January 1979

Historical and Projected Municipal and Industrial Water Usage in Utah 1960-2020

Roger D. Hansen

Herbert H. Fullterton

A. Bruce Bishop

Trevor C. Hughes

Ronald Christensen

Davis S. Bowles

See next page for additional authors

HISTORICAL AND PROJECTED MUNICIPAL AND INDUSTRIAL WATER USAGE IN UTAH 1960 - 2020

by

Roger D. Hansen
Herbert H. Fullerton
A. Bruce Bishop
Trevor C. Hughes

Data processing by

Ronald Christensen
David S. Bowles

Data collection by

Roger D. Hansen
Kyle Matteson
Herschel G. Hester, III
Ronald Mead
Randy Simmons

In cooperation with

Utah League of Cities and Towns
Utah State Division of Water Quality
Utah State Division of Water Rights
Utah Job Service

WATER RESOURCES PLANNING SERIES
UWRL/P-79/02

Utah Water Research Laboratory
Utah State University
Logan, Utah

February 1979

ABSTRACT

This publication reports the results of a municipal and industrial water use inventory. Data reported covers the period 1960 through 1976. Time series information is aggregated from municipal and industrial system level to county and state totals. Total municipal and industrial withdrawals are divided between surface and groundwater sources.

Yearly per capita withdrawal rates are estimated for 50 Utah municipalities and for each of Utah's 29 counties. Per capita withdrawal rates range from a high of over 400 gallons per capita per day (gcd) in the communities of Delta, Fillmore, Hyrum, Logan, and Morgan to a low of 100 gcd in Bountiful, Washington Terrace, Centerville, and South Ogden. A three year average (1974, 1975, and 1976) of Utah's per capita withdrawal rate is 262 gcd. Also reported are return flow rates for 13 Utah waste treatment facilities.

Withdrawal and return flow rates are also reported for Utah's major water using industries. These rates are reported in gallons per employee per day (or gallons per unit of output).

The publication also discusses methodologies for projecting municipal and industrial usage in Utah to the year 2020. Also reported are population projections for multicounty districts, counties and major cities by ten year intervals from 1960-2020.

ACKNOWLEDGMENTS

This is the final report of a project which was supported by the Bureau of Reclamation under agreement No. 7-07-40-50381 with the Utah Water Research Laboratory and Utah State University. The collection of data on water pricing was supported by the Bear River Association of Governments under Contract No. 78-10-6-158. The authors wish to acknowledge the excellent cooperation and valuable assistance of the following individuals: Kyle Matteson and Herschel G. Hestor, III, Utah League of Cities and Towns; Harold Donaldson and David Mills, Utah Division of Water Rights; and Kenneth Bousfield and Robert Sperling, Utah Division of Water Quality.

The municipal data collection instruments were mailed and collected by the Utah League of Cities and Towns. The files of the Division of Water Rights and Bureau of Environmental Health were made available to us and their data were used extensively. The authors owe a particular debt of gratitude to the municipal officials and industrial managers who completed and returned the data collection instruments. Without their conscientious efforts this report would not have been possible.

The following individuals assisted with the collection of data: Bill Wright, N. Budiman, Ralph Swiss, Ronald Snyder, Jill Mills, and Gary Whitely. These individuals through their regional contacts enhanced the geographical breadth of the historic water use data.

The computer graphics are the work of Jerald Fifield. All other graphical work was done by Susan Bissland and Art Rivers.

The quotes at the beginning of each chapter are taken from the poem by Charles Tomlinson entitled, "Written on Water."

TABLE OF CONTENTS

	Page
LIST OF FIGURES	vii
LIST OF TABLES	ix
GLOSSARY	xi
TABLE OF WATER EQUIVALENTS	xiii
TABLE OF WATER ABBREVIATIONS	xiii
CHAPTER I INTRODUCTION	1
Sand and Sagebrush	1
Critical Future Issues	1
Previous Studies	2
Study Organization	3
Information Management System	3
CHAPTER II HISTORIC MUNICIPAL WATER USAGE	9
Statewide Withdrawals	9
County Withdrawals	9
System Withdrawals	12
Per Capita Demands	12
Peak Month and Peak Day Demands	12
Water Pricing	25
System Return Flows	28
CHAPTER III HISTORIC INDUSTRIAL WATER USAGE	31
Steam-electric Power	31
Manufacturing	31
Military Facilities	33
Other Firms	33
CHAPTER IV PROJECTED MUNICIPAL AND INDUSTRIAL WATER USAGE	35
Municipal Rate Projections	35
Withdrawal Rate Projections	35
Return Flow Rate Projections	37
Industrial Rate Projections	37
Steam-electric Power	37
Manufacturing Use Rates	38
Mining and Energy	38
CHAPTER V HISTORIC AND PROJECTED POPULATION	41
Historic Population	41
Future Population Projections	41
Future Housing Patterns	42
CHAPTER VI WRITTEN ON WATER	47
General Summary	47
Problems Associated with Projections	47
REFERENCES	49
APPENDIX A LIST OF SUPPLEMENTARY SYSYTEMS	51
APPENDIX B TIME SERIES PLOTS OF PER CAPITA WITHDRAWAL RATES FOR MUNICIPAL SYSTEMS	53

LIST OF FIGURES

Figure		Page
1	Utah counties, multicounty districts, and 50 municipalities (numbered, see Table 1) included in study	4
2	Salt Lake County water systems and wastewater treatment districts included in study	5
3	Weber and Davis County water systems and wastewater treatment districts included in study	6
4	Per capita withdrawal rates (gcd) for Utah: 1960-1976	11
5	Percentage of county's water supply obtained from surface and groundwater sources: average of 1974, 1975, and 1976	16
6	Per capita withdrawal rates (gcd) for Davis, Salt Lake, Utah and Weber Counties: 1960-1976	17
7	Per capita withdrawal rates (gcd) for 50 Utah municipal systems: average of 1974, 1975, and 1976	21
8	Per capita withdrawal rates (gcd) for the Ogden City Water Department: 1923-1976	23
9	Per capita withdrawal rates (gcd) for Bountiful, Ogden, Provo, and Salt Lake City: 1960-1976	24
10	Graphical representation of the relationship between average daily demand and peak month and peak day demand	27
11	Per capita withdrawal and return flow rates (gcd) for 13 Utah areas: average of 1974, 1975, and 1976	28
12	Salt Lake City per capita withdrawal and return flow rates (gcd) for 13 Utah areas: average of 1974, 1975, and 1976	29
13	Provo City per capita withdrawal, consumptive use, and return flow rates (gcd): 1960-1976	29
14	Per employee withdrawal rates (ged) for Utah's major water using industries: average 1974, 1975, and 1976	34

LIST OF TABLES

Table		Page
1	Descriptive information on 50 municipal water systems included in study: 1975	8
2	Utah municipal withdrawals--inventoried and non-inventoried: 1960-1976	10
3	Utah municipal withdrawals--surface and groundwater: 1960-1976	10
4	Utah population, total withdrawals and withdrawal rates: 1960-1976	11
5	Estimated total quality of water withdrawn (mg) for Utah's 29 counties: 1960-1976	13
6	Estimated population for Utah's 29 counties: 1960-1976	15
7	Estimated per capita withdrawal rates (gcd) for Utah's 29 counties: 1960-1976	16
8	Total quantity of water withdrawn (mg) for 50 Utah municipal water systems	18
9	Estimated population served by 50 Utah municipal water systems: 1960-1976	19
10	Estimated per capita withdrawal rates (gcd) for 50 Utah minicipal systems: 1960-1976	20
11	Per capita withdrawal rate (gcd) statistics for 50 Utah municipalities: 1960-1976	22
12	Salt Lake City and Ogden per capita withdrawal rate (gcd) statistics	25
13	Hypothetic user fees for 50 Utah municipalities using 1975 rate structures	26
14	Per capita return flow rates (gcd) statistics for 13 wastewater facilities: 1960-1976	27
15	Water withdrawal consumptive use and return rates for four Utah steam electric power plants	32
16	Utah industrial (manufacturing) water withdrawal rates (gcd and m^3cd) for major water using firms: average of 1974, 1975, and 1976	32
17	Total quantity of water withdrawn (and in parenthesis returned) by Utah's major military facilities (units = mg)	33
18	Projected municipal demand in 43 Utah municipalities	36
19	Comparison of the USBR construction index and the consumer price index (CPI)	37
20	Values for computing manufacturing water use for a 10 year interval	37

LIST OF TABLES (CONT.)

Table		Page
21	Water consumptive use rates for energy conservation and transportation processes	39
22	Historic population estimates for multicounty districts (in parentheses is the percentage increase or decrease in population over the previously reported year): 1960-1975	42
23	Baseline population projections for Utah multicounty districts, counties, and selected cities for 1980, 1990, 2000, 2010, and 2020	43

GLOSSARY

The terminology used in water resources is often troublesome. Economists, engineers, and planners frequently use and understand terminology differently. Each can find support in his discipline for the terms he uses. Thus, each can be proven right within his own context. The problem then becomes one of agreeing on terms.

The definitions that follow will not solve all semantic difficulties. They will, hopefully, add a small degree of clarity to this report.

Acre-foot - The quantity of water required to cover 1 acre to a depth of 1 foot.

Consumptive use - Water withdrawn from a supply which, because of absorption, transpiration, evaporation, or incorporation in a manufactured product, is not returned directly to a surface or groundwater supply; hence, water which is lost to immediate further use. For this report consumptive use is computed by subtracting return flow from water withdrawn.

Demand approach - An economic approach to water use forecasting where the effects of water pricing are considered. Projected water requirement is viewed as but one point on a demand curve, the usage for the current price of water. Usage will be more at lower prices and be less at higher prices.

Gallons per capita per day - The standard unit for reporting municipal water withdrawal, consumptive use, and return flow. It is computed by dividing the total quantity of water withdrawn, consumed, or returned for a given period by the population served and by the length of the time period in days. The metric unit used in this study for reporting water use rates is cubic meters per capita per day.

Groundwater - (for the tables in this report) Water which is located beneath the land surface and water discharged from springs.

Industrial water - Water used by mining and manufacturing firms, steam electric generation plants, and military and defense establishments. The water may be purchased from public supply systems or self-supplied from private sources.

M and I water - A short designation referring to municipal and industrial water. Three categories are included in M and I water use: 1) water supplied by public water supply systems; 2) water used by rural domestic users not supplied by public supply systems; and 3) water used by industry not supplied from public supply systems but supplied from self-supplied privately developed sources.

Municipal water - Water used to serve the non-industrial needs of cities and towns (as well as other small residential entities). The water may be used for fire protection, street flushing, irrigation of lawns and gardens, domestic purposes as well as by commerce and public institutions, i.e. schools, churches, government, etc.

Price elasticity - A change in demand (Q) for water at a given price (P) as measured by the normalized slope of the demand curve. This is referred to as the price elasticity (E) and is measured as follows:

$$E = \frac{\Delta Q}{\Delta P} \cdot \frac{P}{Q}$$

Requirements approach - A method of water use forecasting where noneconomic engineering parameters are used to project water "requirements." In its most simple application, projected population figures are multiplied by average use per capita. The requirement approach, as commonly used, overlooks the relationship between per capita demand and price and thus ignores the question of optimum per capita water use. It has encouraged the impression that water is unrealistically inexpensive.

Return flow - The portion of the withdrawn water which is not used consumptively and that returns instead to its source or to another body of water.

Rural-domestic water - Water used by homes and farms which is not obtained from a public supply system. It includes not only water used for domestic supplies but also for watering lawns and flower and vegetable gardens as well as stock watering in barns and corrals. The water is self-supplied from wells and springs. For this report rural-domestic water is computed by multiplying the county population not served by a reporting municipal system by the average county per capita use.

SIC (Standardized Industrial Classification) - A system used to classify sectors of the economy developed by the U.S. Department of Commerce. The system has three levels of disaggregation which depend on the number of digits. For example, the number 20 represents "Food and Kindred Products" and 2011 the subset "Meat Packing Plants". The longer the number, the more specific the representation.

Withdrawal - The diversion and removal of water from a natural water course, also called "diversion."

TABLE OF WATER EQUIVALENTS

1 acre-foot	.3259 million gallons
1 acre-foot	1,233.5 cubic meters
1 million gallons	3.07 acre-feet
1 million gallons	3,785.4 cubic meters
1 cubic meter	265.7 gallons
1 million gallons per day	1,120 acre-feet per year
1 cubic hectometer	265.7 million gallons

TABLE OF WATER ABBREVIATIONS

million gallons	mg
million gallons per day	mgd
gallons per capita per day	gcd
gallons per employee per day	ged
thousand gallons	kg
cubic meters per capita per day	m^3cd
cubic hectometers	hm^3
cubic meters per employee per day	m^3ed

CHAPTER I

INTRODUCTION

at a confluence of two ways
refusing to be one without resistance,
shoulderings of foam collide, unskein

Tomlinson

Sand and Sagebrush

In 1852 Daniel Webster took the floor of the United States Senate and gave his considered opinion of the Rocky Mountain West. He described it as a region of Indians and wild animals, of shifting sands and dust whirlpools. He finished his speech with the rhetorical question to "what use could we ever hope to put these great deserts and these endless mountain ranges?" The Great Basin and Upper Colorado River Basin left early travelers with a rather empty impression. Samuel Bowles in 1865 viewed the Great Basin as a region "whose uses are unimaginable, unless to hold the rest of the globe together, or to teach patience to travelers, ..."

Much of Utah was transformed into highly productive agricultural land with the development of irrigation. The resourcefulness of the state's early settlers in wresting abundance from arid lands remains to this day an impressive accomplishment. The modern-day writer Bernard Devoto (May, 1976) describes the mastery of his grandfather:

> Through a dozen years of Jonathan's journal we observe the settlers of Eaton (Uinta) combining to bring water to their fields. On the bench lands above their valley, where gulches and canyons come down from the Wasatch, they made canals, which led along the hills. From the canals smaller ditches flowed down to each man's fields, and from these ditches he must dig veins and capillaries for himself. Where water ran, civilization was possible; where it didn't the sagebrush of the desert showed unbroken.

The development of irrigated agriculture on a regional basis involved problems of a monumental scale and complexity.

Modern-day water problems, however, may dwarf even the problems faced by the early pioneers. The dilemma facing Utah is aptly described by Wallace Stegner (1978):

> One thing is clear. There will not, under the best of circumstances, be enough water to maintain a significant agriculture and provide for municipal needs and mine fossil fuels and produce power from them and keep sufficient instream flows for healthy fishing and honor all the downstream commitments. A hundred years ago, John Wesley Powell was warning the West that there was not enough water to supply more than perhaps a fifth of its land, and he was not allowing for the demands of industry.

Critical Future Issues

Utah possesses extensive mineral and fossil fuel deposits which are now undeveloped or only partially developed. These deposits include reserves of coal, oil shale, tar sands, phosphate rock, and alunite. Exploitation of these resources will require substantial quantities of water. Due to the extensive coal reserves in the state, Utah is being considered for several large coal powered electric generation plants. A complex of nuclear powered plants has been proposed as well. The water requirements of these electric plants would be in competition with the water supply requirements for oil shale development, mineral extraction, and continued municipal, industrial, and agricultural development.

Population, economic, and industrial growth in Utah has been remarkable in recent years. All parts of the state have experienced substantial population growth since 1970. Population and industrial development projections indicate that growth will continue to take place. Large scale developments could result in water shortages and conflicts among users, particularly within the Upper Colorado River Basin (White et al., 1978). Aside from growth in established metropolitan centers, it has been suggested that the West might provide locations for new growth centers, transferring substantial population and industry into western states (Koelzer, 1976). Competition for water is currently intense. As growth continues decisions will have to be made to resolve or lessen this increasing competition.

It is vital that Utah's future water needs be studied. The structural projects used in modern water management, like dams, water importation systems, and water and wastewater treatment facilities, are expensive and take considerable time and effort to build. Years pass from authorization, through the planning and construction stages, to operation. Once built, structural projects can limit a region's pattern of water management for generations, thereby influencing rates of economic growth, levels of health, and amenities of living. In view of this, and the finite quantities of water available, Utah's water resource planners must make important decisions regarding future water needs. To make these decisions, they require a data base of useful historic water usage and well-grounded projections of future needs.

Previous Studies

The last comprehensive study of M and I water usage in Utah was accomplished in 1961. The Bureau of Economic and Business Research (1963) at the University of Utah published a work entitled "Use of Water for Municipal and Industrial Purposes: Utah Counties 1960-1961." The study was prepared in cooperation with the Utah State Engineer's Office and the Utah Water and Power Board. The publication was mainly concerned with reporting the results of a survey conducted by the University of Utah in 1960. Two questionnaires were used; one was for municipalities and the other for industries. The results of the study indicated considerable variance in the quantities of water used by households around the state.

The Utah Division of Water Rights has been informally monitoring water suppliers since 1960. Each year questionnaires have been distributed to approximately 300 municipal systems. Of the 300, less than 100 have been returning questionnaires with usable information. Time-series data collected include: 1) total number of service connections; 2) total quantity of water withdrawn; and 3) peak-day demand. The Division has also gathered information from a limited number of industrial water users. There has been, however, no comprehensive compilation of the data from any of the questionnaires.

The Utah Bureau of Economic and Business Research (1966) using their 1961 data base made M and I water use projections. Their report states:

> . . .the 1960 per capita water usage for each county was modified for use in the years 1980, 2000, and 2020. It was assumed that generally speaking, there would be increased daily per capita use of water in the future. Typically, this was assumed to amount to about 20 gallons for the first 20 years, 10 gallons for the second 20 years and 10 gallons for the third 20 years.

The authors, however, did not give any explanation for their assumed rate of increase.

Kirkpatrick (1976) criticized the Bureau of Economic and Business Research projections. He analyzed the water use records of Salt Lake City Water Department for the years 1913 through 1969 and concluded that per capita water withdrawal is neither increasing nor decreasing with time. He found it to be soundly fixed at 214 gallons per capita per day (gcd). Kirkpatrick suggests that this figure be used in computing future water requirements in Salt Lake County.

Recent emphasis on water quality has stimulated collection of some data related to water quantity. The Salt Lake County Council of Governments commissioned a report by Glenne (1977) entitled: "Water Supply and Use: Status and Outlook in Salt Lake County." The report gives a detailed account of water uses--municipal, industrial, and agricultural--as well as flow from various sources. Glenne also makes water withdrawal projections to the year 1995. For municipal water projections, he uses a per capita withdrawal figure of 236 gcd.

Another water quality study which gives some useful data was completed as a joint effort by the consulting firms of Templeton, Linke and Alsup and Engineering-Science, Inc., for the Utah Division of Water Quality. The report (1975) considers water quantity as a parameter affecting quality and summarizes water use figures for Davis, Salt Lake, Utah, Wasatch, and Juab Counties. There is some information in these reports concerning the quantity of water used by major industries in the Utah Lake-Jordan River Hydrologic Basins. Water use projections to the year 2020 are also made. The municipal projections involve per capita withdrawal estimates which increase over time.

Estimated water use figures are published in the U.S. Geological Survey (USGS) circular series, "Estimated Use of Water in the United States." Water use is estimated for all the states and broken down according to use and reported every five years. The series also gives a breakdown of withdrawals by source; all figures, however, are given on a statewide basis. Although the numbers are not considered to be exact, the report indicates general state and national water use trends.

A somewhat more detailed series of reports has been published by the USGS in cooperation with the Utah Division of Water Resources. The series is entitled, "Developing a State Water Plan: Ground Water Conditions in Utah." Although the series only deals with groundwater, use is delineated for each groundwater area in the state. The series details withdrawals on a historical and areal basis and gives a description of the geology of each aquifer. The data are collected by USGS through a combination of metering, power consumption, and other water measuring techniques.

Study Organization

This study collects into one document available information concerning Utah's historic and projected water usage for the period 1960 to 2020. The remaining chapters fall into two general classifications--historic and projected information. Chapters II and III report historic M and I water use from 1960 to 1976. The fourth and fifth chapters make projections of Utah M and I water usage and future population levels. The sixth chapter is a summary and conclusion.

The information in this study is reported at four levels of disaggregation: 1) statewide, 2) multi-county district, 3) county, and 4) major city. Utah is divided into seven multi-county districts and 29 counties (see Figure 1). Information was collected on M and I water usage for 24 of the 29 counties. Use estimates in the five counties whose records were inadequate for estimation purposes are made based on data from surrounding counties.

The municipalities reported in this publication were selected using a three stage process. An attempt was first made to find water information for Utah's largest communities. Second, an effort was made to find data on cities and towns in all parts of the state. And third, the quality and quantity of the water withdrawal information was evaluated. If communities meeting the first two criteria had reasonably accurate water data, they are included in this report. The 50 communities selected are shown in Figure 1 and listed in Table 1. They include 40 of Utah's 46 cities with a population exceeding 3000. The municipalities have a good geographic distribution; they span 22 of Utah's 29 counties. The general characteristics of each municipal water system are shown in Table 1.

Information on the return flows to 13 Utah wastewater treatment facilities are also included in this report. Since information on municipal return flows are compared with withdrawal figures, it is important to note that in Weber, Davis, and Salt Lake Counties the boundaries of the water supply and wastewater treatment systems do not necessarily coincide. The various system boundaries are illustrated in Figures 2 and 3.

Information Management System

Information collected on individual municipal and industrial systems was entered into an information management system (IMS) which was designed specifically for this study (Hansen et al., 1979). The IMS aggregates system level data to produce county and statewide water use totals. All water use totals are also divided between groundwater and surface sources. The IMS also computes per capita and per employee water use rates.

A description of the output formats from the IMS is contained in Hansen et al., (1979). Anyone desiring the complete output should contact the Utah Water Research Laboratory. It is anticipated the Utah State Division of Water Rights will endeavor to keep the data collected for this study updated.

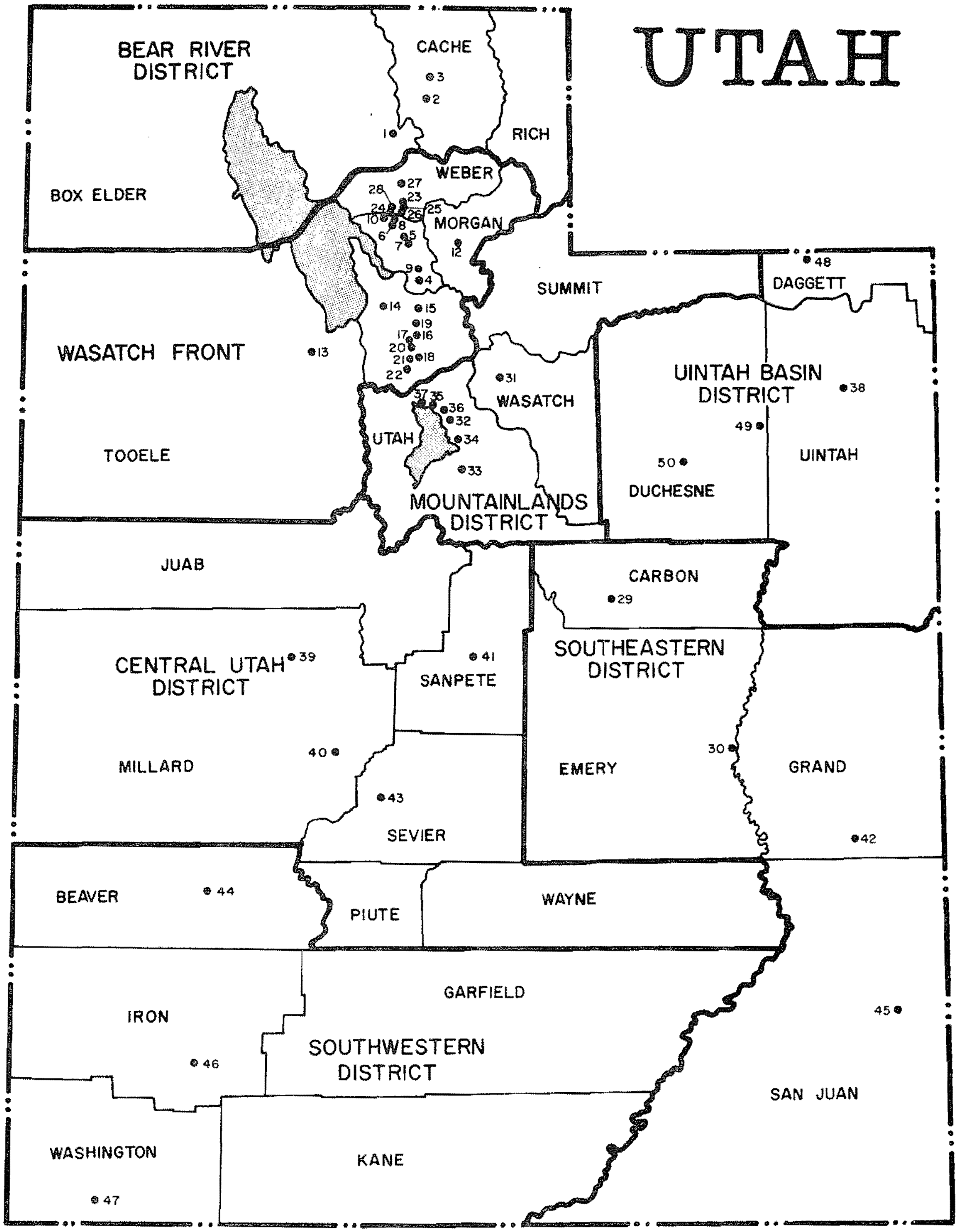


Figure 1. Utah counties, multi-county districts, and 50 municipalities (numbered, see Table 1) included in study.

