Table XIV-3

Summary of Domestic (Household) Use

Type of Study Area	Mean of Annual Uses	Mean of Maximum Daily Uses	Mean of Peak Hourly Uses
	(gallons per day per dwelling unit)		
(1)	(2)	(3)	(4)
Metered public water and public sewers			
West (10 areas)	247	454	1,214
East (13 areas)	209	271	536
Metered public water and septic tanks			
(5 areas)	191	247	530
Flat-rate public water and public sewers			
(8 areas)	236	431	1,016
Apartment Areas			
(5 areas)	157	220	659
All 41 study areas	215	338	809

Table XIV-4

Summary of Sprinkling Use

Type of Study Area	Mean of Annual Uses	Mean of Maximum Daily Uses	Mean of Peak Hourly Uses
	(gallons per day per dwelling unit)		
(1)	(2)	(3)	(4)
Metered public water and public sewers			
West (10 areas)	186	707	2,076
East (13 areas)	80	556	1,534
Metered public water and septic tanks			
(5 areas)	42	523	1,583
Flat-rate public sater and public sewers			
(8 areas)	420	2,083	4,812
Apartment Areas			
(5 areas)	18	194	745
All 41 study areas	160	857	2,251

Table XIV-5

Comparison of Actual Lawn Sprinkling and Potential Lawn Sprinkling Requirements, October 1963--September 1965

Type of Study Area (1)	Annual (2)	Summer (inches of water) (3)	Maximum Day (4)
Metered public water and public sewers			
West (10 areas)			
Potential Evapotranspiration	29.8	11.5	0.25
Potential Lawn Sprinkling Requirement	22.5	11.5	0.25
Lawn Sprinkling	14.0	7.4	0.15
East (13 areas)			
Potential Evapotranspiration	30.3	15.8	0.29
Potential Lawn Sprinkling Requirement	15.0	9.5	0.29
Lawn Sprinkling	7.0	4.7	0.14
Metered public water and septic tanks			
(5 areas)			
Potential Evapotranspiration	27.8	15.3	0.29
Potential Lawn Sprinkling Requirement	12.4	8.1	0.29
Lawn Sprinkling	1.1	0.79	0.03
Flat-rate public water and public sewers			
(8 areas)			
Potential Evapotranspiration	25.4	14.7	0.29
Potential Lawn Sprinkling Requirement	14.8	10.3	0.29
Lawn Sprinkling	39.4	24.5	0.51

Table XIV-6

Comparison of Metered versus Flat-Rate Use

	Metered Areas (10) (1)	Flat-rate Areas (7) (2)
	(gallons per day per dwelling unit)	
Average Annual		
Leakage	25	35
Domestic or household	247	236
Sprinkling	186	420
Total	458	690
Maximum Day	979	2,354
Peak Hour	2,481	5,171
	(inches of water)	
Annual		
Actual lawn sprinkling	14.0	39.4
Potential sprinkling requirements	22.5	14.8
Summer		
Actual lawn sprinkling	7.4	24.5
Potential sprinkling requirements	11.5	10.3
Maximum Day		
Actual lawn sprinkling	0.15	0.51
Potential sprinkling requirements	0.25	0.29

APPENDIX XV

Ideal Sprinkling

Ideal Sprinkling

The amount of water needed by the lawn and amount actually applied to the lawn must be determined. Hankc has defined "Ideal Sprinkling" as the "amount of water that should be applied to a given yard to maintain its aesthetic quality, a green appearance."[9] Ideal sprinkling is also referred to as potential sprinkling requirements (from Howe-Linaweaver, reference (9)).

Hanke has defined ideal sprinkling as

$$\overline{Q}_s = ca\overline{L}_s\overline{E}$$

where c is a constant, a is the number of dwellings served, $\overline{L}_s$ is the average lawn sprinkling area and $\overline{E}$ is the average evapotranspiration. So ideal sprinkling is that amount of water needed to meet the average evapotranspiration rate of the lawn. Average evapotranspiration,

$$\overline{E} = u - R_e$$

where u is the consumptive use given by the Blaney-Criddle formula

$$u = kf$$

and R_e is the effective rainfall (adjusted for runoff). Comparisons of actual lawn sprinkling and potential lawn sprinkling have been given in the Howe-Linaweaver report "A Study of Residential Water Use," reference (13) and were summarized in Table 10 (however their calculations of evapotranspiration are the result of using Thornthwaite's and Penman's rather than Blaney-Criddle).

