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Consumptive Use and Water Requirements for Utah

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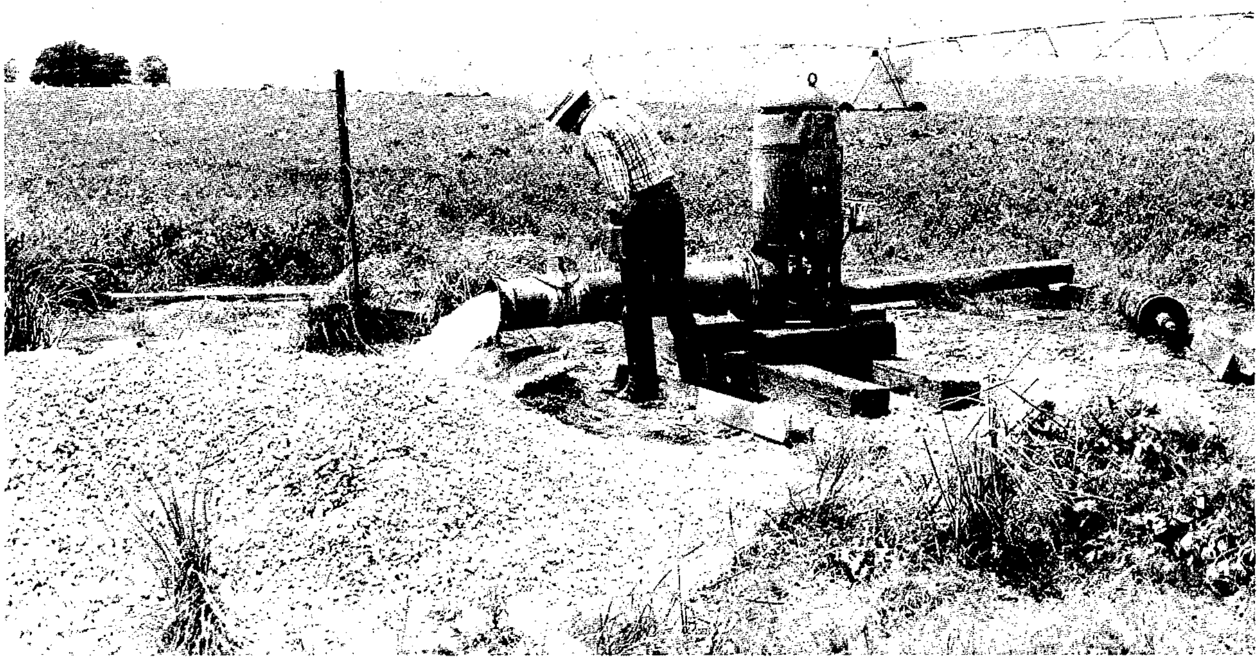

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DEPARTMENT OF NATURAL RESOURCES

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SCOTT M. MATHESON
Governor

This report was prepared as a part of the Statewide cooperative water-resource investigation program administered jointly by the Utah Department of Natural Resources, Division of Water Rights and the United States Geological Survey. The program is conducted to meet the water administration and water-resource data needs of the State, as well as the water information needs of many units of government and the general public.

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CONSUMPTIVE USE AND WATER REQUIREMENTS FOR UTAH

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by

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Prepared Cooperatively by the Water Rights Division,
Utah Department of Natural Resources
and
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TABLE OF CONTENTS

Page

INTRODUCTION 1

Need for Water Use Standards 1
Water Requirements in Single and Aggregated Uses 1

AGRICULTURAL WATER REQUIREMENTS 3

Selection of a Potential Consumptive Use Formula 3
Calculating Potential Consumptive Use 6
Geographical Variation in Consumptive Use 20
Irrigation Water Requirements 23

Upward adjustments to crop evapotranspirational needs 25
Downward adjustments to crop evapotranspirational needs 28
Calculation of irrigation water requirement 30