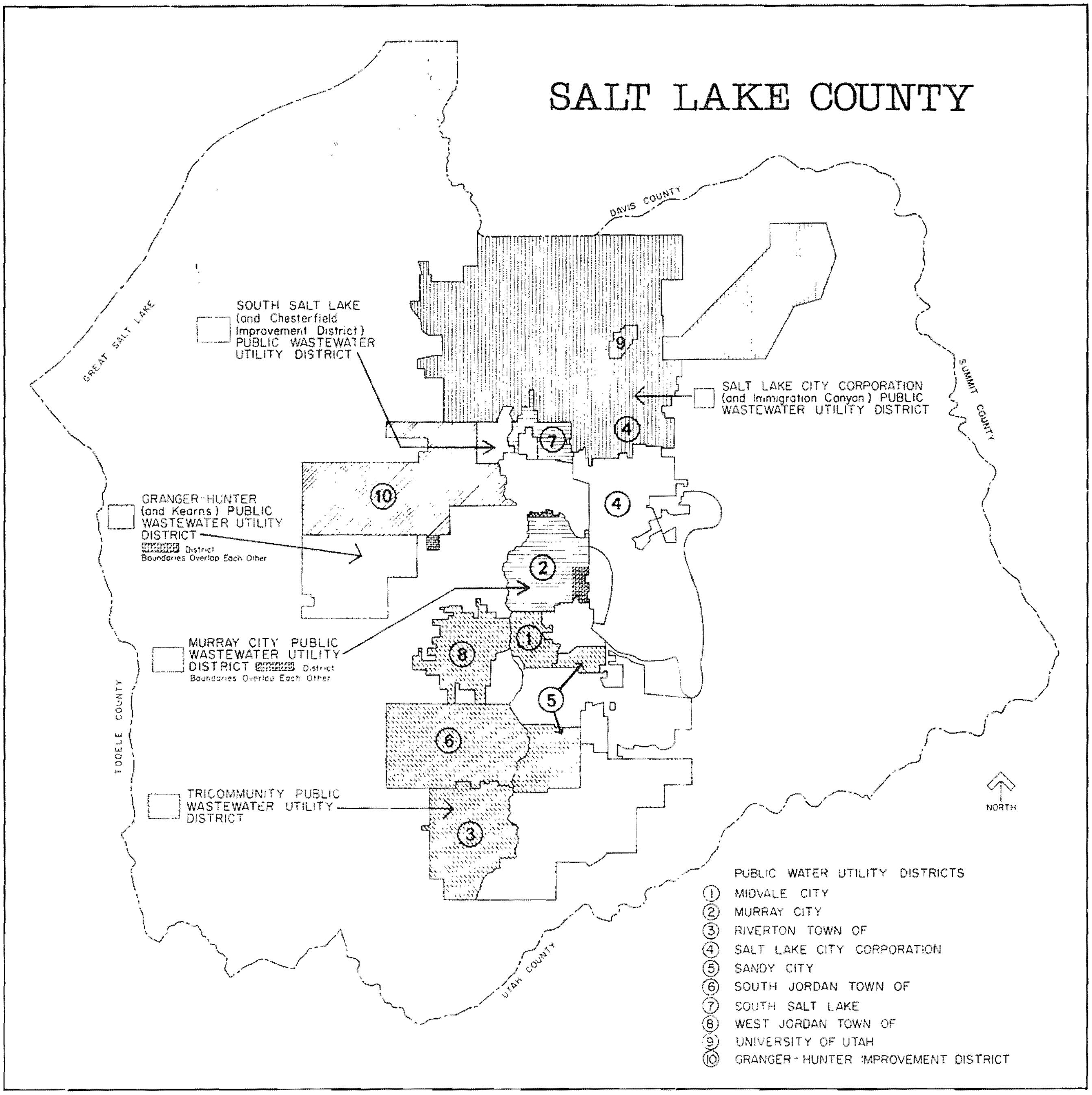


Figure 2. Salt Lake County water systems and wastewater treatment districts included in study.

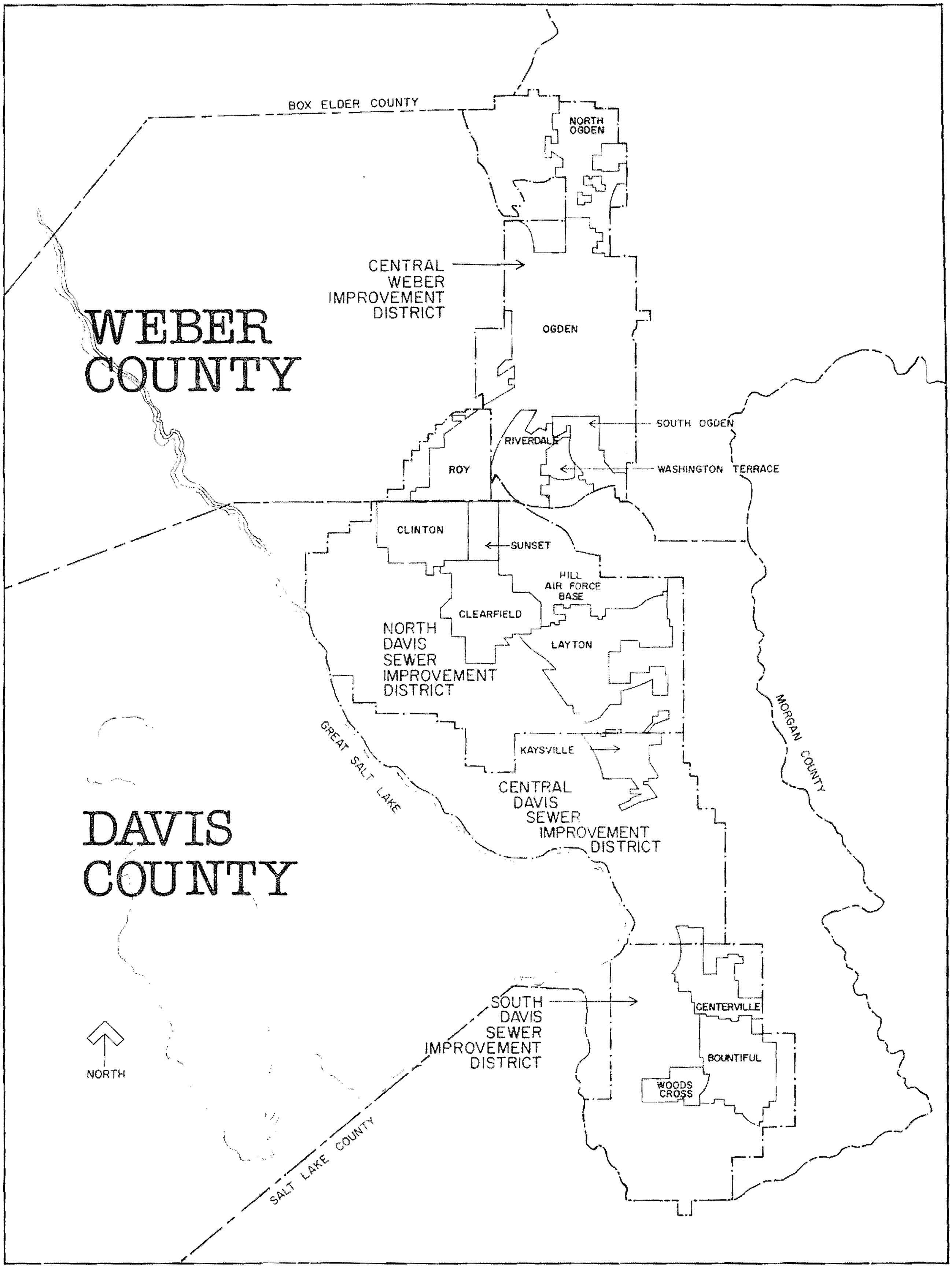


Figure 3. Weber and Davis County water systems and wastewater treatment districts included in study.

Table 1. Descriptive information on 50 municipal water systems included in study: 1975.

Map No. (Figure 1)	Name	County	District		Population	Number of Connections	Connections (percent metered)	Master Meters
			Water	Sewer				
35	American Fork	Utah	–	–	10,462	2,958	100	Partial
4	Bountiful	Davis	WBWCD	S. Davis	30,358	6,806	100	yes
1	Brigham City	Box Eld	–	–	14,157	4,003	100	yes
46	Cedar City	Iron	–	–	10,349	2,600	100	yes
9	Centerville	Davis	WBWCD	S. Davis	5,198	1,200	100	yes
6	Clearfield	Davis	WBWCD	N. Davis	13,416	2,625	100	yes
10	Clinton	Davis	WBWCD	N. Davis	3,629	990	100	yes
39	Delta City	Millard	–	–	2,016	689	99	yes
50	Duchesne	Duchesne	–	–	2,198	459	100	yes
41	Ephraim	Sanpete	–	–	2,380	721	99	yes
40	Fillmore	Millard	–	–	1,826	885	97	Partial
14	Granger-Hunter[a]	Salt Lake	SLCWCD	–	55,600	13,100	100	yes
30	Green River	Emery	–	–	968	362	99	yes
31	Heber City	Wasatch	–	–	3,633	1,259	4	yes
2	Hyrum	Cache	–	–	3,137	1,021	98	yes
7	Kaysville	Davis	WBWCD	C. Davis	7,553	1,224	100	yes
5	Layton	Davis	WBWCD	N. Davis	17,511	4,365	100	yes
37	Lehi	Utah	–	–	5,736	1,686	100	yes
3	Logan	Cache	–	–	23,810	6,025	98	yes
48	Manila	Daggett	–	–	345	200	100	yes
17	Midvale	Salt Lake	–	Tri-Com.	8,310	2,906	100	yes
44	Milford	Beaver	–	–	1,283	505	0	yes
42	Moab	Grand	–	–	4,500[b]	1,312	100	yes
45	Monticello	San Juan	–	–	1,726	612	98	yes
12	Morgan	Morgan	–	–	1,704	582	100	Partial
16	Murray	Salt Lake	SLCWCD	–[c]	23,595	5,220	100	yes
27	N. Ogden	Weber	–	C. Weber	6,566	1,740	100	Partial
23	Ogden	Weber	WBWCD	C. Weber	68,978	19,424	100	yes

Table 1. Continued.

Map No. (Figure 1)	Name	County	District Water	District Sewer	Population	Number of Connections	Connections (percent metered)	Master Meters
37	Orem	Utah	-	-	35,584	9,334	100	yes
36	Pleasant Gr.	Utah	-	-	7,074	1,966	100	yes
29	Price	Carbon		Price R.	7,391[d]	4,124	100	yes
34	Provo	Utah	-	-	55,593	10,788	100	yes
43	Richfield	Sevier	-	-	4,947	1,741	100	yes
28	Riverdale	Weber	WBWCD	C. Weber	4,707	988	100	yes
22	Riverton	Salt Lake	SLCWCD	Tri-Com.	3,442	1,307	100	Partial
49	Roosevelt	Duchesne	Ute Tribe	-	3,943	1,250	100	yes
24	Roy	Weber	WBWCD	N. Davis	16,781	3,982	100	yes
15	Salt Lake City	Salt Lake	-	-	169,971[e]	73,349	100	yes
18	Sandy	Salt Lake	SLWCD	-	10,077[f]	8,670	99	Partial
21	S. Jordan	Salt Lake	SLWCD	Tri-Com.	4,098	1,071	100	yes
25	S. Ogden	Weber	WBWCD	C. Davis	10,175	3,219	100	yes
19	S. Salt Lake	Salt Lake	SLWCD	-	9,041	2,626	100	yes
33	Spanish Fork	Utah	-	-	8,065	2,376	98	yes
47	St. George	Washington	-	-	8,760	2,500	100	yes
8	Sunset	Davis	WBWCD	N. Davis	6,300	1,478	100	yes
13	Tooele	Tooele	-	-	12,905	4,325	98	yes
38	Vernal	Uintah	-	-	5,492[g]	3,000	100	yes
26	Washington Terr.	Weber	WBWCD	C. Weber	8,078	1,972	100	yes
20	West Jordan	Salt Lake	SLWCD	Tri-Com.	11,405	3,200	100	yes
11	Woods Cross	Davis	WBWCD	S. Davis	3,219	790	100	yes

[a]Granger-Hunter is an unicorporated area

[b]Moab water system serves a population of 4,600

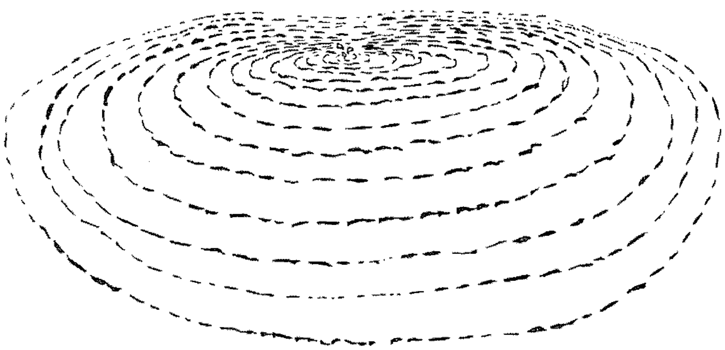
[c]Parts of Murray are in surrounding districts

[d]Price system serves approximately 10,310 people including: South Price, Wellington, Spring Glen, Carbonville Fassio, East Carbonville, West Side, Haycock Lane, Old Highway, and Emery Star

[e]Salt Lake City water department serves approximately 275,000 including 105,000 in Salt Lake County

[f]Sandy department estimates it serves approximately 36,000 customers

[g]Vernal serves approximately 14,000 including Jensen, Air Village and Maesar (which takes water off the Vernal water line)



CHAPTER II

HISTORIC MUNICIPAL WATER USAGE

links of water chiming on one another,
water-ways permeating the rock of time

Tomlinson

This chapter summarizes a municipal water use inventory conducted by the Utah Water Research Laboratory and the Utah League of Cities and Towns. The objectives of the inventory were to: 1) estimate the quantity of water withdrawn by municipalities; 2) divide the withdrawals between surface and groundwater sources; 3) estimate per capita water withdrawal rates; 4) estimate the quantity of municipal water returned to surface sources; and 5) estimate per capita return flow rates. Using the IMS, municipal level data were aggregated to produce county and statewide water withdrawal estimates.

To accomplish the objectives listed above, questionnaires were sent to all of the public and private municipal water systems in Utah by the League of Cities and Towns. Seventy-five questionnaires were returned with usable historic withdrawal information. Data from questionnaires were supplemented with information obtained from the Utah Division of Water Rights. In all, usable withdrawal information was obtained on over 100 systems. These systems in 1975 served over 1,000,000 residents or over 80 percent of Utah's total population. Information on 50 individual municipal systems is included in this report. Data collected on the remainder of the systems are included in state and county totals. The additional systems are described in Appendix A.

Information on municipal wastewater return flows was obtained from monthly operation reports filed with the Utah Division of Health. These records were available for the period 1969 to 1976. Since some system managers have been more regular than others in filing reports, time-series data are not always continuous. Data on systems along the Wasatch Front were also obtained by visiting treatment plants.

The tables and figures in this chapter contain both 1975 information (based on a 3-year average of 1974, 1975, and 1976) and time-series data for the period 1960 to 1976. Total municipal water usage is reported in million gallons per year. Emphasis is placed on municipal withdrawal and return flow rates. Municipal water use rates are reported as gallons per capita per day. This unit is computed by dividing the total quantity of water withdrawn (or returned) by a municipal system for a given year by the population served and by 365 (the number of days in a year). Where appropriate, units are converted to SI (international system) units.

Statewide Withdrawals

Inventoried Utah withdrawals for the period 1960 to 1976 are shown in Table 2. Also shown are estimates for non-inventoried (or rural domestic) withdrawals. Inventoried plus non-inventoried equals total withdrawals for the State of Utah. A 3-year average (1974, 1975, and 1976) of total withdrawals equals 115.4 billion gallons.

Utah inventoried withdrawals are divided between surface and groundwater sources in Table 3. (The totals in Table 3 are slightly different from those in Table 2 for two reasons: 1) a wholesaler may be represented but all of the retail systems he supplies water to may not, and 2) a system may have been able to report total municipal water withdrawals but unable to distinguish between surface and groundwater sources.) For the years 1974, 1975, and 1976 approximately 60 percent of Utah's municipal water was obtained from springs and wells.

Table 4 and Figure 4 show estimates of Utah's yearly per capita withdrawal rates.

Table 2. Utah municipal withdrawals--inventoried and non-inventoried: 1960-1976.

Year	Withdrawals (mg)				Withdrawals (hm^3)			
	Inventoried	Non-inventoried*	Industrial	Total	Inventoried	Non-inventoried*	Industrial	Total
1960	50122.1	27963.9	N.A.	78247.6	188.642	105.246	N.A.	294.496
1961	50727.5	30391.1	N.A.	81341.9	190.920	114.381	N.A.	306.142
1962	53138.9	31089.9	N.A.	84468.7	199.996	117.011	N.A.	317.910
1963	53444.3	29672.6	N.A.	83355.2	201.145	111.677	N.A.	313.719
1964	58009.4	26398.0	N.A.	84748.7	218.327	99.353	N.A.	318.964
1965	54797.5	24582.8	N.A.	83235.7	206.238	92.521	N.A.	313.269
1966	64717.3	28963.0	N.A.	98719.3	243.573	109.006	N.A.	371.544
1967	60253.6	25853.7	N.A.	90012.9	226.773	97.304	N.A.	338.776
1968	59582.6	25154.7	N.A.	89742.8	224.248	94.673	N.A.	337.760
1969	67623.2	27956.9	N.A.	101012.5	254.510	105.220	N.A.	380.175
1970	68859.1	21241.8	5738.4	95839.4	259.161	79.947	21.597	360.705
1971	75156.9	23175.3	5622.2	103954.4	282.864	87.224	21.160	391.248
1972	81261.2	24588.5	5753.5	111603.2	305.838	92.542	21.654	420.034
1973	79189.7	21735.6	6265.5	107190.8	298.042	81.805	23.581	403.428
1974	92492.9	21480.9	6165.0	120138.7	348.110	80.846	23.203	450.159
1975	86636.1	18825.3	3882.4	111343.8	326.067	70.852	22.139	419.058
1976	91389.9	17360.0	5960.4	114710.3	343.959	65.337	22.433	431.729

*Estimate of unsurveyed municipal withdrawal.

Table 3. Utah municipal withdrawals--surface and groundwater: 1960-1976.

Year	Withdrawals (mg)			Withdrawals (hm^3)		
	Surface	Groundwater	Total	Surface	Groundwater	Total
1960	20256.8	21889.6	42146.4	76.239	82.385	158.624
1961	19367.0	22793.5	42160.5	72.890	85.787	158.677
1962	20628.8	24417.3	45046.1	77.639	91.898	169.537
1963	19505.9	25781.7	45287.6	73.413	97.033	170.446
1964	20657.6	28974.7	49632.3	77.748	109.050	186.798
1965	20530.8	28546.7	49077.5	77.271	107.440	184.710
1966	23398.4	35482.0	58880.4	88.063	133.542	221.605
1967	21363.0	31827.8	53190.8	80.403	119.788	200.191
1968	22334.6	32804.6	55139.2	84.059	123.465	207.524
1969	27039.9	34449.2	61489.1	101.769	129.654	231.423
1970	24479.7	37637.0	62116.7	92.133	141.652	233.785
1971	35168.4	41340.6	76509.0	132.361	155.591	287.953
1972	37777.6	44772.8	82550.4	142.181	168.509	310.690
1973	33919.7	47130.1	81049.8	127.662	177.381	305.043
1974	38396.2	62019.9	100416.1	144.510	233.421	377.930
1975	37507.8	55581.1	93088.9	141.166	209.187	350.353
1976	39222.2	60211.2	99433.4	147.618	226.613	374.232

Table 4. Utah population, total withdrawals and withdrawl rates: 1960-1976.

Year	Population		Total Withdrawal		Withdrawal Rate	
	Total	Inventory (%)*	mg	(hm^3)	gcd	m^3cd
1960	890627	64	78247.6	294.496	241	.907
1961	936000	63	81341.9	306.142	238	.896
1962	958000	63	84468.7	317.910	242	.911
1963	974000	64	83355.2	313.719	234	.881
1964	978000	69	84748.7	318.964	237	.892
1965	991000	70	83235.7	313.269	230	.866
1966	1009000	71	98719.3	371.544	268	1.009
1967	1019000	71	90012.9	338.778	242	.911
1968	1029000	72	89742.8	337.760	239	.900
1969	1047000	72	101012.5	380.175	264	.994
1970	1060273	78	95839.4	360.705	248	.933
1971	1094600	78	103954.4	391.248	260	.979
1972	1127700	78	111603.2	420.034	271	1.020
1973	1150800	80	107190.8	403.428	255	.960
1974	1178700	82	120138.7	450.159	279	1.050
1975	1207000	83	111343.8	419.058	253	.952
1976	1235000	85	114710.3	431.729	254	.956

*Percent of population covered by inventory.

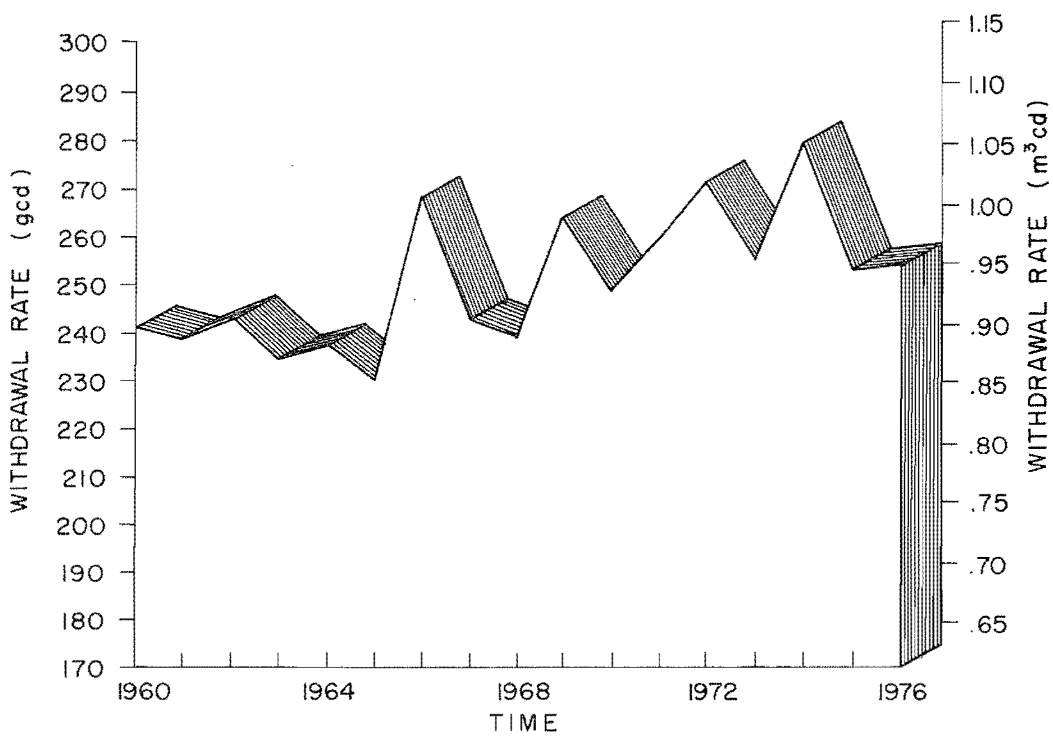


Figure 4. Per capita withdrawal rates (gcd) for Utah: 1960-1976.

The table also reports yearly population estimates (1960 through 1976) and an estimate of the total population served by inventoried systems. The statewide per capita withdrawal rate in 1975 was 262 gcd. This number is slightly higher than the 1960 estimate of 241 gcd. It is considerably higher than the national average of 150 gcd. One of the principal reasons for the high withdrawal rate in Utah is summer lawn sprinkling and garden watering.

County Withdrawals

The estimated total municipal withdrawals for each of Utah's 29 counties for time period 1960 to 1976 are contained in Table 5. The data used to compute each year's figures are contained in printouts and tapes from the IMS. All figures in Table 5 not based on data from the inventory are underlined. The underlined estimates are based on extrapolation of trends or on data from adjacent counties.

The inventoried county withdrawals are divided between groundwater and surface sources by the IMS. A three year average (1974, 1975, and 1976) of the percentage of water supplied from each is illustrated in Figure 5. (Weber and Davis County percentages have been combined because they both receive water from Weber Basin Water Conservancy District.) Allowances have been made for systems in each county not included in the inventory; thus reported figures should approximate the actual percentage. Except for Carbon and Emery, only Wasatch Front counties withdraw sizable quantities of surface water for municipal usage.

To compute county per capita withdrawal estimates, county population estimates are required. These were obtained from the Utah Population Work Committee and the U.S. Bureau of the Census. Yearly county population estimates for the period from 1960 to 1976 are contained in Table 6. Using the information in Tables 5 and 6, county per capita withdrawal rates were computed and are listed in Table 7. Time trend plots of Davis, Salt Lake, Utah, and Weber Counties per capita use estimates are contained in Figure 6.

System Withdrawals

The yearly quantity of water withdrawn by 50 Utah cities and towns for the period 1960 to 1976 is reported in Table 8. The quantities of water obtained from surface and groundwater sources are available as output from the IMS. Table 9 reports yearly population estimates for the 50 municipal water systems.

Per Capita Withdrawal Rates

Using yearly withdrawal figures and population estimates, average daily per capita withdrawal rates were computed (see Table 10). Figure 7 is a bargraph comparing withdrawal rates for each of 50 Utah systems. Delta, Fillmore, Hyrum, Logan, Milford, and Morgan all have comparatively high (over 400 gcd) water withdrawal rates while Bountiful, Centerville, North Ogden, South Ogden, and Washington Terrace have low per capita rates. The residents of the latter systems are served by separate pressure irrigation systems. Thus outdoor water usage is not reflected in their per capita withdrawal rate.

Plots of annual per capita withdrawal rates (1960 to 1976) for each municipality are contained in Appendix B The mean, standard deviation, minimum and maximum and range for each time series are reported in Table 11.

Analysis of the Ogden City Water Department records for the period 1923 to 1976 was accomplished (see Table 12). Figure 8 is a plot of Ogden's yearly per capita withdrawal rates. The time series shows no significant long term increasing or decreasing trend. Kirkpatrick studied per capita water withdrawal rates associated with the Salt Lake City Water Department. The rates were found to be cyclic about a mean of 214 gcd (see Table 12). Kirkpatrick's mean is substantially less than that reported in Table 11. The reason for this difference is in the manner the Salt Lake City Water Department estimates population. Their 1976 estimate of customers served is 350,000.[1] The estimates used in this report, based largely on demographic studies (i.e. Wasatch Front Regional Council. 1977), is considerably smaller, 280,000. Kirkpatrick used the estimates of the Salt Lake City Water Department.