APPENDIX XVI

Calculation of Present Worths

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      PROGRAM JWRIGHT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      DIMENSION D(50),X(50),E(50),ANPW(50),TNPW(50),TE(50),TB(50),B(50),
     *M(50),TWP(50)
C     S=THE TOTAL SUPPLY WITH JOE WRIGHT WATER
C     CM=THE ANNUAL COST OF MAINTENANCE AND INSPECTION
C     D=THE PROJECTED DEMAND
C     E=THE ES
C     E=THE EXCESS WATER NOT CONSUMED
C     B=THE RETURN FROM RENTAL OF THE EXCESS WATER
C     CC IS THE INITIAL CAPITAL COST
      CC=4370300
C     S IS THE TOTAL RAW WATER SUPPLY WITH JOE WRIGHT
      S=30426
      DO 10 I=1,41
C     CM IS THE ANNUAL MAINTENANCE COST
      CM=4800.
      X(I)=I
C     D IS THE PROJECTED DEMAND
      D(I)=(4581.+76.61*X(I)+2.66*(X(I))**2.)/.325851
      E(I)=S-D(I)
      CWN=0.
      IF(I.GT.5)GO TO 11
      E(I)=0.
   11 IF(E(I).GT.6455.)GO TO 12
      GO TO 13
   12 E(I)=6455.
   13 IF(E(I).GT.0.)GO TO 15
      E(I)=0.
      IF(I.LT.6)GO TO 15
C     WN IS THE WATER NEEDED WHEN THE SUPPLY IS EXHAUSTED
      WN=D(I)-S
      CWN=WN*7.00
C     B IS THE RETURN FROM THE LEASE OF EXCESS WATER
   15 B(I)=E(I)*7.00
      IF(I.GT.1)GO TO 3
      TB(I)=B(I)
      GO TO 4
    3 TB(I)=TB(I-1)+B(I)
    4 M(I)=1972+I
      IF(I.GT.5)GO TO 14
      CM=0.
C     CALCULATION OF ANNUAL NET PRESENT WORTH
C     ANPW IS THE ANNUAL NET PRESENT WORTH
   14 ANPW(I)=(CM-B(I)+CWN)/(1.03**(I-2))
      IF(I.GT.1)GO TO 2
      TNPW(I)=ANPW(I)
      GO TO 5
C     CALCULATION OF TOTAL NET PRESENT WORTH
C     TNPW IS THE TOTAL NET PRESENT WORTH
    2 TNPW(I)=ANPW(I)+TNPW(I-1)
    5 IF(I.GT.1)GO TO 6
      TE(1)=E(1)
      GO TO 7
    6 TE(I)=E(I)+TE(I-1)
    7 CONTINUE
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      IF(I.LT.6)GO TO 20
      TWP(I)=6455.
      TWP(I)=TWP(I-1)+TWP(I)
      GO TO 21
   20 TWP(I)=0.
   21 CONTINUE
      WRITE(6,100)M(I),D(I),S,E(I),B(I),TB(I),ANPW(I)
  100 FORMAT(* *,I10,6F12.2)
   10 CONTINUE
C     THE FC"S ARE THE TOTAL 1974 PRESENT WORTHS FOR 10,20,30, AND 40
C     YEAR PERIODS
      FC10=CC+TNPW(11)
      FC20=CC+TNPW(21)
      FC30=CC+TNPW(31)
      FC40=CC+TNPW(41)
      WRITE(6,101)TNPW(10),TNPW(20),TNPW(30),TNPW(40)
  101 FORMAT(* *,4F20.2)
C     THE C"S ARE THE COST PER ACRE-FOOT FOR THOSE PERIODS
      C10=FC10/TWP(11)
      C20=FC20/TWP(21)
      C30=FC30/TWP(31)
      C40=FC40/TWP(41)
      WRITE(6,103)FC10,FC20,FC30,FC40
  103 FORMAT(* *,4F20.2)
      WRITE(6,102)TWP(11),TWP(21),TWP(31),TWP(41),C10,C20,C30,C40
  102 FORMAT(* *,4F20.2/4F20.2)
      END
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      PROGRAM WATMTR(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      DIMENSION H(50),TWS(50),ANM(50),TNPW(50),ANPW(50),ANMM(50),IMY(50)
     *,ACMT(50),ACRBM(50),ACE(50),ATTC(50),AANMM(50)
C     CMET=THE COST OF METERS AND MATERIALS
C     CXI=THE COST OF INSTALLATION
C     XRB=THE COST OF READING AND BILLING
C     XMN=THE COST OF MAINTENANCE
C     XMT=THE TOTAL COST OF METERS AND INSTALLATION
C     S=THE PRESENT RAW WATER SUPPLY IN 1974
C     TS=THE TOTAL SUPPLY INCLUDING WATER SAVED BY METERING
C     WS=THE WATER SAVED BY METERING
C     C=THE PROJECTED CONSUMPTION AFTER METERING
C     E=THE EXCESS WATER PRODUCED BY METERING