Time-series plots of per capita withdrawal rates for Bountiful, Ogden, Provo, and Salt Lake are shown in Figure 9. The reason

---

[1]The Salt Lake City Water Department computes its population served by multiplying the number of units using the sewer (which includes all apartment, hotel and motel rooms) by 3.4. Since Salt Lake City has over 6000 Class A hotel and motel rooms, they alone inflate the population by 20,400. The Tri-Arc Motor Lodge has 400 rooms and uses approximately 200 gallons of water per room per day. At two persons per room, this represents a withdrawal rate of 100 gcd. (At 3.4 per room, this is 60 gcd). This is far below SLC's withdrawal rate. Thus the city is deflating its per capita withdrawal by overestimating the transient population. Since census population figures are used almost exclusively throughout this report, Salt Lake City estimates are based on census as adjusted to recent demographic studies.

Table 5. Estimated total quality of water withdrawn (mg) for Utah's 29 counties: 1960-1976.

County	Year 1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Beaver	534[a]	540	548	544	540	549	557	552	561	554	548	608	682	650	683	796	786
Box Elder	4823	4161	6611	6209	6521	7112	6790	3424	3756	4048	3864	3734	3638	3784	4351	3849	2280
Cache	5617	5744	6447	6858	5827	6125	6418	6258	6535	6625	7417	7486	8093	8370	8613	8504	8733
Carbon	2084	1623	2092	1862	1385	1641	1923	1592	1782	1986	1895	1811	1955	1973	1852	2124	2164
Daggett	127	138	153	168	76	51	62	52	56	68	72	87	84	65	79	78	81
Davis	3392	3800	3887	4224	4413	4356	5084	4811	4904	5382	5452	5801	6796	6499	7267	6459	7411
Duchesne	866	779	668	729	892	835	1003	1122	1023	1113	1077	1055	1307	1714	1532	1504	1324
Emery	389	371	340	264	413	405	454	443	469	559	530	497	450	434	474	500	572
Garfield	392	383	383	372	372	372	361	339	339	339	345	350	339	339	361	372	383
Grand	300	387	463	509	517	430	482	489	496	508	515	523	582	537	620	525	595
Iron	770	780	907	823	946	991	1105	1017	1133	1125	1140	1230	1260	1259	1323	1337	1397
Juab	545	534	534	546	546	546	522	522	522	534	542	546	534	593	617	617	629
Kane	243	246	246	246	237	237	219	219	219	219	221	228	246	292	301	319	329
Millard	838	870	820	973	1132	1084	1165	1185	1186	1220	1213	1210	1288	1052	1275	1400	1034
Morgan	335	371	372	372	369	350	396	395	428	460	490	559	620	641	723	790	813
Piute	131	137	137	127	127	127	119	119	119	119	106	100	100	110	110	119	119
Rich	123	124	124	124	117	117	117	117	117	117	118	117	110	110	117	117	117
Salt Lake	33265	34265	34939	33875	35272	32403	41412	37424	36225	43302	39197	45663	47696	43709	51979	46436	48369
San Juan	1155	1111	1009	971	996	1009	1150	997	1056	1259	1243	1262	1395	700	1216	1222	1194
Sanpete	1412	1418	1405	1392	1379	1367	1354	1367	1379	1392	1402	1431	1532	1858	1814	1604	1714
Sevier	1202	1245	1204	1029	1090	1040	1202	1156	1150	1185	1254	1531	1545	1649	1702	1748	1682
Summit	725	728	715	715	715	728	741	741	754	754	751	767	779	830	830	843	894
Tooele	1630	1742	1870	1944	1944	1916	1916	1971	1989	1971	1966	2016	2008	2034	2099	2135	2153
Uintah	1890	1937	1910	1851	1732	1342	1329	1501	1809	1923	1687	1742	1790	1928	2019	1978	1482
Utah	9817	11778	10855	10359	10488	10996	12635	12098	11835	13338	13187	14236	15960	15550	17026	16375	17628
Wasatch	606	634	652	670	711	726	754	781	820	828	972	867	973	1033	1009	1047	1181
Washington	845	862	854	845	854	871	903	953	1010	1068	1132	1125	1227	1139	1361	1326	1514
Wayne	158	155	155	155	146	146	146	137	137	137	135	137	137	146	146	146	155
Weber	8204	8175	8953	9073	8753	9148	10613	10345	10182	10500	10345	9788	10786	10712	10847	10031	10462

[a] not based on data from inventory.

Table 6. Estimated population for Utah's 29 counties: 1960-1976.

County	Year																
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Beaver	4331	4300	4300	4200	4100	4100	4100	4000	4000	3900	3800	3800	4100	4100	4200	4200	4200
Box Elder	25061	28900	31100	31300	29500	28000	27000	26400	27200	27600	28129	28500	30100	30100	30100	30800	31100
Cache	35788	37400	38700	39400	39700	40000	40200	40600	41200	41800	42331	43000	45000	46000	47500	48500	49300
Carbon	21135	20400	19700	18700	17700	17300	16900	16800	16400	16100	15647	16100	16500	17000	17000	18900	19300
Daggett	1164	1300	1500	1700	800	700	600	600	600	600	666	700	700	700	700	800	800
Davis	64760	70100	75600	80000	82000	86000	91000	93000	95000	97000	99028	103000	107000	109500	113000	116000	120000
Duchesne	7179	7200	7100	7000	6700	6500	6500	6700	7000	7100	7229	7900	9700	11200	11600	11800	11300
Emery	5546	5500	5400	5400	5400	5400	5300	5200	5200	5100	5137	5300	5200	6100	6200	6700	8000
Garfield	3577	3500	3500	3400	3400	3400	3300	3100	3100	3100	3157	3200	3100	3100	3300	3400	3500
Grand	6345	8100	9000	8500	7500	6900	6600	6700	6800	6800	6688	6300	6200	6300	6500	65000	6900
Iron	10795	11200	11200	10700	10600	10700	11000	11300	11600	11900	12177	12900	13200	13600	14000	14400	14800
Juab	4597	4500	4500	4600	4600	4600	4400	4400	4400	4500	4574	4600	4500	5000	5200	5200	5300
Kane	2667	2700	2700	2700	2600	2600	2400	2400	2400	2400	2421	2500	2700	3200	3300	3500	3600
Millard	7866	8100	7800	7500	7300	7100	7000	7000	7000	7000	6988	7200	7700	7700	7900	8200	8200
Morgan	2837	3000	3000	3000	3000	3200	3300	3400	3500	3800	3983	4100	4400	4500	4600	4700	4800
Piute	1436	1500	1500	1400	1400	1400	1300	1300	1300	1300	1164	1100	1100	1200	1200	1300	1300
Rich	1685	1700	1700	1700	1600	1600	1600	1600	1600	1600	1615	1600	1500	1500	1600	1600	1600
Salt Lake	383035	402300	411800	423100	429800	436000	443000	447000	449000	455000	458607	473500	482000	488000	500000	508000	520000
San Juan	9040	8700	7900	7600	7800	7900	8500	8900	8900	9300	9606	10200	10700	10700	10800	11200	11200
Sanpete	11053	11100	11000	10900	10800	10700	10600	10700	10800	10900	10976	11200	11900	12400	12500	13000	13000
Sevier	10565	10500	10400	10100	9900	9800	9600	9600	9800	9900	10103	10500	10900	11800	12400	13300	13200
Summit	5673	5700	5600	5600	5600	5700	5800	5800	5900	5900	5879	6000	6100	6500	6500	6600	7000
Tooele	17868	19100	20500	21300	21300	21000	21000	21600	21800	21600	21546	22100	22000	22300	23000	23400	23600
Uintah	11582	12400	12800	13000	12800	12800	12600	12500	12400	12400	12684	13300	14400	15200	16000	17500	17300
Utah	106991	112200	113600	114500	114800	119000	124600	126000	128000	134600	137776	144600	150000	155000	160000	166000	172000
Wasatch	5308	5400	5400	5400	5600	5600	5700	5800	5800	5800	5863	6200	6500	6500	6500	6700	7000
Washington	10271	10500	10400	10300	10400	10600	11000	11600	12300	13000	13669	14900	16000	16000	16500	17200	18000
Wayne	1728	1700	1700	1700	1600	1600	1600	1500	1500	1500	1483	1500	1500	1600	1600	1600	1700
Weber	110744	117000	118600	119300	119700	120800	122500	123500	124500	125500	126278	128800	133000	134000	135000	136000	137000

Sources:

1960	U.S. Bureau of the Census, 1963
1961-1969	Utah Population Work Committee, 1972
1970	U.S. Bureau of the Census, 1973
1971-1976	Utah Population Work Committee, 1976

Table 7. Estimated per capita withdrawal rates (gcd) for Utah's 29 counties: 1960-1976.

County	Year																
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Beaver	338	344	349	355	361	367	372	378	384	389	395	438	456	435	446	519	513
Box Elder	527	394	582	543	606	696	689	355	378	402	376	359	331	344	396	342	201
Cache	430	421	456	477	402	420	437	422	435	434	480	477	493	499	497	480	485
Carbon	270	218	291	273	214	260	312	260	298	338	332	308	325	318	298	308	307
Daggett	300	290	280	270	260	198	282	239	257	310	295	340	330	253	308	269	276
Davis	143	149	141	145	147	139	153	142	141	152	151	154	174	163	176	153	169
Duchesne	331	296	258	285	365	352	423	459	400	429	404	366	369	419	362	349	321
Emery	192	185	173	134	210	205	235	234	247	300	283	257	237	195	209	204	196
Garfield	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
Grand	129	131	141	164	189	171	200	200	200	205	211	227	257	233	261	221	236
Iron	238	233	232	219	225	204	256	247	268	259	256	261	262	254	259	254	259
Juab	325	325	325	325	325	325	325	325	325	325	325	325	325	325	325	325	325
Kane	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250
Millard	292	294	288	355	425	418	456	464	464	477	476	460	458	374	442	468	345
Morgan	324	338	340	339	337	300	329	319	335	332	337	374	386	390	431	460	464
Piute	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250
Rich	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Salt Lake	238	233	232	219	225	204	256	229	221	261	234	264	271	245	285	250	255
San Juan	350	350	350	350	350	350	371	307	325	371	355	339	357	179	308	299	292
Sanpete	350	350	350	350	350	350	350	350	350	350	350	350	353	411	398	338	361
Sevier	312	325	317	279	302	291	343	330	322	328	340	400	388	383	376	360	349
Summit	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350
Tooele	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225
Uintah	447	428	408	390	371	287	289	329	400	425	364	359	341	348	346	310	235
Utah	251	288	262	248	250	253	278	263	253	271	262	270	292	275	292	270	281
Wasatch	313	322	331	340	348	355	362	368	387	391	388	383	410	435	425	428	462
Washington	225	225	225	225	225	225	225	225	225	225	227	207	210	195	226	211	230
Wayne	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250
Weber	203	191	207	208	200	207	237	229	224	229	224	208	222	219	220	202	209

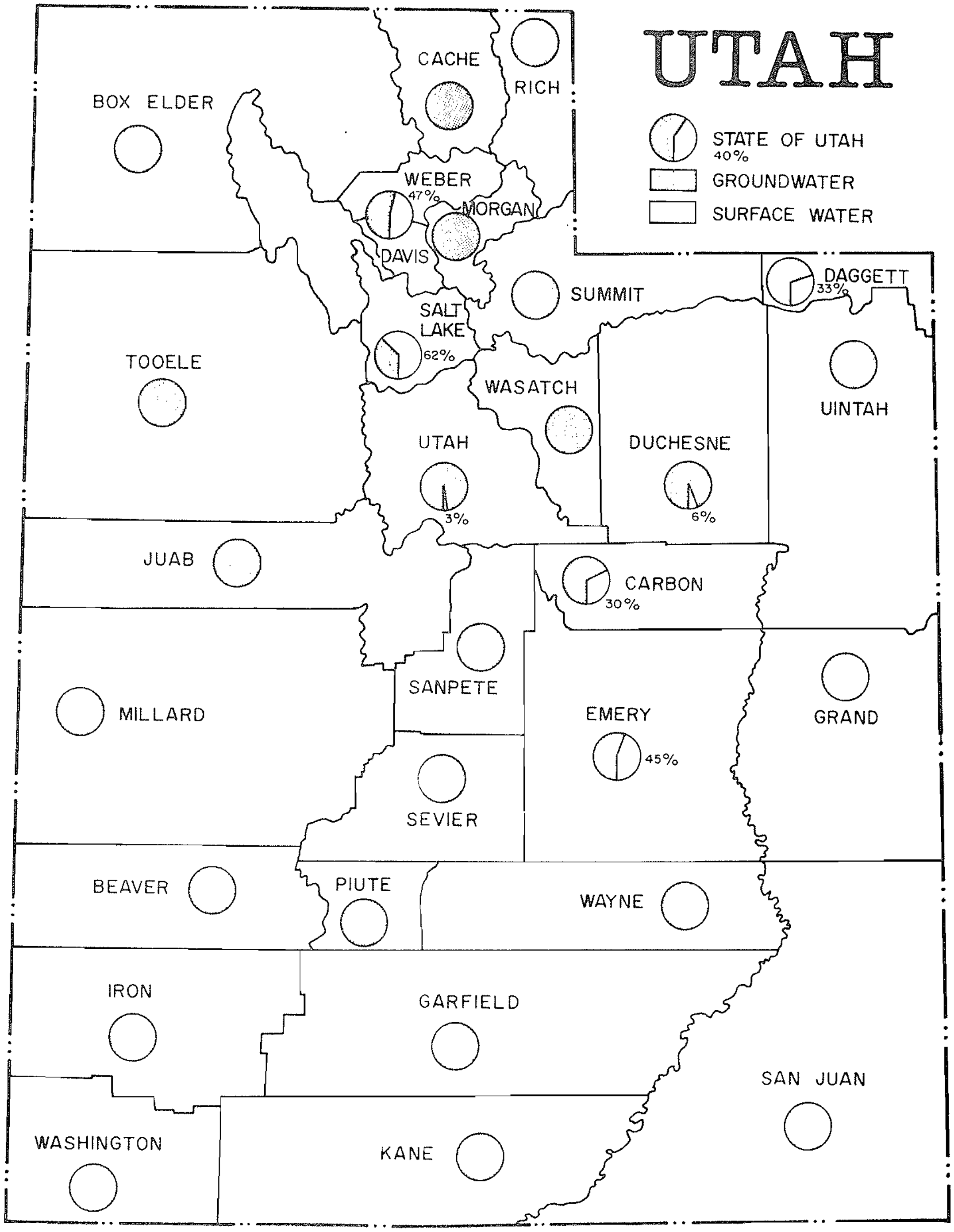


Figure 5. Percentage of county's water supply obtained from surface and groundwater sources: average of 1974, 1975, and 1976.

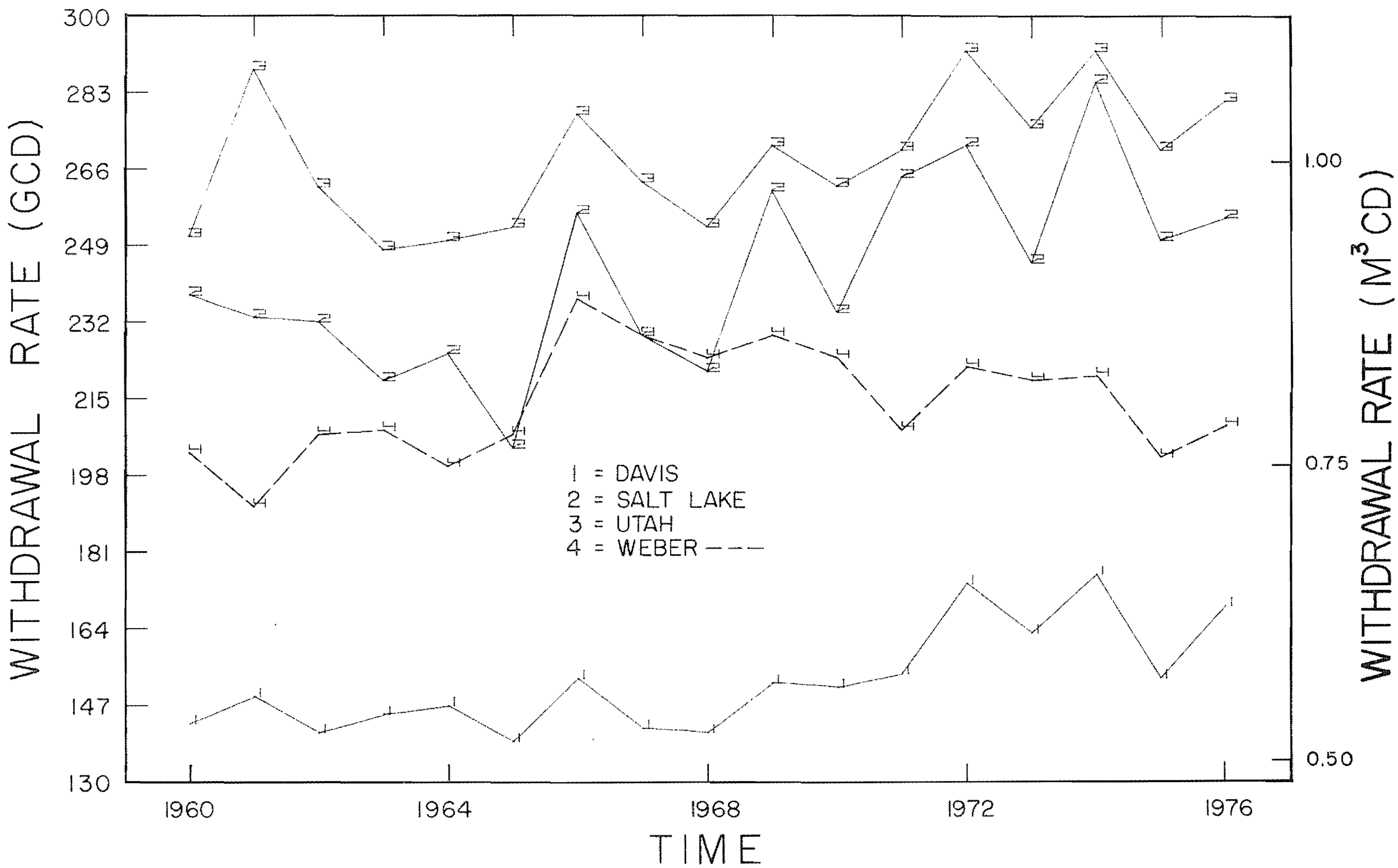


Figure 6. Per capita withdrawal rates (gcd) for Davis, Salt Lake, Utah and Weber Counties: 1960-1976.

Table 8. Total quantity of water withdrawn (mg) for 50 Utah municipal water systems.

County	Year 1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
American Fork	405	391	314	389	410	400	380	414	411	505	480	550	624	581	764	829	909
Bountiful	630	852	585	806	774	867	903	997	1,012	1,072	1,139	1,039	1,121	1,220	1,257	1,175	1,224
Brigham City	2,342	1,779	2,682	2,614	3,006	3,524	3,539	1,774	1,966	2,119	1,999	1,930	1,809	1,961	2,289	2,045	1,166
Cedar City	538	525	611	585	636	631	762	692	761	745	751	795	822	850	869	888	901
Centerville						139	130	117	106	98	163	162	174	146	147	160	183
Clearfield	602	530	700	594	594	542	682	604	614	637	673	691	716	691	1,045	864	1,129
Clinton	29	38	41	47	60	45	75	67	71	89	86	107	131	143	179	169	218
Delta	189	189	121	197	283	281	296	320	323	329	329	332	332	332	332	363	199
Duchesne																220	206
Ephraim												178	278	331	324	282	310
Fillmore	164	166	223	230	229	220	250	236	230	236	232	239	256	277	287	290	297
Granger-Hunter	630	772	746	1,134	1,381	1,377	1,933	1,911	2,001	2,396	2,371	2,782	2,910	2,767	2,988	3,119	3,380
Green River	45	43	40	19	55	48	64	64	74	108	111	78	81	80	80	80	80
Heber City									427	444	449	454	501	549	552	562	613
Hyrum				352	361	398	416	479	483	497	495	483	472	520	524	529	531
Kaysville											530	484	495	447	521	490	516
Layton	657	663	701	779	834	807	1,035	894	938	1,084	991	1,048	1,502	1,284	1,298	1,100	1,313
Lehi	535	429	467	371	443	530	459	431	407	445	418	402	395	386	378	395	345
Logan	2,951	2,810	3,100	3,387	2,988	3,181	3,429	3,195	3,371	3,376	4,054	4,149	4,339	4,520	4,493	4,417	4,631
Manila												34	34	23	32	31	32
Midvale					531	693	708	735	737	742	778	807	824	1,024	1,059	1,093	1,133
Milford											188	210	221	212	213	243	243
Moab	221	224	242	282	326	295	347	348	348	357	370	385	419	364	418	365	400
Monticello							182	155	171	199	185	186	206	208	190	188	189
Morgan	154	164	168	172	173	158	177	175	186	190	195	220	230	235	264	290	299
Murray	1,079	1,079	1,182	1,261	1,324	1,259	1,511	1,545	1,447	1,619	1,637	1,773	1,991	2,111	2,478	2,790	3,684
North Ogden			306	310	300	250	250	255	260	260	200	219	230	230	253	267	329
Ogden	6,143	5,734	6,102	6,284	5,940	6,248	6,957	7,014	6,773	6,841	7,103	6,324	6,707	6,704	6,504	6,166	6,421
Orem	1,467	1,711	1,778	1,813	1,853	2,013	2,393	2,330	2,377	2,782	2,816	3,050	3,424	3,448	3,949	3,420	3,968
Pleasant Grove	247	263	261	262	320	255	308	285	261	345	415	571	645	686	750	862	1,005
Price					617	824	934	721	800	905	871	799	982	927	1,000	1,042	1,016
Provo	3,955	4,871	4,314	4,102	4,206	4,599	5,128	5,041	5,007	5,408	5,341	5,532	6,414	6,209	6,564	6,223	6,611
Richfield	502	524	513	452	489	471	557	536	524	535	555	653	639	634	651	640	650
Riverdale				127	129	157	188	200	224	269	228	267	280	290	340	334	345
Riverton													211	233	328	306	156
Roosevelt	258	245	221	250	300	290	375	421	361	398	374	402	482	616	563	570	550
Roy	593	655	669	699	757	785	1,173	952	1,022	1,210	1,149	1,181	1,407	1,303	1,559	1,308	1,520
St. George											586	596	618	616	786	766	887
Salt Lake City	21,320	21,185	21,466	20,372	21,246	18,968	24,644	21,763	21,008	25,627	23,277	27,466	28,338	26,097	31,024	27,459	28,109
Sandy															2,989	2,401	3,091
South Jordan	49	52	59	64	74	74	102	109	111	132	119	172	170	200	223	292	322
South Ogden	263	263	300	264	308	326	352	293	332	343	343	394	456	456	456	461	490
South Salt Lake						596	667	688	685	762	758	727	850	889	940	967	986
Spanish Fork	511	807	715	601	687	549	636	580	561	629	713	732	638	696	634	715	895
Sunset	247	260	299	320	337	323	413	374	377	451	399	438	453	398	458	387	406
Tooele																	1,004
Vernal					1,203	945	963	1,111	1,358	1,450	1,250	1,360	1,400	1,510	1,600	1,520	1,230
Washington Terrace	194	252	185	178	206	203	224	215	236	243	264	262	282	260	294	282	311
West Jordan											244	427	619	900	988	947	1,332
Woods Cross			69	74	90	95	104	129	140	160	174	191	225	264	313	231	281

Table 9. Estimated population served by 50 Utah municipal water systems: 1960-1976.

County	Year																
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
American Fork	6,373	6,453	6,532	6,695	6,658	6,731	6,811	6,924	7,213	7,379	7,713	8,092	8,341	8,839	9,586	9,818	10,900
Bountiful	17,039	17,928	18,893	20,205	21,609	22,124	24,329	25,703	26,127	26,919	27,751	28,431	29,021	29,575	29,907	30,358	31,514
Brigham City	11,728	11,956	12,184	12,412	12,640	12,868	13,096	13,324	13,552	13,780	14,007	14,300	14,600	15,000	15,300	15,800	16,100
Cedar City	7,543	7,550	7,550	7,600	7,711	7,925	8,120	8,242	8,584	8,745	8,946	9,266	9,586	9,908	10,128	10,349	10,500
Centerville						2,850	2,900	2,950	2,950	3,100	3,268	3,500	3,825	4,200	4,500	4,800	5,160
Clearfield	8,833	9,143	9,453	9,763	10,073	10,383	10,690	11,000	11,600	12,458	13,316	13,283	13,250	13,217	13,317	13,416	13,288
Clinton	1,025	1,048	1,086	1,161	1,247	1,278	1,309	1,400	1,452	1,544	1,768	2,047	2,240	2,657	3,363	3,629	4,660
Delta	1,576	1,579	1,582	1,586	1,589	1,592	1,596	1,599	1,602	1,606	1,610	1,703	1,730	1,891	1,955	2,016	2,220
Duchesne																2,198	2,200
Ephraim												2,224	2,278	2,306	2,331	2,380	2,415
Fillmore	1,602	1,583	1,564	1,545	1,526	1,507	1,488	1,469	1,450	1,431	1,411	1,491	1,571	1,651	1,736	1,820	1,950
Granger-Hunter	15,745	18,880	21,860	25,975	30,000	32,050	33,490	35,230	36,970	42,000	42,222	44,065	45,909	47,753	49,597	55,640	59,357
Green River	1,075	1,071	1,067	1,063	1,059	1,055	1,051	1,046	1,042	1,038	1,033	1,029	1,025	1,021	995	968	960
Heber City									3,021	3,111	3,171	3,245	3,349	3,453	3,557	3,595	3,633
Hyrum				2,048	2,191	2,194	2,201	2,208	2,228	2,284	2,340	2,485	2,630	2,776	2,957	3,132	3,369
Kaysville											6,192	6,523	6,854	7,184	7,369	7,553	7,800
Layton	10,265	10,604	11,220	11,660	12,210	13,086	13,803	14,397	14,810	15,255	15,652	16,116	16,667	17,222	17,568	18,333	19,000
Lehi	3,529	3,574	3,621	3,705	3,756	3,798	3,819	3,876	3,908	3,994	4,035	4,359	4,891	5,210	5,693	6,160	6,742
Logan	18,731	19,000	19,200	19,800	20,300	20,500	21,000	21,200	21,600	22,000	22,600	23,000	23,500	23,900	24,200	24,500	24,800
Manila												249	272	294	320	345	360
Midvale					7,200	7,300	7,500	7,500	7,600	7,700	7,800	8,000	8,150	8,500	8,750	9,000	9,300
Milford											1,304	1,315	1,326	1,337	1,310	1,283	1,300
Moab	4,682	4,693	4,704	4,715	4,726	4,737	4,748	4,759	4,770	4,781	4,793	4,618	4,443	4,268	4,384	4,500	4,616
Monticello							1,344	1,384	1,443	1,469	1,431	1,506	1,581	1,657	1,692	1,726	1,775
Morgan	1,299	1,323	1,353	1,386	1,408	1,446	1,471	1,504	1,524	1,570	1,586	1,613	1,632	1,650	1,680	1,723	1,766
Murray	16,806	16,939	17,187	17,720	17,985	18,130	18,635	18,884	18,970	19,355	21,206	23,718	24,649	24,821	25,611	27,112	28,000
North Ogden			3,465	3,671	3,961	4,137	4,310	4,475	4,824	5,005	5,182	5,257	5,700	6,375	6,627	7,036	7,445
Ogden	70,197	70,387	70,746	70,714	70,463	70,304	70,121	70,010	69,863	69,780	69,728	69,395	69,062	68,730	68,979	69,228	69,100
Orem	18,652	19,817	20,200	20,608	21,054	21,583	22,393	23,115	24,046	25,075	26,692	27,892	29,584	31,934	33,328	36,091	39,278
Pleasent Grove	4,772	4,814	4,868	4,925	4,973	5,070	5,121	5,193	5,212	5,284	5,351	5,494	5,590	5,847	6,200	6,512	7,110
Price				-	9,408	9,475	9,510	9,573	9,613	9,328	9,648	9,685	10,181	10,244	10,379	11,068	10,836
Provo	36,047	37,346	38,756	39,485	41,123	42,854	44,538	46,400	48,103	51,148	53,131	54,421	55,711	57,000	59,000	61,000	63,000
Richfield	4,412	4,418	4,424	4,430	4,436	4,442	4,448	4,454	4,460	4,466	4,471	4,480	4,508	4,536	4,740	4,874	5,100
Riverdale				1,992	2,041	2,100	2,274	2,415	2,858	3,342	3,704	3,902	4,174	4,315	4,494	4,707	4,841
Riverton													2,851	3,180	3,311	3,442	3,687
Roosevelt	1,912	1,925	1,941	1,957	1,972	1,986	2,036	2,065	2,084	2,100	2,111	2,573	3,035	3,240	3,620	4,000	4,250
Roy	9,239	9,672	10,180	10,900	11,396	11,692	11,872	12,418	12,964	13,505	14,347	15,000	15,500	16,099	15,440	16,781	18,600
St. George											7,153	7,420	7,794	8,582	8,903	9,292	9,864
Salt Lake City	224,996	227,408	230,454	234,668	236,208	239,536	241,302	242,570	243,628	244,492	249,879	252,420	255,017	269,023	272,124	275,000	279,388
Sandy															25,600	36,000	43,000
South Jordan	1,354	1,470	1,565	1,668	1,771	2,014	2,193	2,354	2,517	2,717	2,942	3,060	3,120	3,627	3,745	4,098	4,605
South Ogden	8,600	9,074	9,192	9,418	9,866	10,164	10,030	10,273	10,588	10,747	10,900	10,980	11,246	11,498	11,552	11,800	12,184
South Salt Lake						7,450	7,500	7,600	7,700	7,755	7,810	7,974	8,138	9,303	8,900	9,041	9,088
Spanish Fork	6,472	6,558	6,644	6,729	6,815	6,900	6,987	7,045	7,073	7,148	7,565	7,625	7,918	8,339	8,780	9,218	9,812
Sunset	4,235	4,803	5,124	5,424	5,588	5,648	6,138	6,168	6,207	6,220	6,268	6,268	6,240	6,201	6,230	6,300	6,313
Tooele																	13,250
Vernal					8,889	9,010	9,132	9,254	9,307	9,350	9,400	10.300	11,200	11,800	12,568	13,320	14,140
Washington Terrace	6,441	6,521	6,601	6,681	6,761	6,841	6,921	7,001	7,081	7,161	7,241	7,447	7,657	7,798	7,852	8,078	8,200
West Jordan											4,221	4,453	6,519	8,320	10,400	11,405	15,360
Woods Cross			1,065	1,139	1,239	1,483	1,753	2,105	2,432	2,709	3,124	3,186	3,221	3,248	3,232	3,219	3,267

Table 10. Estimated per capita withdrawal rates (gcd) for 50 Utah municipal systems: 1960-1976.

County	Year																
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
American Fork	174	166	132	159	169	163	153	164	156	188	170	186	205	180	218	231	231
Bountiful	101	130	85	109	98	107	102	106	106	109	103	110	106	113	115	106	106
Brigham City	547	408	603	577	652	750	740	365	397	421	391	370	340	358	410	355	198
Cedar City	195	191	222	211	226	218	257	230	243	233	230	235	235	235	235	235	235
Centerville						133	123	109	98	86	137	127	125	95	89	91	97
Clearfield	187	159	203	167	162	143	175	151	145	140	138	143	148	143	215	176	216
Clinton	78	99	102	111	131	97	157	131	135	157	133	143	160	147	146	128	128
Delta	328	328	210	340	488	484	509	548	552	560	559	534	525	481	465	493	245
Duchesne																274	256
Ephraim												219	335	394	380	325	352
Fillmore	281	287	391	409	411	400	461	439	435	452	451	439	446	293	453	437	417
Granger-Hunter	110	112	119	120	126	118	158	149	149	156	154	173	174	159	165	154	156
Green River	114	109	103	49	143	124	167	167	194	284	294	208	216	215	220	226	228
Heber City									387	391	388	383	410	435	425	428	462
Hyrum				471	451	497	518	595	594	596	580	532	492	513	486	463	432
Kaysville											234	203	198	171	194	178	181
Layton	175	171	171	183	187	169	205	170	173	195	173	178	247	204	202	164	189
Lehi	415	329	353	274	323	238	330	305	285	305	284	253	221	203	182	176	140
Logan	432	405	442	469	403	425	447	413	428	420	491	494	506	518	509	494	512
Manila												370	339	218	274	246	244
Midvale					202	260	259	268	266	264	273	276	277	330	331	333	334
Milford											395	438	456	435	446	519	513
Moab	129	131	141	164	189	171	200	200	200	205	211	228	258	233	261	222	237
Monticello							371	307	325	371	355	339	357	179	308	299	292
Morgan	324	338	340	339	337	300	329	319	335	332	337	374	386	390	431	460	464
Murray	176	174	188	195	202	190	222	224	209	229	212	205	221	233	265	282	360
North Ogden			242	231	208	166	159	156	148	142	106	114	111	99	105	104	121
Ogden	240	223	236	243	231	243	272	274	266	269	279	250	266	267	258	244	255
Orem	215	237	241	241	241	255	293	276	271	304	289	300	317	296	325	260	277
Pleasant Grove	142	149	147	146	176	138	165	150	137	179	212	285	316	321	331	363	387
Price					180	238	269	206	228	258	247	226	264	248	264	258	257
Provo	301	357	305	285	280	294	315	298	285	290	275	279	315	298	305	280	288
Richfield	312	325	317	279	302	291	343	330	322	328	340	400	388	383	376	360	349
Riverdale				174	173	205	226	227	214	220	169	187	184	184	207	194	195
Riverton													203	200	271	244	116
Roosevelt	369	349	312	350	417	400	504	559	474	519	485	428	435	521	426	390	355
Roy	176	185	180	176	182	184	271	210	216	245	219	216	249	222	260	214	224
St. George											224	220	217	197	242	226	246
Salt Lake City	259	255	255	238	246	217	280	246	236	287	255	298	304	265	312	274	275
Sandy															320	217	235
South Jordan	99	96	102	105	114	100	127	127	121	133	111	154	150	151	163	195	191
South Ogden	84	79	89	77	86	88	96	78	86	87	86	98	111	109	108	107	110
South Salt Lake						219	243	248	244	269	266	250	286	293	289	293	297
Spanish Fork	216	337	295	245	236	218	249	226	217	241	258	263	221	229	198	212	250
Sunset	160	148	160	161	165	156	184	166	166	199	174	191	199	176	201	168	176
Tooele																	208
Vernal					371	287	289	329	400	425	364	362	342	351	349	313	238
Washington Terrace	82	106	77	73	84	81	88	84	91	93	100	96	101	91	102	96	104
West Jordan											158	263	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Woods Cross			176	177	199	175	163	168	158	162	152	164	191	223	265	196	235

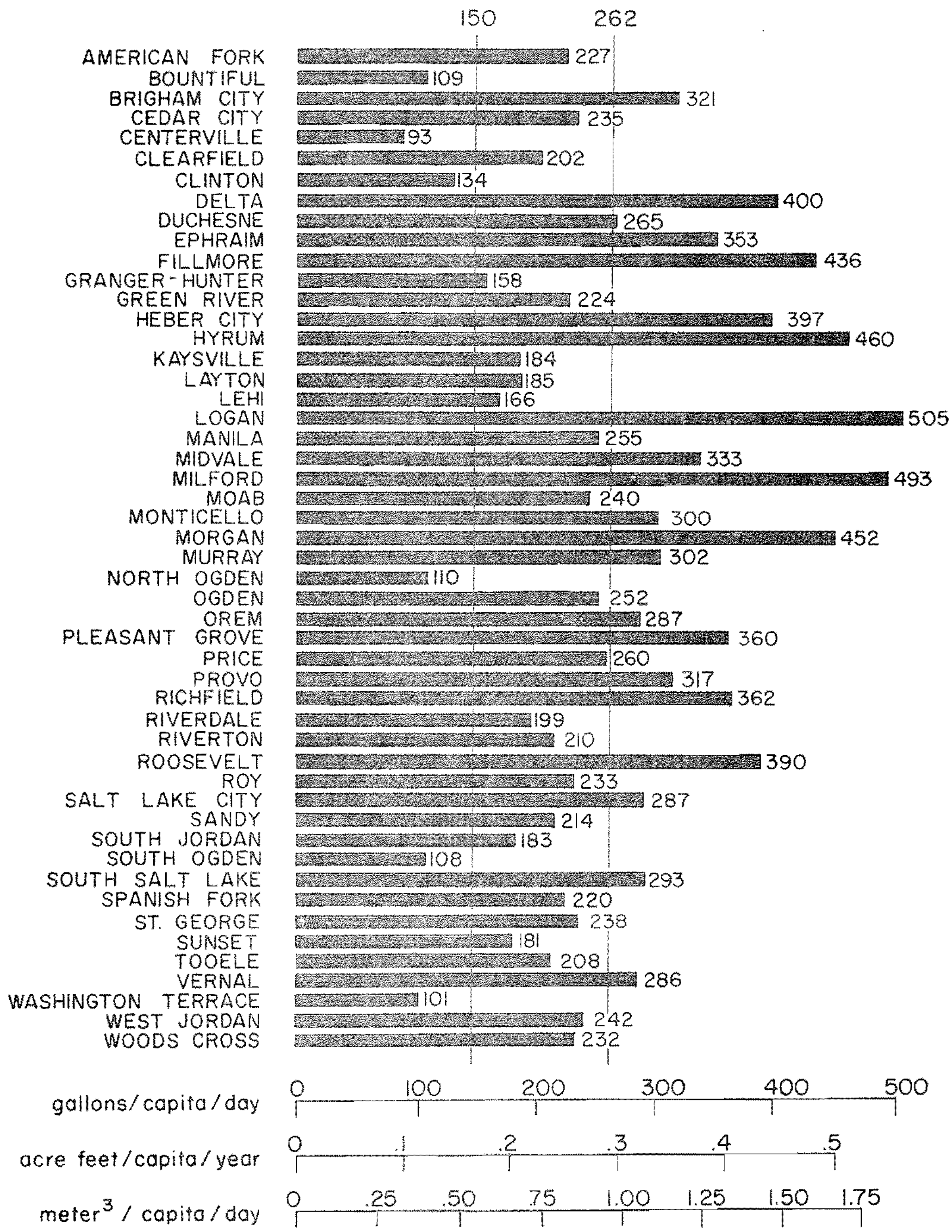


Figure 7. Per capita withdrawal rates (gcd) for 50 Utah municipal systems: average of 1974, 1975, and 1976. (The vertical lines represent the rational (150) and statewide (262) per capita withdrawal rate (gcd).)

Table 11. Per capita withdrawal rate (gcd) statistics for 50 Utah municipalities: 1960-1976.

Municipality	Years of Data	Mean	Standard Deviation	Minimum	Maximum
			Statistics		
American Fork	17	179	27.8	132	231
Bountiful	17	107	8.9	85	130
Brigham City	9	361	62.7	198	421
Cedar City	11	223	19.3	191	257
Centerville	12	109	18.7	86	133
Clearfield	17	165	27.0	138	216
Clinton	17	128	23.7	78	160
Delta	17	450	108.8	210	560
Duchesne	2	265			
Ephraim	6	334	62.2	219	394
Fillmore	17	406	60.2	281	461
Granger-Hunter	17	144	12.5	110	174
Green River	13	206	49.1	124	294
Heber	9	412	27.3	387	462
Hyrum	14	516	56.2	432	596
Kaysville	7	194	21.0	171	234
Layton	17	186	20.6	169	247
Lehi	17	272	71.7	140	415
Logan	17	459	41.5	403	519
Manila	6	282	59.8	218	370
Midvale	13	283	39.1	202	334
Milford	7	457	44.3	395	519
Moab	17	199	40.7	129	261
Monticello	11	318	54.4	179	371
Morgan	17	361	49.3	300	464
Murray	17	223	45.4	174	360
North Ogden	15	147	47.1	99	242
Ogden	17	254	16.6	223	279
Orem	17	273	31.4	215	325
Pleasant Grove	17	220	90.6	138	387
Price City	13	242	26.0	180	269
Provo	17	302	20.6	275	357
Richfield	17	338	34.6	279	400
Riverdale	14	197	19.7	169	227
Riverton	5	207	58.8	116	271
Roosevelt	17	429	71.7	312	559
Roy	17	213	30.7	176	271
Salt Lake City	17	265	25.8	217	312
Sandy	3	257			
South Jordan	17	132	31.2	96	195
South Ogden	17	93	12.0	77	111
South Salt Lake	12	266	25.5	219	297
Spanish Fork	17	241	33.5	198	337
St. George	7	225	16.4	197	246
Sunset	17	174	16.2	148	201
Tooele	1	208			
Vernal	13	336	53.0	226	429
Washington Terrace	17	91	9.9	73	106
West Jordan	7	245	40.1	168	296
Woods Cross	15	187	32.1	152	265

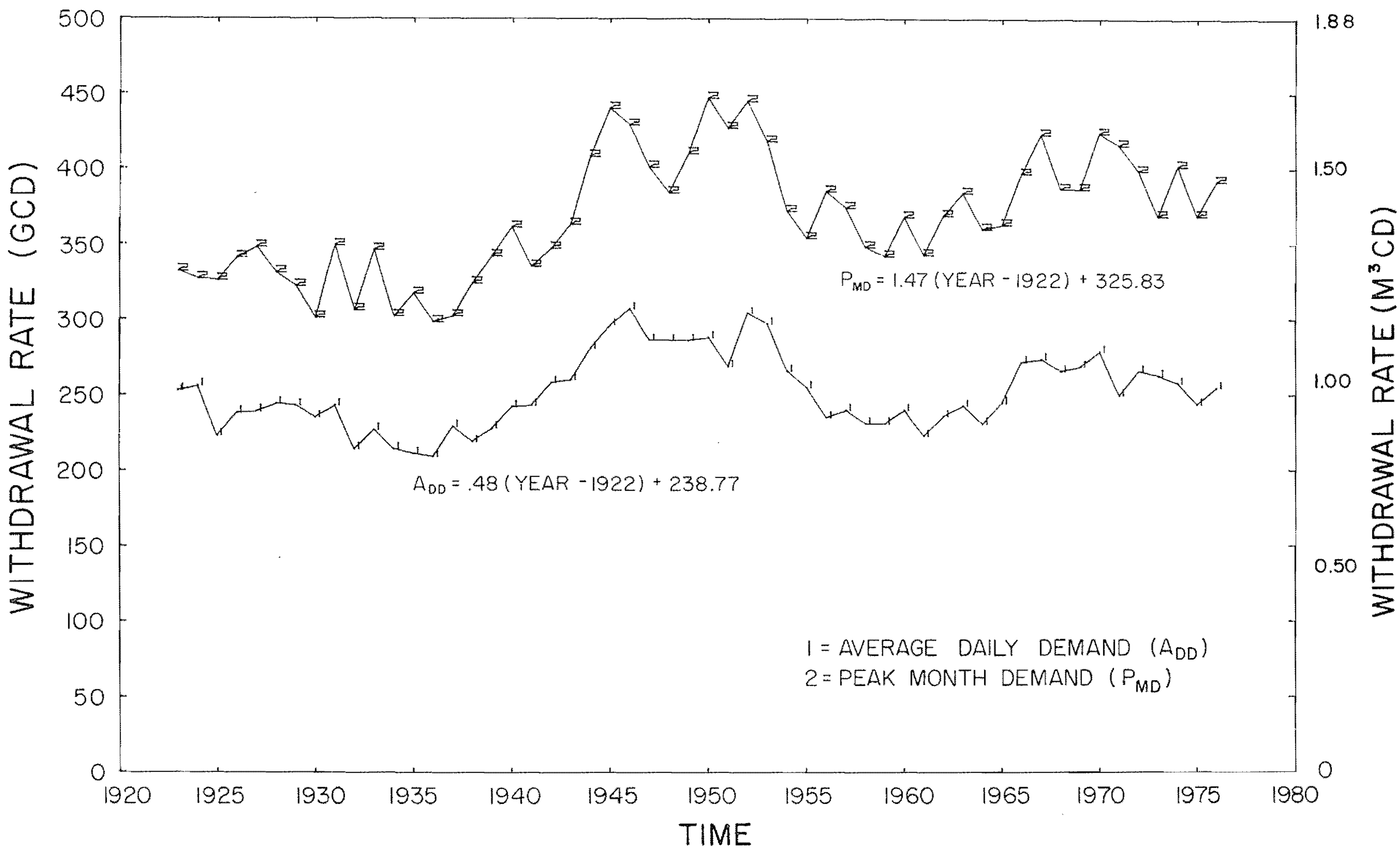


Figure 8. Per capita withdrawal rates (gcd) for the Ogden City Water Department: 1923-1976.

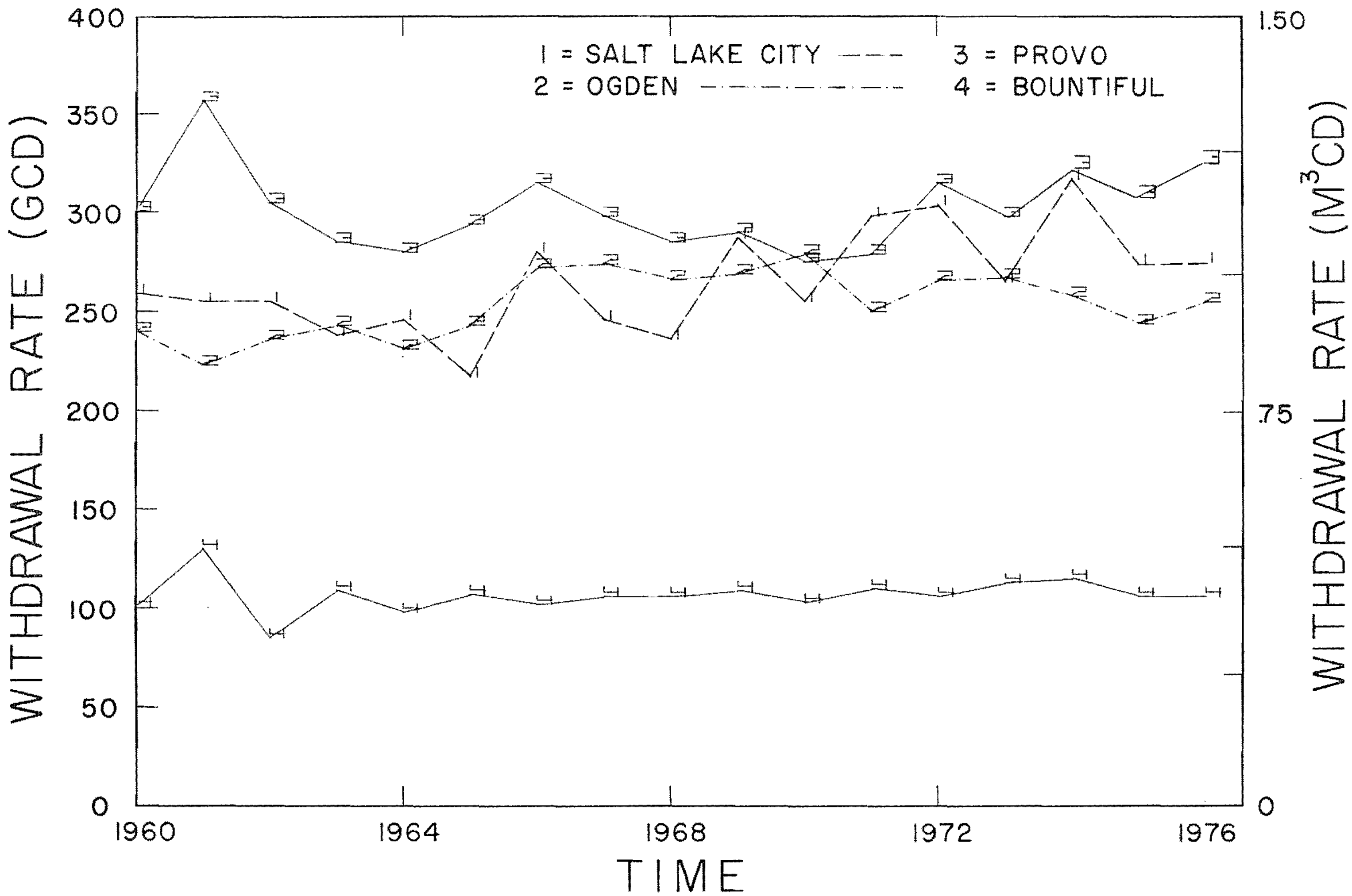


Figure 9. Per capita withdrawal rates (gcd) for Bountiful, Ogden, Provo, and Salt Lake City: 1960-1976.

Table 12. Salt Lake City and Ogden per capita withdrawal rate (gcd) statistics.

	Municipality	
Statistics	Salt Lake City[a]	Ogden
Time period	1923-1969	1923-1976
Sample size	47	54
Maximum	250	307
Minimum	179	209
Range	71	98
Mean	214	251
Standard deviation	21.1	26.2
Median	214	245

[a]Source: Kirkpatrick (1976).

again for Bountiful low per capita withdrawal rate is the availability of water from a separate pressure irrigation system. The withdrawal rate in the other three systems appears to have stabilized at between 250 and 300 gcd.

There are many reasons for differences in the per capita withdrawal by users of municipal water. Some of the reasons that have been suggested include differences in climate, size of city or town, type of domestic residence, lot sizes, types of industries using municipal water, availability of irrigation water for outdoor use, amount and type of water charges, condition of conveyance system, use or non-use of meters, and a wide variety of socio-economic factors. In Chapter IV several determinants of municipal water usage will be discussed in detail.

As a caveat on the use of per capita withdrawal rates for small municipal systems, a brief examination of Amalga's water system is in order. Amalga is a rural community in Cache County with a population of 210 and an average per capita withdrawal rate of 1682 gcd. At first glance this number might appear excessive. The town is, however, the home of a large cheese manufacturing plant. This firm uses approximately 70 percent of the town's culinary water. Amalga is also the home of several large dairy herds; cows, in fact, out number the town's human inhabitants. The cattle drink culinary water and the milking facilities are cleaned using town water. When the town's unique situation is considered, its water withdrawal cannot be considered excessive. Thus, care should be taken in the interpretation of per capita withdrawal rates.

Peak Month and Peak Day Demands

Water demands do not remain constant throughout the year. Monthly, weekly, daily, hourly and instantaneous variations in water withdrawal occur. In the summer months, more water is consumed in drinking, bathing, and watering lawns and gardens. On weekends and holidays residential water withdrawal may be high. Several municipal water utility managers expressed concerns in responding to their questionnaires about their system being characterized by average daily per capita withdrawal rates. They felt that for design purposes peak month and peak day were more reliable statistics.

In a recent study, Hughes and Gross (1979) examined 14 Utah and western Colorado public water systems. Average daily and peak month data were available for all 14 systems and peak day measurements were available for 10 systems. Using regression analysis, peak month and peak day demands were correlated with average daily demand.

Hughes and Gross found that peak monthly demand can be estimated using the following relationship:

$$P_{MD} = -108.1 + 2.432\ A_{DD} \quad . \quad . \quad . \qquad (1)$$

where P_{MD} equals peak monthly demand, A_{DD} is average daily demand and P_{MD} and A_{DD} are in gcd. The relationship is plotted in Figure 10. This function should be an adequate predictor as its R^2 is 0.932 (where 1.0 implies perfect correlation).

Since many water supply components (i.e., treatment plants, storage facilities, pump motors, etc.) are sized using demand during the peak 24 hour period, a relationship between average day and peak day demand is important (see Figure 10). Hughes and Gross found that:

$$P_{DD} = -49.4 + 2.497\ A_{DD} \quad . \quad . \quad . \qquad (2)$$

where P_{DD} is peak day demand and P_{DD} and A_{DD} are in gcd. The R^2 for this relationship is 0.953.

The annual daily demands reported in Figure 7 can be used to estimate peak monthly and peak daily demand. Since storage components of a municipal water system are generally designed for monthly flows while transmission facilities are usually designed for daily flows, the designer must consider usage over both periods in system design.

Water Pricing

The 1975 fee structures for culinary water in the study municipalities were analyzed. Table 13 indicates the prices associated with the withdrawal of various quantities of water. For example, a household in American Fork would be charged $6.31 for 27,930 gallons (statewide average month) and $11.85 for 55,043 gallons (statewide peak month). An estimated average monthly water bill is $5.58 (or $0.236 per 1,000 gallons) and an estimated water bill

Table 13. Hypothetic user fees for 50 Utah municipalities using 1975 rate structures.