C     TWS=THE TOTAL WATER SAVED BY METERING
C     CE=THE RETURN FROM LEASE OF EXCESS WATER
C     H=THE TOTAL OCCUPIED 1 AND 2 FAMILY HOUSING UNITS
      A=0.
      M=0
      CMET=125.
      CXI=225.
      XRB=5.52
      XMN=8.09
      XMT=350.
      ET=0.
      S=23971.
      X=155.
C     CALCULATION OF OCCUPIED 1 AND 2 FAMILY UNITS
      DO 20 J=1,41
      XJ=J
      H(J)=10091.+89.65*XJ+4.57*XJ*XJ
   20 CONTINUE
      HWS=H(13)-(.1*H(1))
      DO 10 I=1,41
      XI=I
C     CALCULATION OF PROJECTED DEMAND AND WATER SAVED BY METERING
      D=(4581.+76.61*XI+2.66*XI*XI)/.325851
      IF(M.LT.4)GO TO 1
      IF(M.GT.13)GO TO 13
      A=A+.1
    1 M=M+1
      IF(I.GT.13)GO TO 13
      WS=HWS*X/325851.*365.*A
      GO TO 14
   13 WS=H(I)*(X/325851.)*365.
C     WS IS IN ACRE-FEET
   14 TS=23971.+WS
      C=D-WS
      E=S-C
      CWN=0.
      IF(E.GT.WS)GO TO 21
      GO TO 22
   21 E=WS
   22 IF(E.GT.0.)GO TO 23
      E=0.
      IF(I.LT.5)GO TO 23
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C     WATER NEEDED WHEN SUPPLY IS EXHAUSTED
      WN=C-S
      CWN=WN*7.00
   23 MY=1972+I
      IF(I.GT.1)GO TO 24
      TWS(1)=WS
      GO TO 25
   24 TWS(I)=WS+TWS(I-1)
   25 CE=E*7.00
      WRITE(6,100)MY,D,C,WS,E,CE,TWS(I),TS
  100 FORMAT(* *,I10,7F15.0)
C     CALCULATION OF COSTS OF METERS AND INSTALLATION
      HT=(H(13)-(.1*H(1)))/10.
C     CMI IS THE INITIAL COST OF PURCHASING THE NUMBER OF METERS NEEDED
C     THROUGH 1985
      CMI=HT/.95*CMET*10.
      IF(I.GT.13)GO TO 31
      IF(I.GT.3)GO TO 30
      ANM(I)=0.
      GO TO 32
C     DIVIDE BY .95 TO GET TOTAL UNITS NEEDING METERS
   30 ANM(I)=HT/.95
      GO TO 32
   31 ANM(I)=(H(I)-H(I-1))/.95
   32 CONTINUE
      IF(I.GT.13)GO TO 33
      CMT=ANM(I)*CXI
      GO TO 34
   33 CMT=ANM(I)*XMT
C     CALCULATION OF COSTS OF READING, BILLING AND MAINTENANCE
   34 TXRBM=XRB+XMN
      IF(I.GT.1)GO TO 37
      ANMM(1)=0.
      TANMM=0.
      GO TO 38
C     MULTIPLY BY .95 TO GET OCCUPIED UNITS
   37 ANMM(I)=ANM(I-1)*.95
      TANMM=ANMM(I)+TANMM
   38 CRBM=TANMM*TXRBM
      IF(I.LT.5)GO TO 35
      GO TO 36
   35 CRBM=0.
   36 TTC=CMT+CRBM-CE+CWN
      IF(I.LT.4)GO TO 51
C     ANNUAL NET PRESENT WORTH
      ANPW(I)=TTC/(1.03**(I-2))
      GO TO 52
   51 ANPW(I)=0.
   52 IF(I.GT.1)GO TO 40
      TNPW(I)=ANPW(I)
      GO TO 41
C     TOTAL NET PRESENT WORTH
   40 TNPW(I)=ANPW(I)+TNPW(I-1)
   41 CONTINUE
      IMY(I)=MY
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      ACMT(I)=CMT
      ACRBM(I)=CRBM
      ACE(I)=CE
      ATTC(I)=TTC
      AANMM(I)=TANMM
   10 CONTINUE
      WRITE(6,204)
  204 FORMAT(*1*,*NEW PAGE*)
      DO 50 N=1,41
      WRITE(6,200)IMY(N),ACMT(N),ACRBM(N),ACE(N),ATTC(N),ANPW(N),TNPW(N)
  200 FORMAT(* *,I10,6F15.0)
   50 CONTINUE
C     THE C"S ARE THE 1974 PRESENT WORTHS FOR 10,20,30, AND 40 YEAR TIME
C     PERIODS
      C11=TNPW(11)+CMI
      C21=TNPW(21)+CMI
      C31=TNPW(31)+CMI
      C41=TNPW(41)+CMI
C     THE CAF"S ARE THE COSTS PER ACRE-FOOT FOR THOSE TIME PERIODS
      CAF11=C11/TWS(11)
      CAF21=C21/TWS(21)
      CAF31=C31/TWS(31)
      CAF41=C41/TWS(41)
      WRITE(6,201)C11,C21,C31,C41,TWS(11),TWS(21),TWS(31),TWS(41),CAF11,
     *CAF21,CAF31,CAF41
  201 FORMAT(* *,4F15.2/4F15.0/4F15.2)
      END
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