Municipalities	Cost of Water			
	System Average Month[a] ($/1000 gallons)	System Peak Month[b]	Statewide Average Month[c]	Statewide Peak Month[d]
American Fork	$ 5.58 (.236)	$10.07	$ 6.31	$11.85
Bountiful	3.10 (.295)	3.84	6.46	12.00
Brigham City	8.88 (.260)	16.78	5.36	10.90
Cedar City	6.28 (.255)	9.85	6.46	11.45
Centerville	4.68 (.446)	5.97	10.56	20.26
Clearfield	5.20 (.248)	8.75	6.46	10.60
Clinton	2.23 (.170)	3.71	5.06	10.60
Delta	7.08 (.169)	12.94	5.32	8.64
Duchesne	8.88 (.308)	13.61	9.60	13.15
Ephraim	10.45 (.284)	17.89	8.56	13.74
Fillmore	10.19 (.228)	18.08	7.60	11.75
Granger-Hunter	6.00 (.362)	7.15	6.90	12.84
Green River	11.85 (.502)	20.84	13.32	24.41
Heber City[e]	4.00	4.00	4.00	4.00
Hyrum	8.72 (.185)	16.53	5.92	9.80
Kaysville	4.18 (.227)	7.10	5.96	11.00
Layton	5.28 (.287)	8.20	7.06	12.10
Lehi	4.65 (.253)	6.89	6.96	12.05
Logan	11.06 (.210)	23.77	5.96	11.50
Manila	15.63 (.595)	28.75	16.15	30.01
Midvale	6.84 (.200)	13.60	5.61	10.60
Milford	4.75	4.75	4.75	4.75
Moab	7.84 (.299)	13.61	8.07	14.16
Monticello	7.88 (.250)	16.31	6.83	13.76
Morgan	6.82 (.144)	14.70	4.02	7.90
Murray	6.26 (.198)	10.99	5.67	9.55
North Ogden	4.00 (.381)	4.39	6.75	11.74
Ogden City	7.71 (.294)	14.27	7.98	14.91
Orem	7.09 (.245)	10.09	4.68	9.70
Pleasant Grove	12.86 (.350)	27.31	9.56	19.26
Price City	9.25 (.352)	19.75	9.46	21.01
Provo	7.78 (.228)	13.78	6.68	11.12
Richfield	9.19 (.250)	19.51	6.83	13.76
Riverdale	5.23 (.249)	8.60	6.36	11.35
Riverton	7.20 (.342)	10.94	8.46	14.00
Roosevelt	14.50 (.345)	26.70	10.69	17.76
Roy	5.09 (.215)	9.36	5.79	11.05
Salt Lake City	5.06 (.175)	9.86	4.81	9.24
Sandy	8.91 (.377)	16.12	9.83	16.76
South Jordan	6.89 (.375)	10.33	8.94	15.31
South Ogden	2.35 (.224)	3.09	5.71	11.25
So. Salt Lake	6.79 (.216)	14.22	5.87	11.96
Spanish Fork	4.79 (.207)	8.01	5.35	9.13
St. George	7.65 (.291)	12.07	7.86	13.40
Sunset	5.58 (.304)	8.68	7.48	12.50
Tooele	4.47 (.213)	7.74	5.57	10.42
Vernal	6.28 (.217)	12.31	5.96	12.18
Washington Terrace	5.75 (.548)	5.75	7.41	12.95
West Jordan	9.06 (.345)	15.62	9.33	16.26
Woods Cross	5.33 (.226)	9.82	6.06	11.60

[a] From Figure 7.

[b] Computed using Equation 1.

[c] Assumes a water withdrawal of 262 gallons/capita/day x 30 days/month x 3.5 persons/connection.

[d] Computed using Equation 1.

[e] Flat rate.

during the system's peak month is $10.07. (A system's average monthly water withdrawal is taken from Figure 7 and peak monthly water withdrawal is computed from Equation 1.) The highest price charged for 27,930 gallons is $16.15 and the lowest is $4.68 The system with the highest estimated monthly bill is Manila and the lowest is South Ogden.

The charges in Table 13 represent only the user fees associated with individual meter readings, and not necessarily the actual costs of supplying water. Many municipalities located in water conservancy districts defray part of system costs through a special tax allowed by the "Water Conservancy Act" (Utah Code Annotated, Title 73, Chapter 9). It is the combination of the ad valorem tax and the user fee which represents the real cost of water to the customer. To conclude, from Table 13, therefore, that water in a given community is comparatively inexpensive without examining other sources of financial support may be improper. Only user fees are reported in the table because a water user's decision on whether or not to conserve is based on these fees.

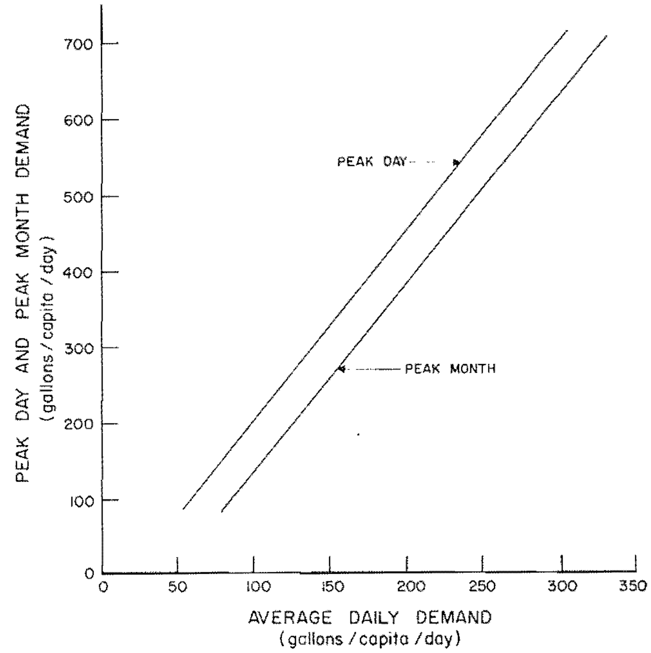


Figure 10. Graphical representation of the relationship between average daily demand and peak month and peak day demand.

Table 14. Per capita return flow rates (gcd) statistics for 13 wastewater facilities: 1960-1976.

Facility	Statistic				
	N	Mean	S.D	Min.	Max.
Brigham City	17	125	19.5	94	150
Central Weber	15	346	26.9	315	396
Granger-Hunter[a]	4	102	-	-	-
Logan[b]	7	372	61.2	302	494
Murray	7	127	18.5	92	152
North Davis	9	169	7.9	154	175
Orem	3	105	-	-	-
Provo	13	232	8.7	211	250
Salt Lake[c]	8	179	26.2	148	219
St. George	3	197	-	-	-
South Davis, North Plant	8	114	5.0	106	120
South Salt Lake[d]	7	323	27.3	262	340
Tri-community	12	129	9.5	115	148

[a]Includes Kearns.

[b]Includes River Heights.

[c]Includes Emigration Canyon.

[d]Includes Chesterfield.

System Return Flow Rates

The yearly quantity of water discharged by Utah wastewater systems for the period 1960 to 1976 is an output from the IMS, as are population served estimates and average daily per capita return flow rates. The mean, standard deviation, minimum and maximum of the time-series per capita return flow rates are contained in Table 14.

The difference between withdrawal and return flow rates in water versus wastewater systems with similar geographical boundaries are illustrated in Figure 11. As is illustrated by the Central Weber comparison (return flow rate exceeds withdrawal rate), infiltration and interflow from groundwater can complicate consumptive use estimates.

Figures 12 and 13 contain time-series withdrawal, return flow, and consumptive use rates for two of Utah's largest municipalities--Salt Lake City and Provo. While Provo's consumptive use has remained relatively constant (25 percent of the withdrawal rate); Salt Lake City's has been inexplicably erratic.

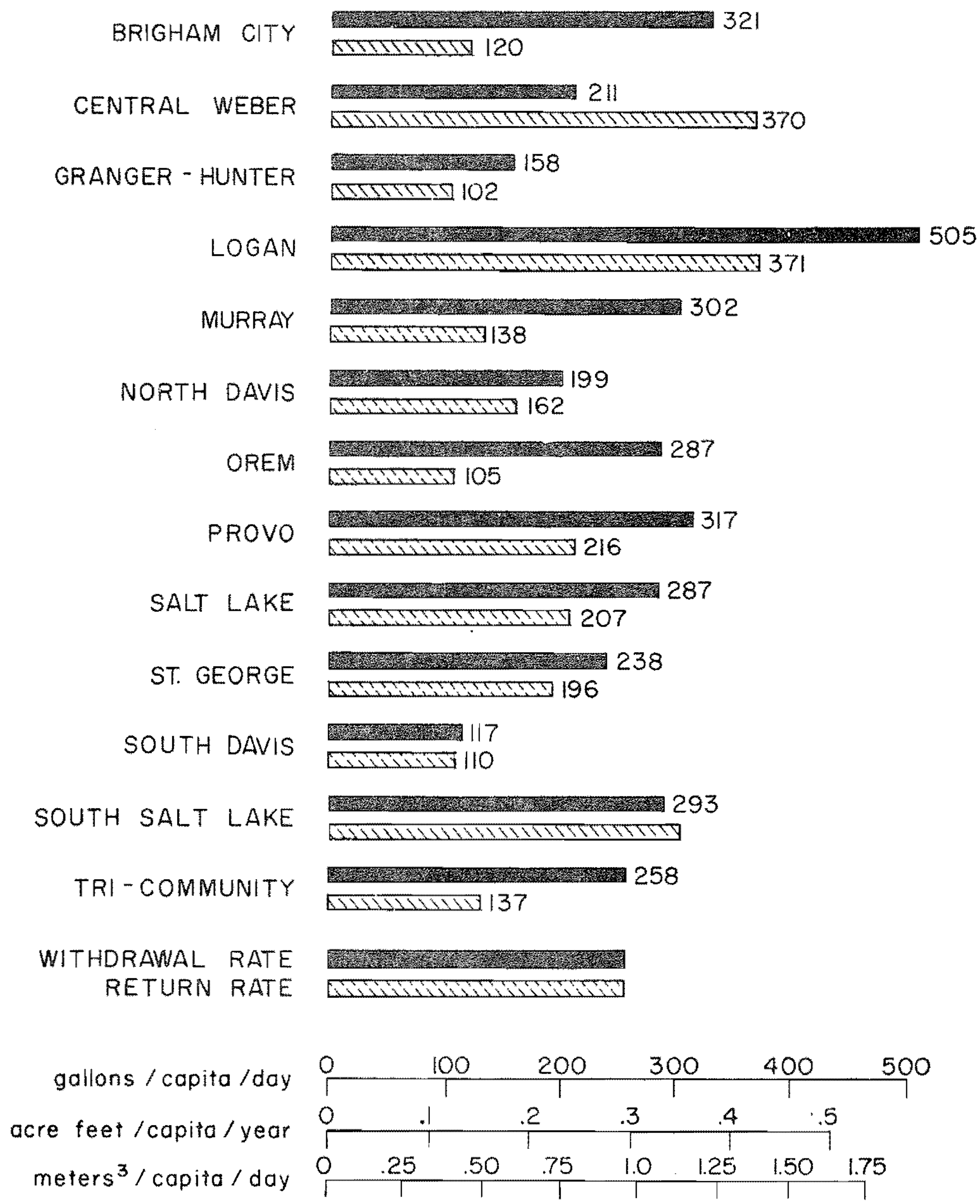


Figure 11. Per capita withdrawal and return flow rates (gcd) for 13 Utah areas: average of 1974, 1975, and 1976.

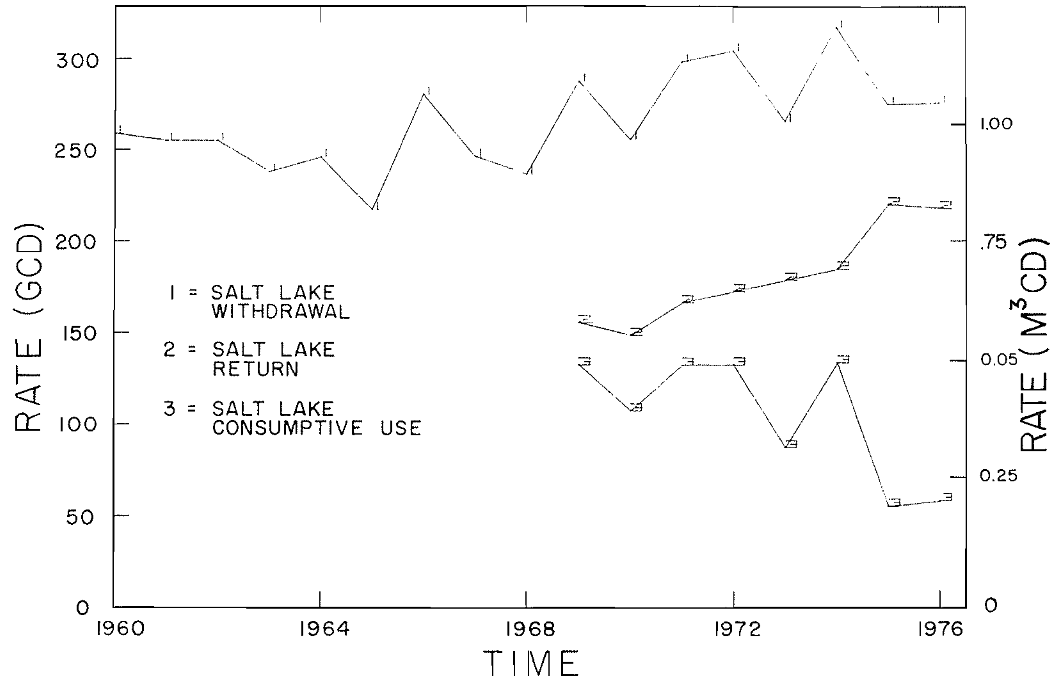


Figure 12. Salt Lake City per capita withdrawal and return flow rates (gcd) for 13 Utah areas: average of 1974, 1975, and 1976.

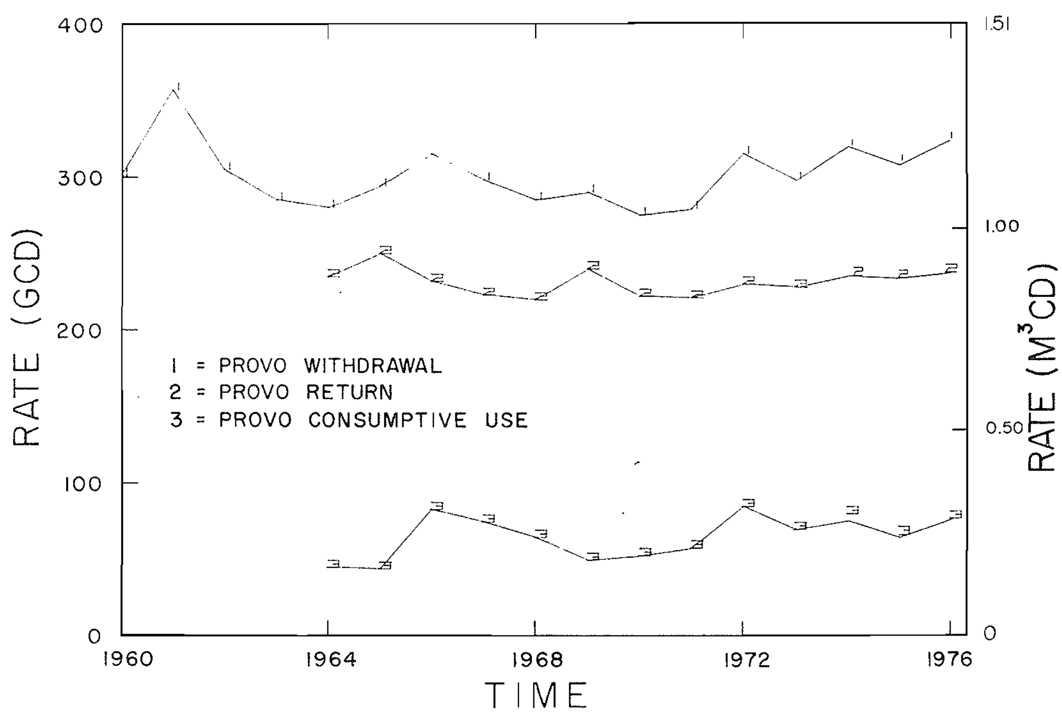
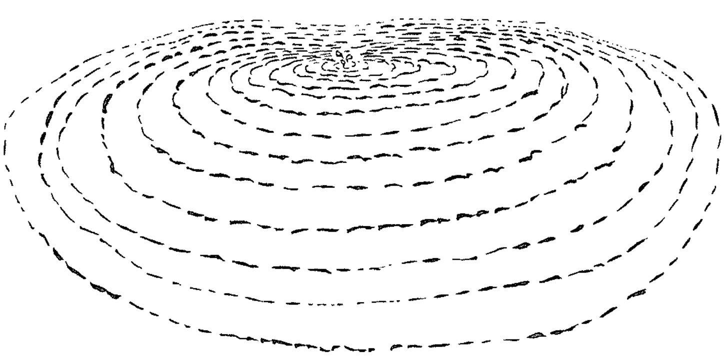


Figure 13. Provo City per capita withdrawal, consumptive use, and return flow rates (gcd): 1960-1976.



CHAPTER III

HISTORIC INDUSTRIAL WATER USAGE

'written on water', one might say
of each day's flux and lapse

Tomlinson

This chapter summarizes the industrial water inventory conducted by the Utah Water Research Laboratory. The principal objectives of the inventory were to: 1) estimate the quantity of water withdrawn by a representative sample of Utah industries and 2) estimate per employee (or per unit of output) withdrawal and return flow rates.

To accomplish these objectives, questionnaires were mailed out by the Utah Water Research Laboratory. For firms not responding to the mailings, personal visits were made--either to the firm itself, to the water system supplying the firm, or both. Firms covered in the survey account for over 50 percent of Utah's total employment in manufacturing, steam-electric generation, and military categories.

The yearly quantity of water withdrawn by inventoried industrial firms for the period 1970 to 1976 is available from the output of the IMS. Also available are quantities of water obtained from surface, groundwater and high-quality sources. The IMS also aggregates industrial firm data to county and statewide totals.

Steam-electric Power (SIC 4911)

The gross amount of water withdrawn and consumed per kilowatt-hour was estimated for each of Utah's four major coal-fired electric power plants. The average withdrawal, consumptive use, and return rate for each facility are shown in Table 15.

The reason for the large water withdrawal rate at plant one, is its once-through cooling system. In once-through cooling, water is circulated through the steam condensers once, and the heated water is discharged directly to a natural water body. Thus, there is a large water requirement, but consumptive use is usually small.

The other plants have closed cooling systems. With closed systems, water is recirculated through condensers and cooled in towers or ponds through spraying or trickling. Cooling ponds serve for storage, and evaporation rates are largely a function of pond design and the local environment. Evaporation cooling towers generally consume more water and are also more expensive. In closed systems, water consumption consists of two parts. "Make-up-water" is added to replace water lost through evaporation and drift, and additional water is added to replace a "blowdown requirement" of water removed from cooling recirculation to prevent excessive mineral buildup.

Manufacturing (SIC: 2 and 3)

Excluding steam-electric generation, industrial water use in Utah is concentrated in five industries: food products (SIC:20), petroleum refining (SIC:2911), primary metals (SIC:33), hydraulic cement (SIC:3241), and inorganic chemicals (SIC:28). Information obtained from the UWRL inventory of industrial water users is contained in Table 16. Water withdrawal rates are reported in gallons per employee per day (ged).

Water usage by manufacturing firms can be divided into three areas: 1) water for manufacturing processes; 2) water used as a cooling agent; and 3) water for sanitary uses (Nemerow, 1971). Water for manufacturing processes includes water used in plating solutions in metal fabrication, water to wash processing equipment in dairy plants, water used for dust control etc. The volume of water used for cooling varies from one industry to another depending on the total quantity of heat to be removed. Although cooling water can become contaminated by small leaks, corrosion products, increased salt concentration, or the effect of heat, the wastewater contains little, if any,

Table 15. Water withdrawal consumptive use and return rates for four Utah steam electric power plants.

Plant	County	Rates (gallons/kwh) Withdrawal	Consumptive Use	Return
One	Utah	110.2	1.83	108.37
Two	Carbon	0.83	0.61	0.22
Three	Salt Lake	0.76	N.A.[a]	N.A.
Four	Emery	0.91	0.91	0.0

[a]Not available.

Table 16. Utah industrial (manufacturing) water withdrawal rates (gcd and m3cd) for major water using firms: average of 1974, 1975, and 1976.

SIC	Code	Firm	Withdrawal for (percent): Product Manufacture	Employee Sanitation	Cooling	Other	Withdrawal Rate gcd	m^{3}cd	Return Flow (% of withdrawal)
Meat Packing	2011	1	79	3	17	1	453	1.71	80
		2	95	1	4	0	1484	5.59	N.A.[a]
Poultry Processing	2016	1	70	5	25	0	1194	4.49	100
Cheese	2022	1	97	1	2	0	2486	9.36	98
		2	69	1	20	10	288	1.08	90
Ice Cream	2024	1	N.A.	N.A.	N.A.	N.A.	507	1.91	N.A.
		2	N.A.	N.A.	N.A.	N.A.	322	1.21	N.A.
Fluid Milk	2026	1	N.A.	N.A.	N.A.	N.A.	873	3.29	N.A.
Canned Vegetables	2033	1	N.A.	N.A.	N.A.	N.A.	4851	18.26	N.A.
Flour	2041	1	85	5	10	0	639	2.41	50
Bread	2051	1	80	10	10	0	633	2.38	70
Candy	2065	1	N.A.	N.A.	N.A.	N.A.	578	2.18	N.A.
		2	N.A.	N.A.	N.A.	N.A.	312	1.17	N.A.
Soft Drinks	2086	1	N.A.	N.A.	N.A.	N.A.	278	1.05	N.A.
Inorganic Chemicals	2819	1	82	1	15	2	8908	33.53	15
Petroleum Refining	2911	1	33	T[b]	65	T	11760	44.26	N.A.
		2	30	3	67	0	7860	29.58	N.A.
		3	45	T	55	0	11738	44.18	N.A.
Hydraulic Cement	3241	1	97	3	T	0	3260	12.27	3
		2	95	T	0	5	3668	13.81	2
Steel Works	3312	1	33	6	56	5	5109	19.23	10
Copper Smelting	3331	1	92	1	6	1	67231	253.03	N.A.

[a]Not available.
[b]Less than one percent.

organic matter. Sanitary water will normally range from 25 to 50 gallons per employee per day This volume depends on many factors, including size of plant, degree of cleanliness required by workers in the manufacturing process, and whether the facility has a bathhouse. Estimates of the percentage of water used for each of the three areas is contained in Table 16. Also estimated is the percentage of water withdrawn which becomes return flow.

The largest industrial water user in Utah is the Kennecott Copper Corporation in Salt Lake County. The Company chose not to respond to the UWRL inventory so the information reported is taken from Glenne (1978). Kennecott uses approximately 126,000 acre feet of water per year. The company's water is taken from the Jordan River via the Utah and Salt Lake Canal and the West Jordan Canal, and withdrawn from groundwater. The company also imports water from a spring in Tooele County.

The state's second largest water user is U.S. Steel-Geneva Works in Utah County. Intake water for 1974, 1975, and 1976 averaged 26,000 acre feet per year. This translates to a water withdrawal rate of 5100 gallons per employee per day. Geneva's sources include West Union Canal, the Provo River, and groundwater from wells. Presently the plant utilizes treated and untreated water. The treated water is used for cooling the furnaces and employee sanitation. The untreated water is used for cooling, scrubbing gases, and lawn watering.

There are four major oil refining facilities in Utah. Husky Oil and Phillips Petroleum obtain most of their water from groundwater sources. Phillips, however, obtains approximately 25 percent of its industrial water from urban storm runoff reaching Mill Creek from Bountiful. This water is treated and used for processing and cooling. American Oil obtains its boiler water from Salt Lake City. Water used for cooling is obtained from groundwater. Chevron Oil purchases both treated and untreated water from Weber Basin WCD and municipal water from Salt Lake City. The four use in excess of 9 mgd or 10,000 acre feet per year. This quantity is roughly equivalent to a community of 34,000 (assuming a per capita usage of 262 gcd). Additional information on the refineries is contained in Table 16.

Utah has two major firms involved in the manufacture of hydraulic cement. The firm in Morgan County obtains its water from wells while the other located in Salt Lake County, purchases water from the Salt Lake City Water Department. Their average withdrawal rate for 1974, 1975, and 1976 was 3,500 gallons per employee per day. Additional information on these manufacturers is contained in Table 16.

The UWRL inventory obtained information on a plethora of food processing firms. Information obtained is summarized in Table 16. An average withdrawal rate for 1974, 1975, and 1976 (weighted by the number of employees) is 900 gallons per employee per day.

A per employee comparison of the withdrawal rates of Utah's major water using manufacturing sectors is contained in Figure 14. On a per employee basis, the primary metals and oil refining firms are the heaviest users of water.

Military Facilities (SIC:9711)

Information on water use at Utah's three major military facilities is contained in Table 17. The average water withdrawal for Hill Air Force Base, Tooele Army Depot, and Dugway Proving Grounds (U.S. Army) between 1969 and 1976 was 6886 acre feet per year. This water withdrawal is roughly equivalent to that of a community of 23,000 (assuming a municipal withdrawal rate of 262 gcd).

Hill Air Force Base in Davis County is the state's largest employer. Its water is supplied from both groundwater sources and purchased from the Weber Basin Water Conservancy District. Its industrial waste is pretreated on the base and then, along with sanitary waste is treated by the North Davis Sewer Improvement District. Hill Field has on-base housing and approximately 60 percent of its water is used for employee sanitation and on-base housing. Dugway Proving Grounds and Tooele Army Base are located in Tooele County. They both obtain their water from groundwater sources and dispose of wastewater in total containment lagoons. Information on water usage at both facilities is reported in Table 17.

Other Firms

The UWRL obtained information on a variety of other firms. These facilities are reported in the IMS. Included are three universities, the Freeport Center, the aerospace industry, and electronic computing equipment firms.

Table 17. Total quantity of water withdrawn (and in parenthesis returned) by Utah's major military facilities (units = mg).

Year	Military Facility			
	Hill AFB	Tooele AB	Dugway AB	Total
1963	N.A.[a]	459	N.A.	-
1964	N.A.	455	N.A.	-
1965	N.A.	465	N.A.	-
1966	N.A.	457	N.A.	-
1967	N.A.	443	509	-
1968	N.A.	494	631	-
1969	1,298	434	668	2400
1970	1,175	401	858	2434
1971	1,263	498	483	2244
1972	1,194 (530)	552	695	2441
1973	1,177 (482)	389	425	1991
1974	1,358 (608)	429	500	2287
1975	1,221 (622)	393	406	2020
1976	1,353 (631)	398	378	2129
Average				2244

[a]Not available.

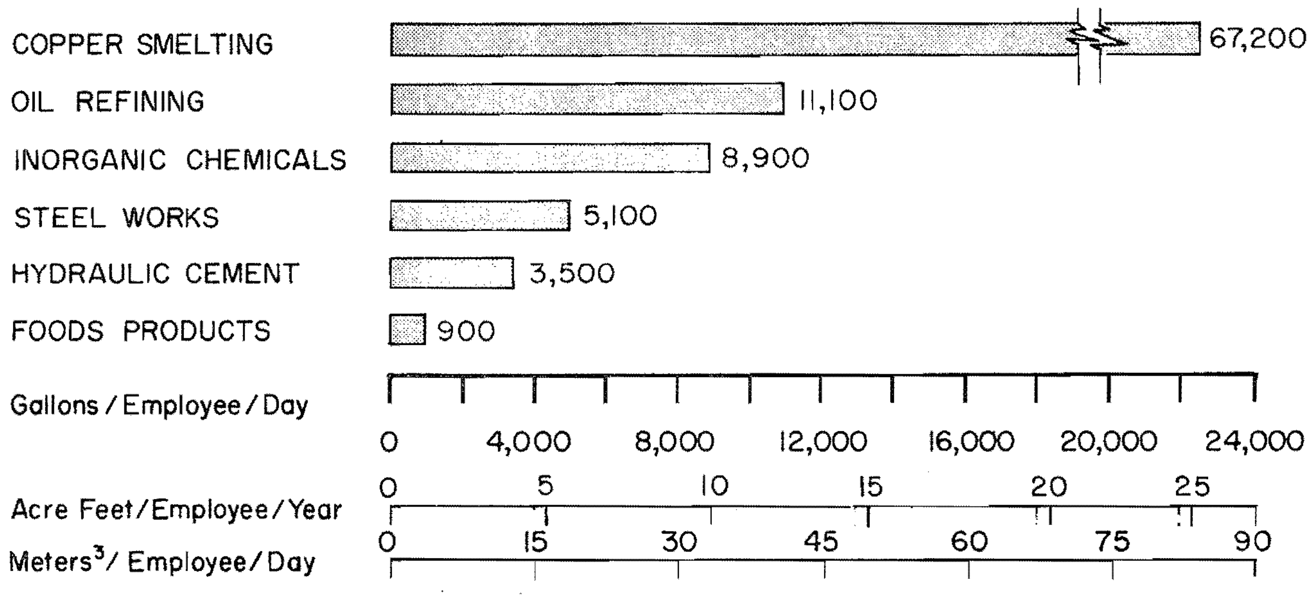
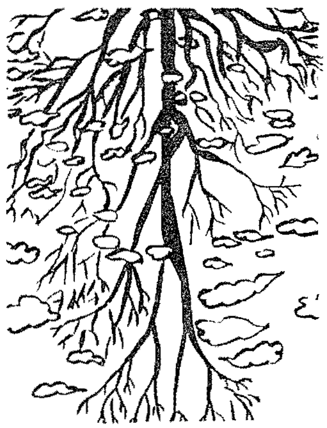


Figure 14. Per employee withdrawal rates (ged) for Utah's major water using industries: average 1974, 1975, and 1976.



CHAPTER IV

PROJECTED MUNICIPAL AND INDUSTRIAL WATER USAGE

it rendered new (time within time)
an unending present, travelling through
all that we were to see and know

Tomlinson

Municipal Rate Projections

Withdrawal Rate Projections

It is common practice in planning studies to include a small growth trend in per capita demand. While some Utah counties have shown some increase in per capita demand since 1960, this trend seems unlikely to continue into the future. The reasons for this are threefold: 1) water will become increasingly expensive; 2) excess system leakage will be eliminated as water becomes more expensive; and 3) as people move closer together they will require less water for outdoor usage.

As discussed briefly in Chapter II, per capita water withdrawal is related to several factors. An important economic determinant of water withdrawal is the price paid by the consumer. Demand functions for Utah communities have been developed by Hughes and Gross (1979) and Gardner and Schick (1964). Using data for 24 of the 50 Utah municipal systems studied, a mathematical function was developed for estimating municipal demands:

$$A_{DD} = C \cdot P^{-0.52} O^{0.15} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where A_{DD} is daily per capita demand (gcd), P is the price of municipal water in dollars per 1000 gallons, O is the percentage of connections without a supplementary outdoor irrigation system and C is 60 for systems along the Wasatch Front and 90 for the remainder of the state. The t-values for the independent values are 3.32 and 1.94 respectively. The R^2 (correlation coefficient) equals 0.65.

The exponent of the price variable (P) is the price elasticity. Gardner and Schick (1963) computed a price elasticity of -0.77 in 43 northern Utah communities. Howe and Linaweaver (1967), for the arid western region, computed an elasticity of -0.231 for indoor usage and -0.703 for outdoor usage. Thus a combined indoor/outdoor elasticity of -0.52 is appropriate. (This means that a 10 percent increase in the price of water would result in a 5 percent decrease in water withdrawal.)

For municipalities delivering little or no water for outdoor lawn sprinkling or garden watering, -0.52 is too high. For such systems, estimates can be made using the following equation (James and Lee, 1976):

$$\hat{A}_{DD} = \left(\frac{P_b}{P}\right)^{-0.231} \bullet A_{DD} \quad . \quad . \quad . \quad (4)$$

where A_{DD} and $\hat{A}_{DD}$ are present and estimated demand, P_b and P are present and estimated price. The price elasticity of -0.231 is from Howe and Linaweaver (1967).

Estimates of water demands using Equation 3 are contained in Table 18. The table contains projections for 43 municipal systems. Two systems are unmetered--Heber and Milford--so price data are unavailable. When these systems are metered then a projected use can be computed. Five systems--Bountiful, Centerville, North Ogden, South Ogden, and Washington Terrace--have complete dual systems. Thus future water use can be projected using Equation 4.

Also contained in Table 18 is the ratio of projected to observed demand. Although there are some large differences, half of the computed demand estimates are within + 10 percent of the observed values (see Figure 7). The average of the ratio approximates

Table 18. Projected municipal demand in 43 Utah municipalities.

System	Outdoor (%)	Price ($/kg)	Projected Demand	Observed Demand	Projected/ Observed
American Fork*	70	0.236	237	227	1.04
Brigham City*	30	0.260	301	321	0.94
Cedar City	90	0.255	360	235	1.53
Clearfield	90	0.248	240	202	1.19
Clinton	70	0.170	284	134	2.13
Delta	65	0.169	425	400	1.06
Duchesne	60	0.308	306	265	1.15
Ephraim*	100	0.284	346	353	0.98
Fillmore*	35	0.228	331	436	0.76
Granger-Hunter	100	0.362	203	158	1.29
Green River*	20	0.505	202	224	0.90
Hyrum*	60	0.185	400	460	0.87
Kaysville*	40	0.227	222	184	1.21
Layton*	80	0.287	218	185	1.18
Lehi	70	0.253	232	166	1.40
Logan*	80	0.210	391	505	0.77
Manila	80	0.595	229	255	0.90
Midvale*	100	0.200	273	333	0.82
Moab	20	0.299	264	240	1.10
Monticello*	100	0.250	370	303	1.22
Morgan	30	0.144	410	452	0.91
Murray*	100	0.198	274	302	0.91
Ogden*	67	0.294	211	252	0.84
Orem*	100	0.245	245	287	0.85
Pleasant Grove	70	0.350	193	360	0.54
Price*	67	0.352	290	260	1.12
Provo*	90	0.228	250	317	0.79
Richfield*	60	0.250	342	362	0.94
Riverdale	60	0.249	225	199	1.13
Riverton	70	0.342	195	210	0.93
Roosevelt*	70	0.345	295	390	0.76
Roy*	30	0.215	219	233	0.94
Salt Lake*	100	0.175	291	287	1.01
Sandy	90	0.377	193	214	0.90
South Jordan	80	0.375	190	183	1.04
South Salt Lake	100	0.216	262	293	0.90
Spanish Fork*	45	0.203	241	220	1.10
St. George*	90	0.291	335	238	1.52
Sunset	100	0.304	219	181	1.21
Tooele	80	0.213	258	208	1.24
Vernal*	60	0.217	369	286	1.29
West Jordan	90	0.345	202	242	0.84
Woods Cross	60	0.226	237	232	1.02

*Used in multiple regression analysis.

unity; this suggests that there is no bias toward a lower or higher value. Possible reasons for high and low ratio values include: measurement error; leakage in distribution systems; the extremely low cost of water; and the fact there is no consideration of population density in Equations 3 or 4.

Municipal water will, in the future, be more expensive as energy and construction costs inflate more rapidly than consumer prices. A comparison of the U.S. Bureau of Reclamation composite construction bid index and the consumer price index over the last decade is contained in Table 19. This comparison indicates that construction costs have increased 11 percent faster than the general cost of living or about 1 percent per year faster than the inflation rate. Increasingly expensive water will result in increasing interest in water conservation.

As municipal water becomes more expensive, it will become increasingly cost effective for municipalities to reduce excessive leakage in conveyance systems. In recent years there has been an increased interest among municipal systems in eliminating water wastage. This trend will not only continue but become increasing significant to the extent that it will cause a decrease in per capita withdrawal rates.

Table 19. Comparison of the USBR construction index and the consumer price index (CPI).

Year	Index USBR	CPI	Ratio (USBR/CPI)
1967	1.0	1.0	1.0
1970	1.16	1.12	1.036
1975	1.87	1.69	1.106
1976	2.01	1.80	1.110

Source: (Hughes et al., 1978)

An important noneconomic determinant of water usage is population density (Romm, 1977; Kirkpatrick, 1976; Glenne, 1977). Per capita water usage decreases as population densities increase. For example, three people living in a house situated on a 1 acre (4000 m^2) use more water than three people in a house situated on a 1/2 acre (2000 m^2). In the house on either lot, each person will use a given amount indoors plus one-third the amount of water used outdoors. Since the amount of water used outdoors will be substantially smaller for the 1/2 acre lot (assuming similar landscaping), each person will effectively have a lower per capita withdrawal rate.

As discussed in the next chapter, lot size will on the average decrease in Utah as people, by necessity, look more toward condominium-type multiple dwelling units and mobile homes. Because of data limitations, this variable was not included in Equation 3. An increase in housing density, however, will cause a decrease in per capita withdrawal rates.

Return Flow Rate Projections

Studies of the Salt Lake City water system indicate that between 50 and 60 percent of the city's water is used for indoor purposes (Kirkpatrick, 1976). Most of this water would be expected to be returned to a waste treatment facility. Wollman and Bonem (1971) have estimated that in the Western United States 60 percent of water withdrawn becomes return flow. This fugure appears reasonable, after examining (if infiltration and interflow are ignored) Utah's return flow data. An exception, however, must be made for areas served by separate pressure irrigation systems. In these areas, most of the culinary water is returned (see South Davis in Figure 11). In fact as leakage is eliminated by both water and wastewater systems the average return flow rate should average around 100 gcd (the average withdrawal rate in Utah cities served by a separate pressure irrigation system).

Industrial Rate Projections

Steam-electric Power

Intake of fresh water per kilowatt-hour is determined by thermal efficiency and the rate of recirculation. As thermal efficiency rises, gross use (flow-through of water, including that which is recirculated) declines, hence intake for any degree of recirculation declines. Assuming that thermal efficiency will rise between now and the year 2000 and remain unchanged until 2020, it has been projected that rates of water use of 0.90, 0.85, 0.80, 0.80 and 0.80 gallons per kilowatt-hour for 1980, 1990, 2000, 2010, and 2020 respectively will occur (Wollman and Bonem, 1971). These withdrawal rates are for coal-fired plants (evaporative cooling); the thermal efficiency of nuclear plants is substantially lower.

Coal and uranium are often viewed as alternative sources of energy for future electric generation. The cooling required for a light-water reactor (LWR) is greater than that for a modern coal-fired plant producing the same electrical power. Consider, for example, an LWR with a thermal efficiency of 33 percent and fossil-fuel plant operating at 38 percent efficiency. For the same output this difference in efficiency results in the release of about 24 percent more waste heat by the LWR. Because a nuclear plant releases all but a small percentage (0-5 percent) of its waste heat directly into the atmosphere, the LWR requires more cooling water than does the fossil plant (Harte and El-Gasseir, 1978). As newer processes become available LWR efficiency will increase.

Table 21 offers several cooling alternatives and varying water uses that accompany the various technologies. Present and projected electrical generation facilities in Utah (except the Hale Plant) are of the evaporative cooling type.

Table 20. Values for computing manufacturing water use for a 10 year interval.

Industrial Group	Factor O	Factor R	Factor T	O / R·T
Food processing	1.34	1.14	1.05	1.12
Chemicals	1.48	1.28	1.11	1.04
Petroleum products	1.46	1.28	1.11	1.03
Primary metals	1.39	1.16	1.05	1.14

Source: Stewart and Metzger, 1970

Manufacturing Use Rates

The following formula was suggested by Stewart and Metzger (1970) for projecting industrial water usage:

$$I_t = F_t I_o \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where I_t is future industrial withdrawals at the time t, I_o is present industrial withdrawals, and F_t is computed as follows:

$$F_t = \frac{E \cdot O}{R \cdot T} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

where the four terms on the righthand side of the equation are defined as follows:

E = the ratio of future employment in manufacturing (E_t) to the present employment (E_o)

O = the ratio of future output per employee to present output

R = the ratio of future recirculation to present recirculation

T = the ratio of the present gross water requirements per unit of production (including recirculated water) to the future gross water requirement.

The terms in Equations 5 and 6 can be rewritten as follows:

$$E = E_t / E_o$$

$$I_o = E_o \cdot W_o$$

$$I_t = E_t \cdot W_t$$

where W_o and W_t are W_o are the present/ and future withdrawal rate per employee. Combining Equations 5 and 6

$$W_t = \frac{O}{R \cdot T} \cdot W_o \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

The values of O, R, and T proposed by Stewart and Metzger are for a 50 year period. Their values are converted to a ten year interval in Table 17. Adjusting Equation 7 to handle multiple intervals, the relationship becomes:

$$W_t = \left(\frac{O}{R \cdot T}\right)^t \cdot W_o \quad . \quad . \quad . \quad . \quad . \quad (8)$$

where t equals 1 for the year 1990, 2 for the year 2000, etc.

Future withdrawal rates can be projected using Equation 8 and the values of (O/R·T) from Table 20 and the values for W_o from Figure 14. For example, the projected water withdrawal rate for the food processing industry for 2000 equals

$$W_2 = (1.12)^2 \cdot 900 = 1129 \text{ ged}$$

Projections using Equation 8 are obtained using a requirements approach and ignoring economic considerations For most industries the cost of water supply is generally less than 2 percent of production costs and thus industrial water demands are generally quite inelastic.

When the price of water gets high enough to make it worthwhile, industry will recirculate greater quantities of water and/or substitute non-water-using procedures in the production process. A steel mill in California, for instance, reduced its water consumption drastically by recirculation. Petroleum refining industry has been shifting toward air cooling. The responsiveness of various industries to changes in the price of intake water and waste discharge were reported by the National Commission on Water Quality (1975). A 10 percent increase in the price of water can result in a 7 percent decrease in water intake by the chemical industry, a 14 percent decrease in the petroleum industry and a 16 percent decrease in the steel industry.

Mining and Energy

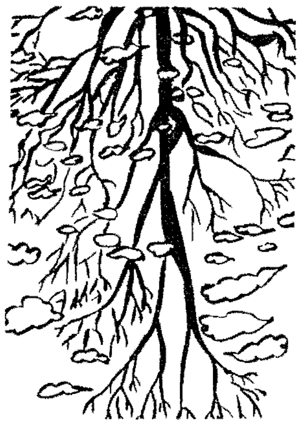
Water requirements for mining have been compiled by the Aerospace Corporation (1978). Their estimates are contained in Table 18. Mining requirements are distributed between actual extraction and those forms of processing that do not fall under the heading of "manufacturing."

An important future user of water in Utah is the energy industries. The proposed developments include additional refineries, oil shale projects, coal gasification and liquefaction, geothermal, and coal slurry pipelines. Each energy conversion and transportation process requires a consumptive use rate as shown in Table 18. Oil refineries have already been discussed in the manufacturing section. Contained in Table 16 and Figure 14 are withdrawal rates (ged) for Utah's refineries. Table 21's consumptive use units are gallons per barrel.

Table 21. Water consumptive use rates for energy conversion and transportation processes.

Energy System	Water Needs
Steam-electric nuclear	
Evaporative cooling	17,000 acre-ft/yr/1000 m W unit
Pond	12,000 acre-ft/yr/1000 m W unit
River	4,000 acre-ft/yr/1000 m W unit
Wet-dry radiator	2,000 acre-ft/yr/1000 m W unit
Steam-electric coal	
Evaporative cooling	15,000 acre-ft/yr/1000 m W unit
Pond	10,000 acre-ft/yr/1000 m W unit
River	3,600 acre-ft/yr/1000 m W unit
Dry radiator	2,000 acre-ft/yr/1000 m W unit
Geothermal	48,000 acre-ft/yr/1000 m W unit
Refineries	39 gal/bbl crude
Oil Shale	7,600 to 18,900 acre-ft/yr/100,000 barrels per day plant
Coal gasification	10,000 to 45,000 acre-ft/yr/250 million scf per day plant
Coal liquefaction	20,000 to 130,000 acre-ft/yr/100,000 barrels per day plant
Coal slurry pipeline	20,000 acre-ft/25 million tons coal (1 cfs will transport about 1,000,000 tons per year)
Coal extraction	$\geq$ 20.9 gallons/ton
Oil extraction	$\geq$ 171 gallons/barrel
Natural gas extraction	$\geq$ 2.9 mg/bcf
Uranium extraction	$\geq$ 0.184 mg/ton

Source: The Aerospace Corporation, 1978
Western States Water Council, 1974



CHAPTER V

UTAH HISTORIC AND PROJECTED POPULATION

but do you recall
that still pool--it also fed its stream--
that we were led, night by night,
to return to, as though to clarify ourselves
against its depth, its silence?

Tomlinson

Historic Population

Utah's growth since 1960 has been substantial. Its population in this period increased approximately 26 percent. Growth along the Wasatch Front--the western face of the Wasatch Mountains between Brigham City and Nephi has been phenomenal. Seventy-seven percent of Utah's people live along the Wasatch Front. The population growth in this area increased from 697,000 in 1960 to 967,000 in 1975, a 39 percent increase. In Salt Lake County, the population increased from 383,000 to more than half a million; new dwelling units jumped from 3,000 to over 9,000 a year; and the annual valuation of authorized construction rose from $50 million to $200 million.

Substantial population growth off the Wasatch Front, however, is a recent phenomenon. The percentage increase in population between 1970 and 1975 is high in each of Utah's seven multicounty districts (see Table 19). Although starting with a smaller base, the percentage increases in population of the multicounty districts off the Wasatch Front are currently keeping pace with those of the Wasatch Front.

Future Population Projections

Utah's population surge is expected to continue. U.S. News and World Report has projected Utah's growth between 1970 and 1980 will be the seventh fastest in the nation. The Rocky Mountain states from Arizona to Montana comprise the fastest growing region in the nation.

Ten-year population estimates beginning in 1980 and extending to the year 2020 were prepared for Utah's multicounty districts, counties, and fifty cities. Base population levels from the 1970 Census of Population (U.S. Department of Commerce, 1973) were also included with the projections of these subdivisions to provide a basis for establishing a comparison with known population levels.

There is no consensus choice among population projection methods (models) which would be most appropriate for the purposes of this study. However, it was the judgment of the study team that estimates should rely on a reproducible method in which alternative sets of assumptions concerning Utah's economy could be evaluated consistently in all regions of the state and in other applications which extend beyond the current study. During the past ten years a considerable effort has been expended on a variety of demographic models by researchers in the state; however, it appears that only the Utah Process Model (UPED), as developed by Utah's State Planning Office, comes close to meeting these requirements at this writing. This model was developed as a part of a joint research effort undertaken by the Four-Corners Regional Commission, the Office of Regional Economic Coordination in the Department of Commerce, and the Utah State Planning Coordinator. A more detailed discussion of the merits of UPED is contained in the Phase I Report on Methodology and in the original report on the Utah Process from the State Planning Coordinator's Office (Office of the State Planning Coordinator, 1972).

Unfortunately, the UPED projections have been limited to the Multicounty Planning Districts (MCD) and currently do not include estimates for Utah's counties or cities. Additionally, projections currently available from earlier runs of the model do not extend beyond 1990. And, in some cases, closer scrutiny of UPED projections at the local level have revealed some unavoidable de-

Table 22. Historic population estimates for multicounty districts (in parentheses is the percentage increase or decrease in population over the previously reported year): 1960-1975.

Multicounty District	Year 1960	1965	1970	1975
Bear River	62,534	69,600 (+11%)	72,075 (+4%)	80,900 (+12%)
Wasatch Front	579,244	667,000 (+15%)	709,441 (+10%)	788,100 (+11%)
Mountainlands	117,972	130,000 (+10%)	149,518 (+15%)	179,300 (+20%)
Central	37,245	35,200 (-5%)	35,288 (+1%)	42,600 (+21%)
Southwestern	31,641	31,400 (-1%)	35,244 (+12%)	42,700 (+21%)
Uintah Basin	19,925	20,000 (+0%)	20,649 (+3%)	30,100 (+31%)
Southeastern	42,066	37,500 (-11%)	37,078 (-1%)	43,300 (+17%)
Statewide	890,627	991,000 (+11%)	1,059,273 (+7%)	1,207,000 (+14%)

viations of actual conditions from projected assumptions concerning the levels and location of economic expansion. The latter situation is especially true for sparsely settled areas where substantial energy-related economic development is occurring. Baseline estimates shown in Table 23 were based on an extrapolation of the most recent UPED model projections 1975-1990 for Utah's MCDs under the Alternative Future Zero.[1]

The total population estimate for the state is shown to increase from 1,259,273 in 1970 to more than 2,670,000 by 2020, an increase of about 2.5 over the 1970 base level. Among MCDs, the largest absolute increase in population for this period is found in the Wasatch Front with an increase of more than 890,000 persons. This increase is greater than total MCD populations for any other MCD in 2020. It is interesting to note, however, that five MCDs show greater proportional expansion in population than the Wasatch Front MCD. The largest proportional increase over 1970 population is noted in the Five-County area at 4.86 followed by Mountain Lands Association of Governments MCD with 3.26. Salt Lake County remains the most populus county in the state at 1,034,410 in the year 2020, which is 2.29 times larger than Utah County, which is the nearest to it in population size at 451,140 in 2020. The five largest cities, Salt Lake City, Ogden, Provo, Orem, and Bountiful remain the same in 2020, but Provo is shown to replace Ogden as the second largest city in the state. The degree of error associated could be expected to increase moving from MCDs, to counties, and cities population can be expected to be most volatile because of their potential for annexing adjacent areas and their relatively more mobile populations.

[1]Alternative Future Zero is a baseline future which is specified as the set of basic employment events viewed as most likely to occur within the projection period (1975-1990). Detailed discussions of events included in this baseline are contained in an earlier publication of the State Planning Office (Office of the State Planning Coordinator, 1974).

Future Housing Patterns

To accommodate Utah's future population growth, new housing must be provided. By necessity, there will be a continuing trend toward multiple family dwellings and away from individual abodes with large landscaped areas. In urban areas along the Wasatch Front an increasingly large percentage of demand will be represented by apartment buildings and condominiums. The reasons for this include: 1) the speculative value of land is increasing at an all-time high rate (and expected to continue to do so), and 2) construction costs are reaching all-time highs and are increasing at a faster rate than ever before (and will probably continue to do so). As a result builders will continue to turn to apartment and condominium construction which has a higher return per acre than single family housing (Salt Lake County 208 Water Quality Project, 1977).

In rural areas which will be impacted by energy development, there should also be a trend away from large lot sizes. The number of multiple family dwellings may not be significant in the future but certainly the number of mobile homes will be. Mobile homes typically have a smaller lot size than more permanent forms of individual housing.

These future housing patterns in the rural and urban regions should cause a significant increase in the population density of the inhabited portions of the state. In the future, Utahns will be living closer together.

Table 23. Baseline population projections[a] for Utah multicounty districts, counties, and selected cities for 1980, 1990, 2000, 2010, and 2020.

Areal Unit	1960	1970	1980	1990	2000	2010	2020
Bear River Association of Governments:	62,534	72,075	98,630	120,340	145,300	169,400	193,500
Box Elder County	25,061	28,129	37,480	45,730	55,210	64,370	73,530
Brigham City	11,728	14,007	21,090	25,730	31,070	36,220	41,380
Cache County	35,788	42,331	59,180	72,200	87,200	101,640	116,100
Hyrum	1,728	2,340	4,320	5,270	6,370	7,420	8,480
Logan	16,832	22,333	30,010	36,610	44,220	51,540	58,870
Rich County	1,685	1,615	1,970	2,410	2,910	3,390	3,870
Wasatch Front Regional Council:	579,244	709,441	907,830	1,062,640	1,246,500	1,423,100	1,599,700
Davis County	64,760	99,028	135,470	158,580	186,000	212,350	238,720
Bountiful	17,093	27,853	42,560	49,810	58,430	66,710	74,990
Layton	9,027	13,603	20,430	23,910	28,050	32,020	35,990
Clearfield	8,833	13,316	18,160	21,250	24,930	28,460	31,990
Kaysville	3,608	6,192	9,080	10,620	12,460	14,230	15,990
Sunset	4,235	6,304	7,940	9,300	10,910	12,450	14,000
Centerville	2,361	3,268	7,380	8,630	10,130	11,560	13,000
Clinton	1,025	1,768	5,670	6,640	7,790	8,890	10,000
Woods Cross	1,098	3,125	4,650	5,450	6,390	7,290	8,200
Morgan County	2,837	3,983	5,370	6,300	7,370	8,430	9,470
Morgan	1,299	1,586	2,020	2,370	2,780	3,180	3,570
Salt Lake County	383,035	458,607	587,030	687,120	806,120	920,170	1,034,410
Salt Lake City	189,454	175,885	204,260	239,100	208,460	320,200	359,930
Granger-Hunter	15,745	42,222	70,780	83,142	97,541	111,341	125,164
Murray	16,806	21,206	31,210	36,530	42,850	48,918	54,990
West Jordan	3,009	4,221	34,040	39,850	46,743	53,370	59,990
Sandy	3,322	6,438	36,310	42,510	49,860	56,920	63,990
South Salt Lake	9,520	7,810	9,650	11,290	13,240	15,120	17,000
Midvale	5,802	7,840	10,550	12,350	14,490	16,540	18,600
South Jordan	1,354	2,942	5,330	6,240	7,320	8,360	9,400
Riverton	1,993	2,820	6,240	7,310	8,570	9,780	11,000
Weber County	110,744	126,278	153,530	179,700	210,000	240,670	270,540
Ogden	70,197	69,478	79,450	92,980	109,070	124,520	139,970
Roy	9,239	14,356	22,700	26,570	31,160	35,580	39,990
South Ogden	7,405	9,991	15,300	17,900	21,000	24,000	27,000
Washington Terrace	6,441	7,241	10,700	12,500	14,600	16,700	18,800
North Ogden	2,621	5,257	9,100	10,600	12,500	14,200	15,900
Riverdale	1,848	3,704	6,100	7,300	8,600	9,800	11,000
Tooele County	17,868	21,545	26,430	30,940	36,300	41,480	34,100
Tooele	9,133	12,539	19,400	22,700	26,600	30,400	34,100

Table 23 Continued.

Areal Unit	1960	1970	1980	1990	2000	2010	2020
Mountain Land Association of Governments:	117,972	149,518	218,430	284,630	352,600	420,200	487,800
Summit County	5,673	5,879	7,760	11,010	12,430	14,910	17,260
Utah County	106,991	137,776	201,980	262,330	326,150	388,580	451,140
Provo	36,047	53,131	75,600	89,500	122,000	145,400	168,800
Orem	18,394	25,729	49,600	58,700	80,100	95,400	110,800
American Fork	6,373	7,713	13,200	15,700	21,400	25,400	29,500
Spanish Fork	6,472	7,284	10,400	12,300	16,800	20,000	23,200
Pleasant Grove	4,772	5,327	9,700	11,500	15,600	18,600	21,600
Lehi	4,377	4,659	7,100	8,400	11,400	13,600	15,800
Wasatch County	5,308	5,863	8,690	11,290	14,020	16,710	19,400
Heber City	2,936	3,245	4,700	5,600	7,700	9,100	10,600
Six-County Commissioners Organization:	37,245	35,288	43,429	48,370	55,400	62,000	68,500
Juab County	4,597	4,574	5,410	5,990	6,890	7,690	8,490
Midvale	5,802	7,840	10,550	12,350	14,490	16,540	18,600
Millard County	7,866	6,988	8,310	9,280	10,680	11,880	13,180
Delta	1,576	1,610	1,900	2,200	2,500	2,800	3,100
Filmore	1,602	1,411	2,000	2,200	2,500	2,800	3,100
Piute County	1,436	1,164	1,300	1,500	1,700	1,900	2,100
Sanpete County	11,053	10,976	13,220	14,680	16,870	18,870	20,870
Ephraim	1,801	2,127	2,350	2,600	3,000	3,300	3,700
Sevier County	10,565	10,103	13,450	14,970	17,060	19,160	21,160
Richfield	4,412	4,471	5,500	6,100	7,000	7,850	8,700
Wayne County	1,728	1,483	1,730	1,950	2,200	2,500	2,700
Five-County Association of Governments:	31,641	35,224	67,230	88,950	117,500	144,400	171,280
Beaver County	4,331	3,800	6,400	8,490	11,180	13,740	17,130
Milford	1,471	1,304	1,750	2,350	3,100	3,800	4,800
Garfield County	3,500	3,157	5,360	7,040	9,280	11,500	13,560
Iron County	10,795	12,177	22,570	29,850	39,470	48,470	57,150
Cedar City	7,543	8,946	16,650	22,000	29,100	35,800	42,400
Kane County	2,667	2,421	5,470	7,260	9,610	11,780	13,890
Washington County	10,271	13,669	27,430	36,310	47,960	58,910	69,550
St. George	5,130	7,097	17,050	22,550	29,800	36,600	43,400

Table 23. Continued.

Areal Unit	1960	1970	1980	1990	2000	2010	2020
Uintah Basin Association of Governments:	19,925	20,649	37,130	34,550	44,700	51,600	58,600
Daggett County	1,164	666	1,030	970	1,210	1,400	1,550
Manila	329	266	370	350	470	500	550
Duchesne County	7,179	7,299	14,280	13,260	17,170	19,840	22,530
Roosevelt	1,812	2,005	4,700	4,350	5,600	6,500	7,500
Duchesne	770	1,094	2,300	2,100	2,750	3,200	3,700
Uintah County	11,582	12,682	21,820	20,320	26,320	30,360	34,520
Vernal	3,655	3,908	6,950	6,450	8,350	9,650	11,150
Southeastern Association of Governments:	42,066	37,078	51,240	61,280	74,000	86,200	98,300
Carbon County	21,135	15,647	21,520	26,170	31,080	36,200	41,280
Price City	6,802	6,218	8,700	10,400	12,550	14,650	16,700
Emery County	5,546	5,137	9,220	10,200	13,320	15,520	17,690
Green River	1,075	1,033	1,200	1,300	1,750	2,050	2,300
Grand County	6,345	6,688	7,690	9,340	11,100	12,930	14,750
Moab	4,682	4,7903	7,150	8,50	10,300	12,000	13,700
San Juan County	9,040	9,606	12,810	15,570	18,500	21,550	24,580
Monticello	1,845	1,431	2,050	2,450	3,000	3,450	3,950

[a]Projections beyond 1990 for MCD are based on trend extrapolation using the 1970 Census of Population estimates and Alternative Future Zero (Office of the State Planning Coordinator, 1975) as the data base. Projected county and city populations were estimated by disaggregating the projected MCD populations consistent with their 1976 proportions. These proportions were taken from Utah Facts (Utah Industrial Development Information System, 1977), and special census reports.

[b]Projections for Granger-Hunter past 1980 are made by multiplying 0.121 (the 1980 population projection/the 1980 county population projection) times the county population.

CHAPTER VI

WRITTEN ON WATER

at a confluence of two ways
refusing to be one without resistance,
shoulderings of foam collide, unskein
the moving calligraphy before
it joins again, climbing forward
across obstructions

Tomlinson

General Summary

1. Utah in 1975 withdrew 115,398 (3-year average) mg of water to meet municipal needs. (This figure does not include water provided by irrigation companies for municipal customers.)

2. Approximately 60 percent of Utah's municipal water in 1975 (3-year average) was supplied from wells and springs. The remainder was obtained from surface sources.

3. Per capita water withdrawal in Utah has increased from 240 gcd in 1961 (3-year average) to 262 gcd in 1975 (3-year average). This translates to a 1.5 gallon increase per year.

4. There is wide diversity in per capita withdrawal rates among Utah's municipal systems. Municipalities with a high per capita rate include Logan, Hyrum, Milford, Delta, and Morgan. Systems with a low withdrawal rate include Bountiful, Centerville, North Ogden, South Ogden, and Washington Terrace. The latter systems are all served by separate irrigation systems.

5. A good estimate of the municipal withdrawal rate to meet indoor needs is 100 gcd.

6. Municipal return flow rates for Utah's major waste treatment systems are very diverse. The principal reason for the diversity is infiltration and interflow.

7. Water usage among manufacturing firms is concentrated in the food processing, inorganic chemicals, primary metals, hydraulic cement and oil refining sectors.

8. For short-term planning, 262 gcd is a good estimation of Utah's per capita water needs.

9. For long-term planning, 262 gcd is excessive. Per capita water usage in the future will decline for three reasons: 1) water will become increasingly expensive thus encouraging water conservation; 2) economic realities will encourage municipal systems to control losses caused by leakage; and 3) as Utahn's move closer together, they will require less water on a per capita basis for outdoor usage.

10. Utah's exhaustible resources (i.e. coal, oil shale, phosphate, etc.) will be increasingly exploited. Coal and/or oil shale conversion processes will strongly compete for Utah's available water.

11. Utah's population will continue to escalate. By 2020 Utah could have a population exceeding 2.5 million. The vast majority of people will continue to reside along the Wasatch Front.

Problems Associated with Projections

Since Chapters IV and V deal with the future, it is important, in parting, to mention the limitations of projections. As a general rule, the farther one looks into the future, the greater the uncertainty. The greater the uncertainty; the more questionable are the forecasts. It should be remembered that the year 2020 is 41 years in the future. A lot has occurred in the last 41 years and a great deal more will occur in the next.

Future population levels and water use will be directly affected by the choices future generations will make in regard to national, regional, and state objectives and policies. The choices they will make are currently unknown. However, even if it were possible to forecast their choices accurately, all of the variabilities in the forecasts would not be accounted for. The remainder of the elements of uncertainty which are inherent in a forecast would still remain.

REFERENCES

Aerospace Corporation. 1978. Water related constraints on energy production. Aerospace Report No. ATR-78 (9409)-1, Germantown, Maryland. June.

Bureau of Economic and Business Research. 1963. Use of water for municipal and industrial purposes, Utah Counties, 1960-61. Salt Lake City: University of Utah.

Bureau of Economic and Business Research. 1966. Municipal and industrial water requirements, Utah Counties, 1960-2020, A summary. Salt Lake City: University of Utah.

Garder, B. Delworth, and Seth Schick. 1964. Factors affecting consumption of urban household water in Northern Utah. Utah State University Experiment Station Bulletin 449.

Glenne, Bard. 1977. Water supply and use, status and outlook in Salt Lake County. Salt Lake City: Salt Lake County 208 Water Quality Project.

Hansen, Roger, Herbert H. Fullerton, A. Bruce Bishop, Trevor Hughes, and David Bowles. 1979. Historic municipal and industrial water usage in Utah. Utah Water Research Laboratory, Logan, Utah.

Harte, John, and Mohamed El-Gasseir. 1978. Energy and water. Science. 199:623-634.

Howe, Charles W. and F. P. Linaweaver. 1967. The impact of price on residential water demand and its relation to system design and price structure. Water Resources Research. 3:13-32.

Hughes, Trevor, and Robert L. Gross. Instantaneous domestic water demand in semiarid regions. In publication.

Hughes, Trevor, L. Douglas James, Frank Haws, and C. Earl Israelsen. 1978. Feasibility of accelerating construction of the Central Utah Project. Logan, Utah: Utah Water Research Laboratory.

Kirkpatrick, William Roger. 1976. Municipal-residential water use study, Salt Lake County, Utah. Salt Lake City: Utah Division of Water Resources.

Koelzer, Victor A. 1976. New growth centers - A role for the Bureau of Reclamation. Journal of the Water Resources Planning and Management Division, ASCE. 102:311-326.

May, Dean. 1976. A latter-day ode to irrigation. Dialogue 10(1):77.

National Commission of Water Quality. 1975. Draft Report. November.

National Water Commission. 1973. Water policies for the future. Washington, D.C.: U.S. Printing Office, June.

Nemerow, Nelson. 1971. Liquid waste of industry. Reading, Mass.: Addison-Wesley Publishing Company.

Office of the State Planning Coordinator. 1972. Report on the development of the Utah process: A procedure for planning coordination through forecasting and evaluating alternative state futures. Salt Lake City, Utah.

Office of the State Planning Coordinator. 1974. Report on economic and demographic projections of the Utah process economic and demographic impact (UPED) model for alternative future zero for the State of Utah and Its Multi-County Districts. Salt Lake City, Utah.

Romm, Jerry. 1977. Water supply, land use, and urban growth. Journal of Water Resources Planning and Management Division, ASCE. 103:271-284.

Stegner, Wallace, and Page Stegner. 1978. Rocky Mountain Country. Atlantic Monthly. 241:45-91.

Stewart, Robert H., and Ivan Metzger. 1970. Industrial water forecasts. Journal of the AWWA. 62:155-157.

Templeton, Linke and Alsup and Engineering-Science, Inc. 1975. Utah Lake-Jordan River hydrologic basins water quality management study. Salt Lake City: Utah Division of Water Quality.

Tomlinson, Charles. 1972. Written on water. Oxford University Press, London.

U. S. Department of Commerce. 1973a. U.S. Bureau of the Census, Census of Population, 1960. General Social and Economic Characteristics. U.S. Government Printing Office, Washington, D.C.

U. S. Department of Commerce. 1973b. U.S. Bureau of the Census, Census of Population, 1970. General Social and Economic Characteristics. U.S. Government Printing Office, Washington, D.C.

Utah Population Work Committee. 1972. 1972 Population Estimates, Utah Economic and Business Review 32(1).

Utah Population Work Committee. 1976. 1976 Population Estimates, Utah Economic and Business Review 36(11).

Wang, Kai. 1701. Mustard seed manual of painting. In Mai-Mai Sze. 1959. The way of Chinese Painting. Vintage Books, New York.

Wasatch Front Regional Council. 1977. Surveillance of land use and socio-economic characteristics 1970, 1975, 1976 and 1995.

Western States Water Council. 1974. Western States water requirements for energy development to 1990. November.

White, Irvin L., et al. 1978. A progress report of a technology assessment of wester energy resource development. Norman, Oklahoma: Science and Public Policy Program.

Wollman, Nathaniel, and Gilbert Bonem. 1971. The outlook for water. Baltimore: The Johns Hopkins Press.

APPENDIX A

LIST OF SUPPLEMENTARY SYSTEMS

Table A-1. Descriptive information on supplementary municipal systems.

Name	County	District Water	District Sewer	Population	Number Connections	Connections (percent metered)	Master Meters
Alpine	Utah	–	–	1,524	369	100	yes
Amalga	Cache	–	–	207	80	100	yes
Ballard	Uintah	Ute Tribe	–	680	194	–	yes
Bona Vista	Weber	–	C. Weber	8,880	2,200	100	yes
Chesterfield	Salt Lake	SLWCD	S. Salt Lake	1,705	512	99	yes
Corinne	Box Elder	–	–	486	176	97	yes
Dutch John	Daggett	–	–	221	95	2	–
East Carbon	Carbon	–	–	2,168	737	0	yes
Elberta	Utah	–	–	70	30	100	yes
Enterprise	Washington	–	–	1,216	265	99	yes
Fayette	Sanpete	–	–	85	53	100	no
Ferron	Emery	–	–	756	475	95	yes
Helper	Carbon	–	PRWID[1]	2,198	900	100	yes
Hiawatha	Carbon	–	–	170	78	0	yes
Kearns	Salt Lake	SLWCD	GHPWUD[2]	15,821	3,887	100	yes
LaPoint	Uinta	Ute Tribe	–	336	96	0	yes
Lewiston	Cache	–	–	1,332	418	0	no
Lindon	Utah	–	–	2,083	494	98	no
Magna	Salt Lake	SLWCD	–	6,735	2,890	95	yes
Manila	Utah	–	–	700	250	100	yes
Mapleton	Utah	–	–	2,727	635	95	yes
New Harmony	Washington	–	–	100	52	100	no
North Emery	Emery	–	–	1,657	483	100	yes
North Logan	Cache	–	–	1,497	461	100	yes
North Salt Lake	Davis	WBWCD	S. Davis	3,092	665	90	Partial
Oak City	Millard	–		302	125	86	yes
Orangeville	Emery	–	–	665	227	100	yes
Ordervi1le	Kane	–	–	472	146	99	yes
Panguitch	Garfieldl	–	–	1,314	514	100	yes
Parowan	Iron	–	–	1,764	611	100	yes
Providence	Cache	–	–	2,293	602	100	yes
Alpine	Utah	–	–	1,524	369	100	yes
River Heights	Cache	–	Logan	954	314	97	yes
Salem	Utah	–	–	1,480	450	99	no
SLWCD	Salt Lake	–	–	18,600	6,200	100	yes
Spring Creek	Salt Lake		SLC#1[3]	1,778	508	–	–
Springdale	Washington	–	–	249	116	100	yes
Sunnyside	Carbon	–	–	519	208	0	yes
Thompson WID	Grand	–	–	176	34	100	yes
Washington	Washington	–	–	2,200	496	100	Partial
White City	Salt Lake	SLCWCD	SSID[d]	10,000	2,111	100	yes
Willard	Box Elder	–	–	1,117	339	99	no

[a]Price River Water Improvement District
[b]Granger-Hunter Public Wastewater Utility District
[c]Salt Lake Suburban #1
[d]Sandy Suburban Improvement District

APPENDIX B

TIME SERIES PLOTS OF PER CAPITA WITHDRAWAL RATES FOR MUNICIPAL SYSTEMS

This appendix includes 10 figures containing time series plots of per capita withdrawal rates for 48 of the 50 municipal systems discussed in this report. (Duchesne's and Tooele's time series were not long enough to warrant plotting.) Each time series containing more than five records was regressed against time. The general linear regression equation is as follows:

$$A_{DD} = m \cdot (\text{year-baseyear}) + b$$

where A_{DD} is average daily demand (gcd), b and m are the intercept and slope, "baseyear" is the year prior to the first year of the time-series and "time" is the year corresponding to the variable A_{DD}.

Table B-1 contains an index for the time series plots. It also contains the computed coefficients for the general linear regression equation for each municipal system. The correlation coefficient (R^2) is also included in the table.

Table B-1. Index of Appendix B figures and results of linear regression analysis.

System	Figure	Coefficients b	m	baseyear	R^2
American Fork	B-7	139.35	4.12	1959	.64
Bountiful	B-4	103.99	.29	1959	.03
Brigham City	B-1	426.53	-12.00	1966	.34
Cedar City	B-10	197.36	4.32	1959	.55
Centerville	B-4	125.80	-2.55	1964	.24
Clearfield	B-3	161.78	.40	1959	.01
Clinton	B-3	100.20	3.13	1959	.45
Delta City	B-8	380.76	7.68	1959	.12
Duchesne[a]	-	-	-	-	-
Ephraim	B-8	272.07	17.74	1970	.28
Fillmore	B-8	372.62	2.40	1959	.03
Granger-Hunter	B-5	163.46	-.46	1968	.02
Green River	B-10	77.23	13.68	1959	.70
Heber City	B-9	340.96	3.55	1959	.02
Hyrum	B-1	535.92	-2.69	1962	.04
Kaysville	B-4	224.43	-7.54	1969	.61
Layton	B-3	171.12	1.55	1959	.14
Lehi	B-7	327.48	-7.79	1959	.37
Logan	B-1	401.60	6.42	1959	.61
Manila	B-9	367.13	-24.37	1970	.58
Midvale	B-6	218.50	9.15	1963	.83
Midford	B-8	385.14	18.07	1969	.78
Moab	B-10	131.76	7.45	1959	.86
Monticello	B-10	365.36	-7.82	1965	.23
Morgan	B-1	289.81	7.90	1959	.65
Murray	B-5	156.90	7.32	1959	.66
N. Ogden	B-2	223.52	-9.51	1961	.81
Ogden	B-2	238.68	1.69	1959	.26
Orem	B-7	231.02	4.64	1959	.56
Pleasant Grove	B-7	80.67	15.58	1959	.78
Price	B-9	216.40	3.79	1963	.31
Provo	B-7	314.13	-2.14	1959	.23
Richfield	B-8	292.10	5.09	1959	.55
Riverdale	B-2	199.03	-.26	1962	.00
Riverton[b]	B-6	-	-	-	-
Roosevelt	B-9	388.45	4.54	1959	.11
Roy	B-3	178.35	3.90	1959	.43
Salt Lake	B-5	238.15	2.97	1959	.34
Sandy[b]	B-6	-	-	-	-
S. Jordan	B-6	89.71	5.67	1959	.84
S. Ogden	B-2	75.30	1.95	1959	.67
S. Salt Lake	B-5	223.80	6.56	1964	.86
Spanish Fork	B-7	267.35	-2.84	1959	.18
St. George	B-10	210.71	3.25	1969	.18
Sunset	B-3	154.93	2.07	1959	.42
Tooele[a]	-	-	-	-	-
Vernal	B-9	366.15	-4.36	1963	.10
Washington Terrace	B-2	80.26	1.21	1959	.38
West Jordan	B-6	227.55	3.67	1969	.05
Woods Cross	B-4	154.96	4.00	1961	.31

[a]Series too short for plot and linear regression
[b]Series too short for linear regression

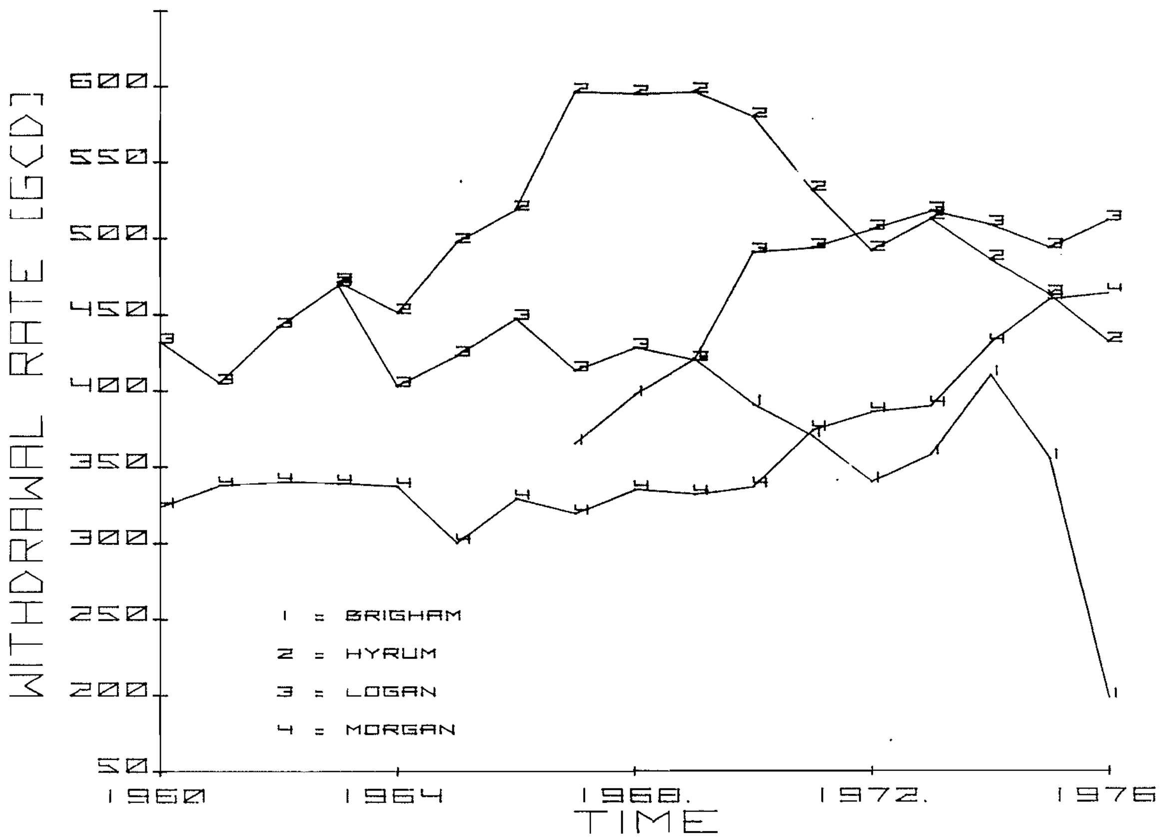


Figure B-1.

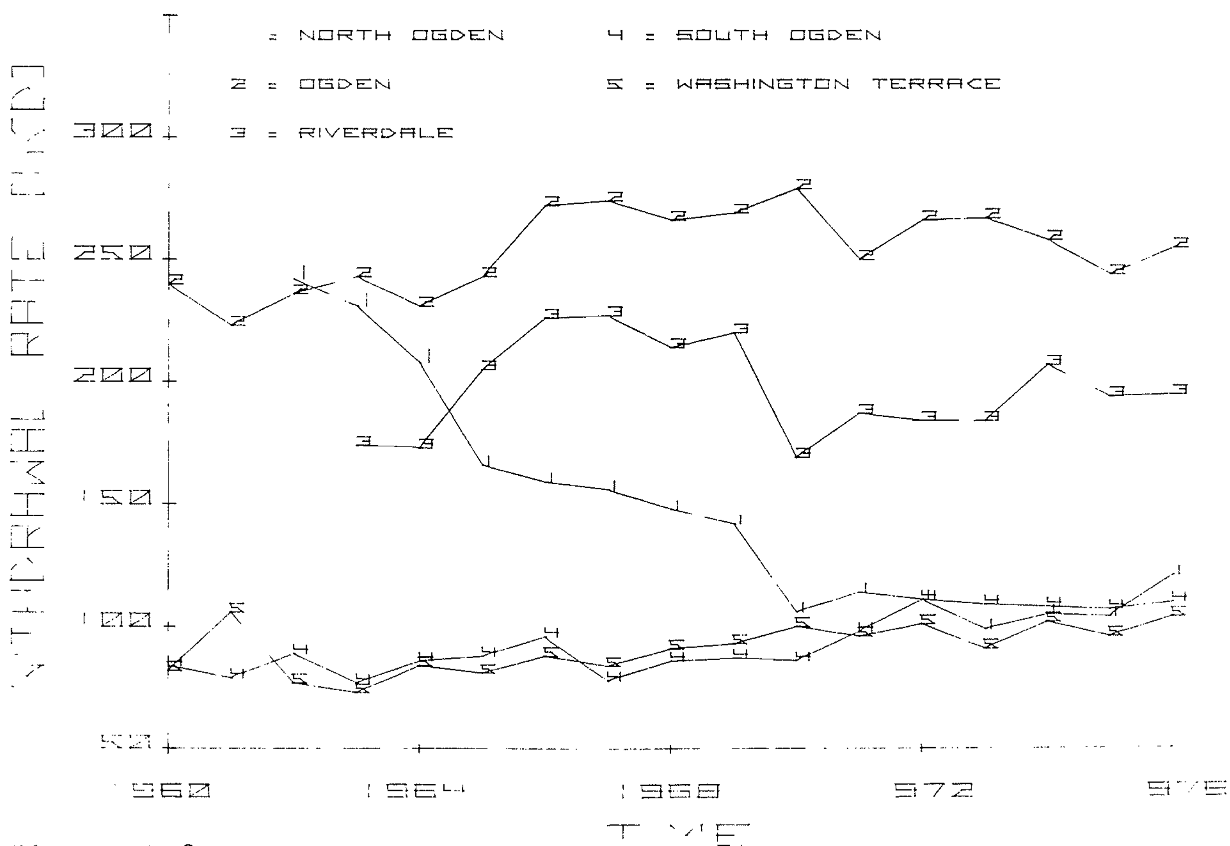


Figure B-2.

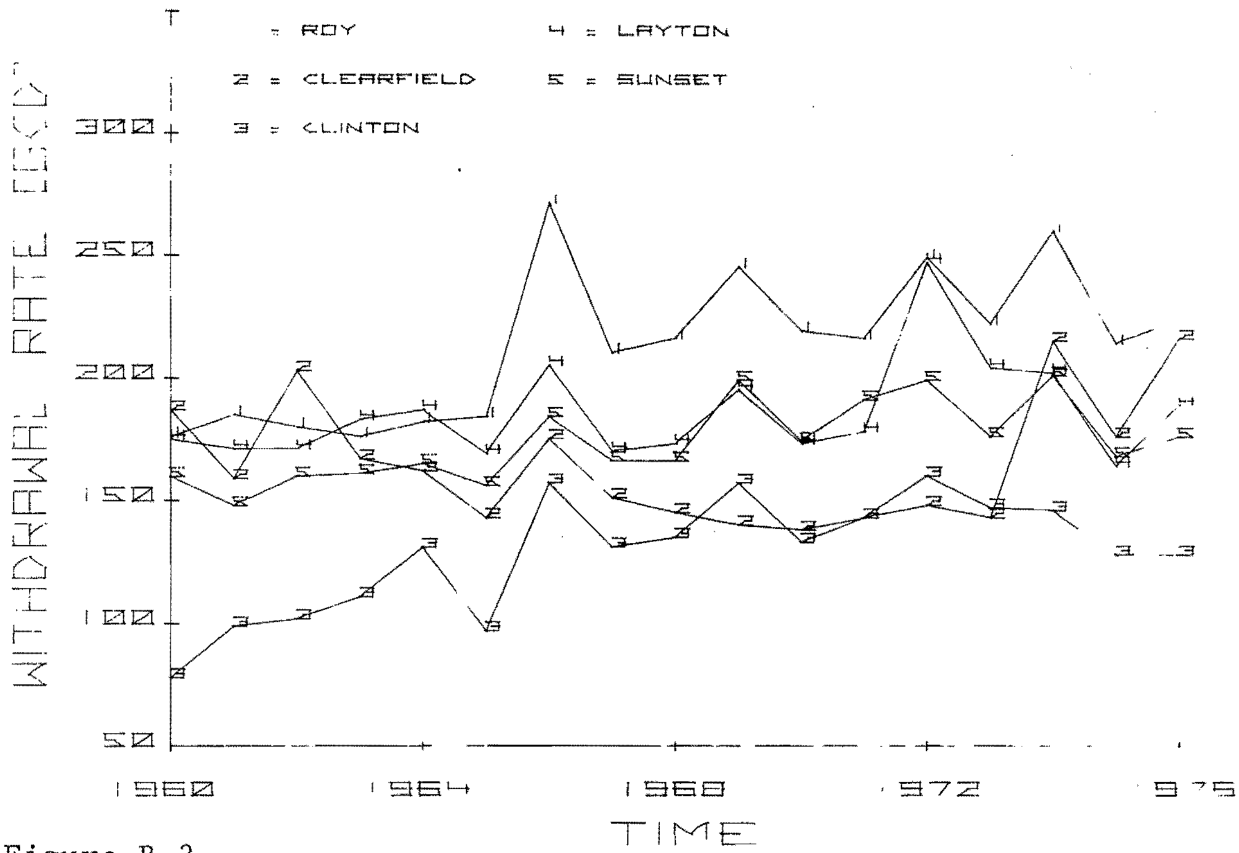


Figure B-3.

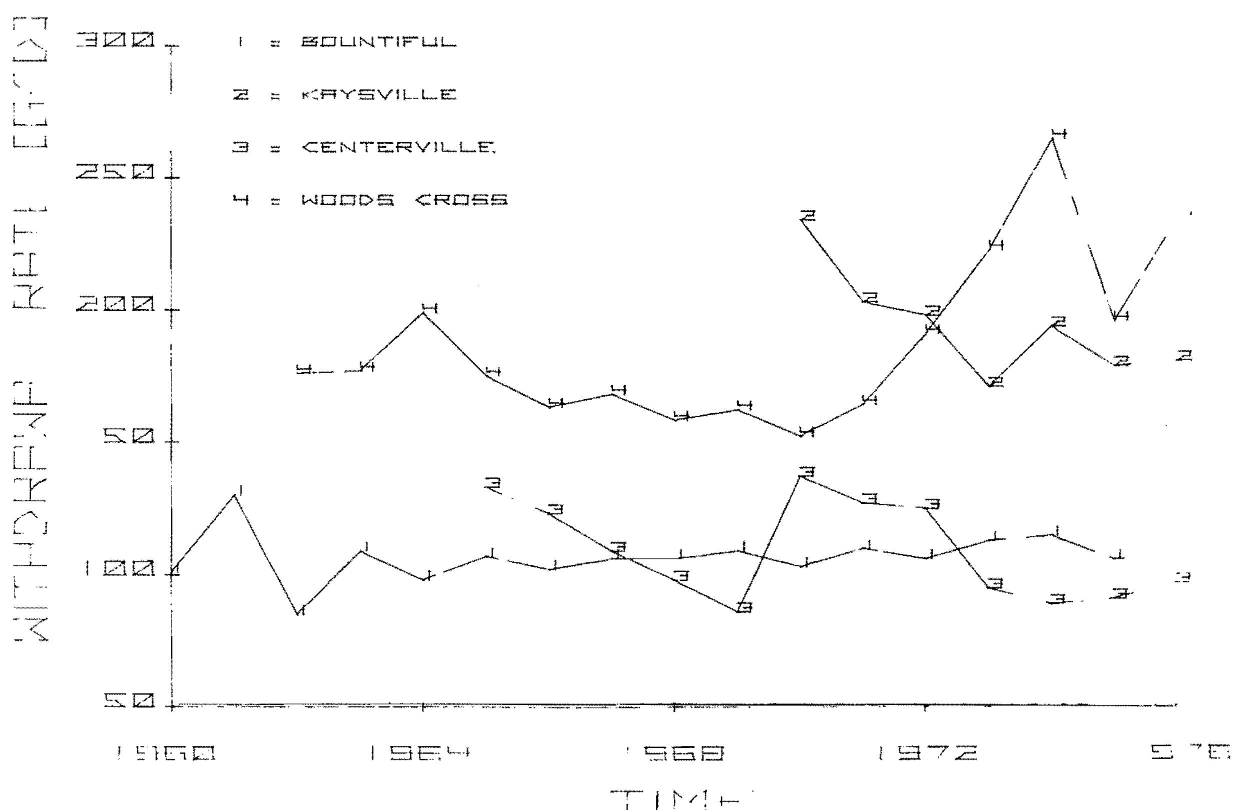


Figure B-4.

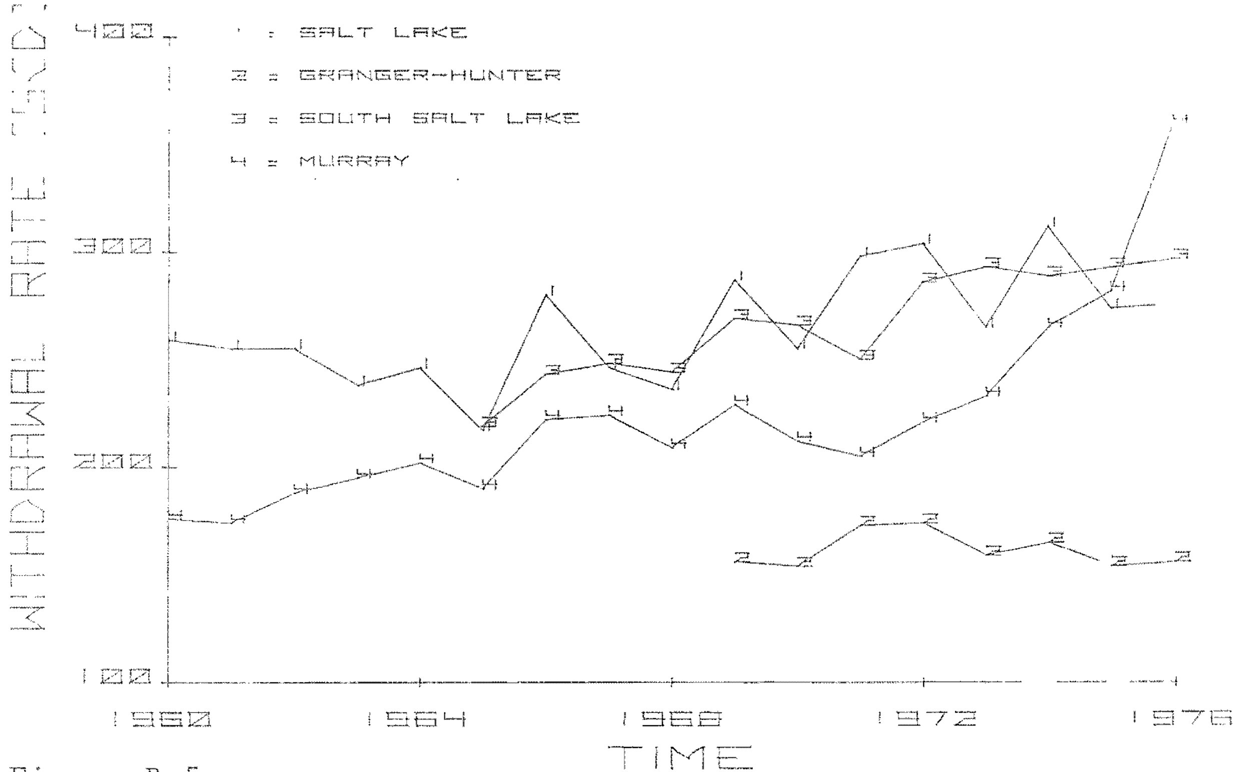


Figure B-5.

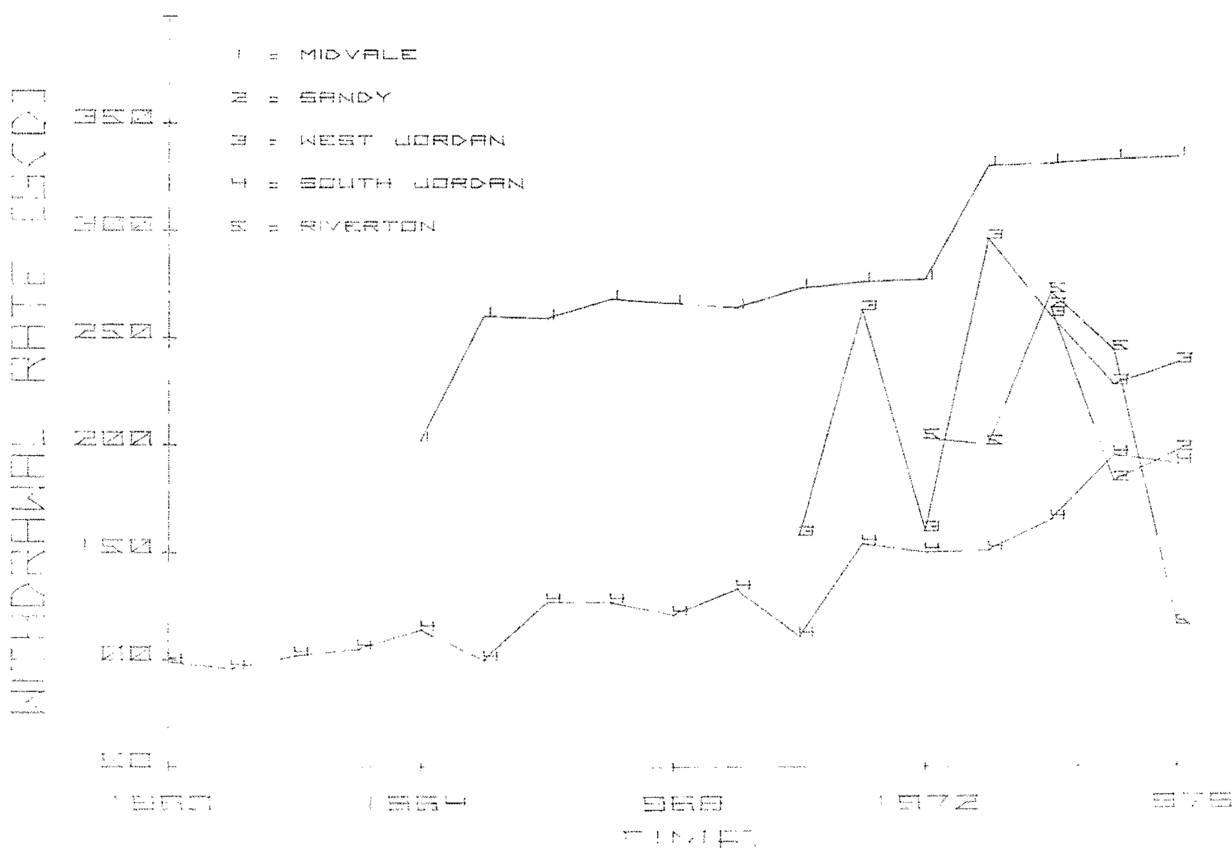


Figure B-6.

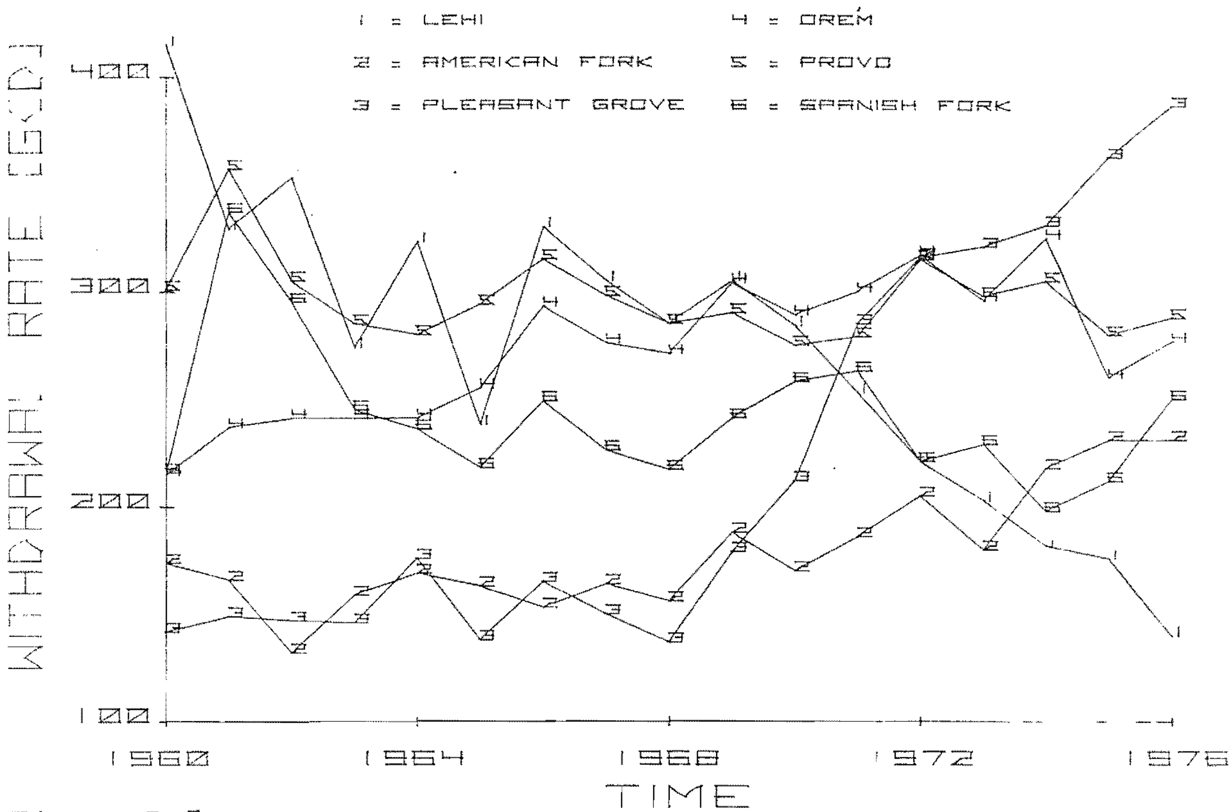


Figure B-7.

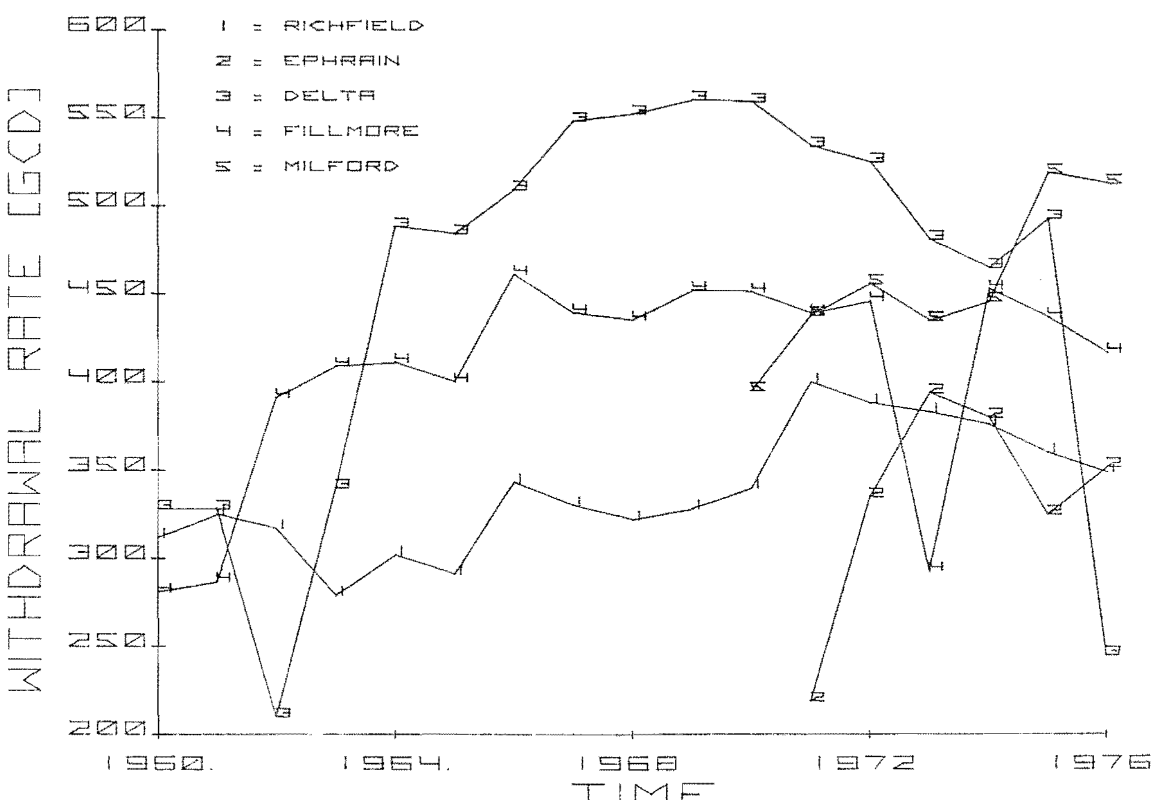


Figure B-8.

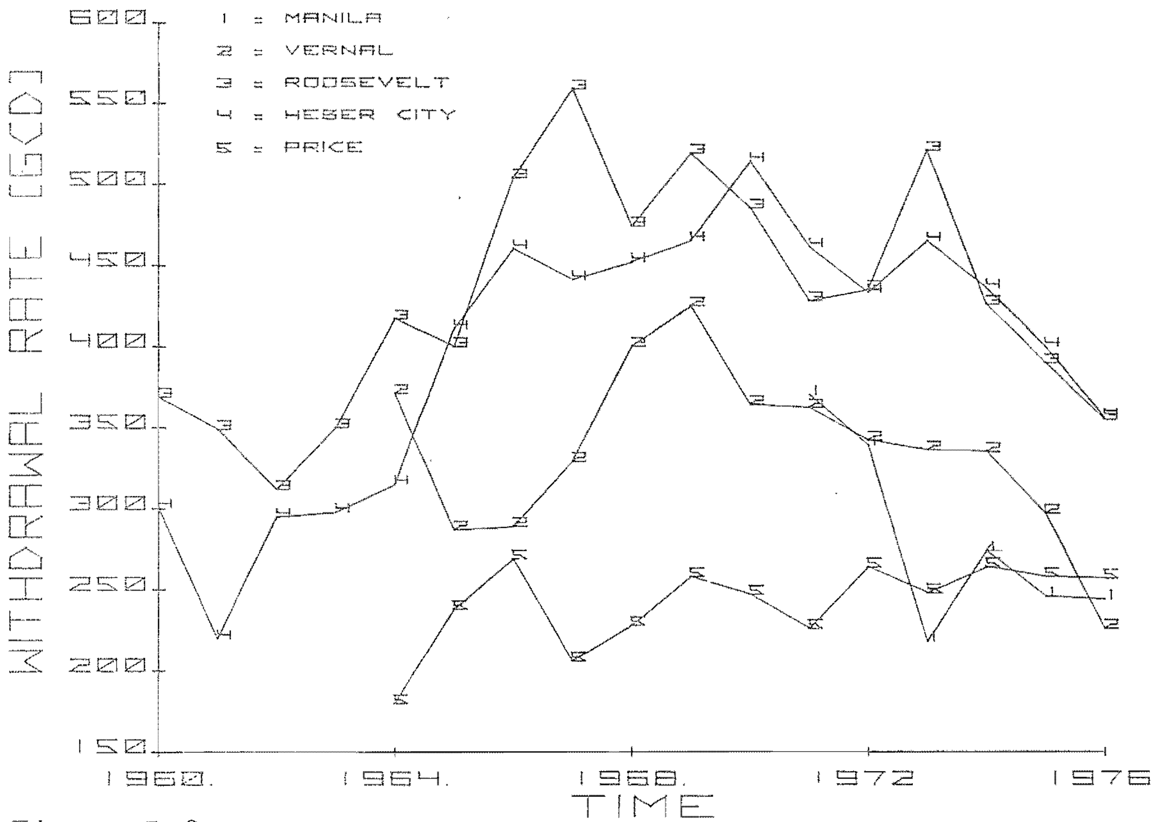


Figure B-9.

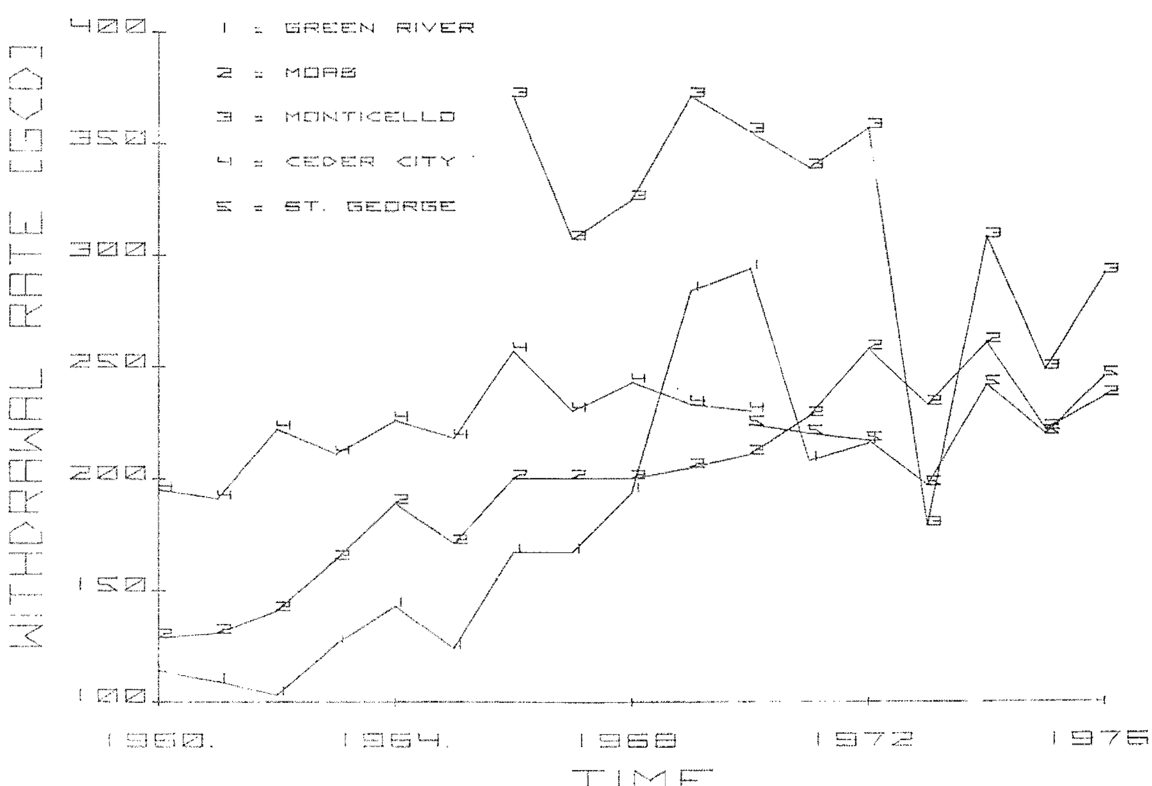


Figure B-10.