WATER REQUIREMENTS OF DOMESTIC ANIMALS 37

MUNICIPAL WATER REQUIREMENTS 41

General Considerations 41
Design of Municipal Systems 47

Average annual use 47
Peak demand 48
Instantaneous peak demand 48
Peak day demand 50
Outdoor water use index and peak day demand 52
Peak month demand 54

Computing Demands - An Example 56

INDUSTRIAL WATER REQUIREMENTS 61

RECREATIONAL WATER REQUIREMENTS 67

Types of Water Related Recreation Activities 67
Evaluating Changes in Recreation Opportunities 68
Domestic Requirements at Developed Recreational Areas . . . 71

REFERENCES 73

APPENDIX: CURVES OF CROP GROWTH STAGE COEFFICIENTS 77

LIST OF FIGURES

Figure		Page
1	Average July 700 millibar temperature map for Utah . . .	21
2	Input, information flow, and output of consumptive use factor model, F, presented schematically	24
3	Illustration of increased volumes of water needed for equivalent service when salt concentration is increased	26
4	Daily per capita withdrawal rates for 50 Utah municipal systems: Average of 1974, 1975, and 1976	43
5	Daily per capita withdrawal rates (gcd) for Bountiful, Ogden, Provo, and Salt Lake City: 1960-1976	46
6	Peak instantaneous demands within municipal water systems in Utah: Utah demand function and Farmers Home Administration average standard	51
7	Peak day demand per connection as a function of average demand	53
8	Peak day demand per person as a function of average demand	53
9	Peak day demand per connection as a function of outdoor use index	55
10	Peak day demand per person as a function of outdoor use index	55
11	Peak month demand per connection as a function of average demand	57
12	Peak month demand per person as a function of average demand	57
13	Normalized water use rates for Utah's major water using industries	65
14	Probability of recreationists using flowing water for two types of recreation: swimming and canoe-fishing . .	70

LIST OF TABLES

Table		Page
1	Seasonal and yearly comparison of average of 15 years evapotranspiration estimates, Ohio	4
2	Data for weather stations in Utah having continuous records of 15 years or more	7
3	Approximate planting dates and length of growing season for annual crops in Utah	9
4	Monthly percentage of daytime hours (p) of the year for latitudes 36^o to 43^o north of the equator	9
5	Average percentage of daylight hours for principal weather station locations in Utah	10
6	Mean monthly temperatures in degrees Fahrenheit for Utah weather station	12
7	Values of the climatic coefficient, k_t, for various mean monthly air temperatures, t	14
8	Sample calculation of average daily, monthly, and seasonal consumptive use by corn at Logan, Utah	15
9	Sample calculation of average daily, monthly, and seasonal consumptive use by alfalfa at Milford, Utah	16
10	Average monthly consumptive use factors, f, Utah stations	17
11	Seasonal consumptive-use crop coefficients (K) for irrigated crops	19
12	Guidelines for interpretation of water quality for irrigation	27
13	Comparison of irrigation systems in relation to site and situation factors	29
14	Values of seepage coefficient "C"	30
15	Multipliers to use in calculating effective precipitation	31
16	Sample calculation of effective precipitation	32
17	Average mean monthly precipitation for principal weather station locations in Utah	33

Table		Page
18	Water requirements of cattle	38
19	Water requirements of sheep	39
20	Water requirements of pigs	39
21	Water requirements of turkeys	40
22	Water requirements of chickens	40
23	Estimated daily withdrawal rates per person (gcd) for 50 Utah municipal systems: 1960-1975	44
24	Per capita withdrawal rate (gcd) statistics for 50 Utah municipalities: 1960-1976	45
25	Average annual domestic water demand for design purposes	49
26	Effects on municipal water system cost of different durations of flow peak	49
27	Outdoor use index (I)	54
28	A summary of flows computed in design example	59
29	Water use rates for energy conversion industries	63
30	Utah industrial water withdrawal rates (ged) for major water using industries: average of 1974, 1975, and 1976	64
31	Outdoor water recreational areas rated by amount of water surface area available	69
32	Minimum stream flow requirement by fisheries	71
33	Guidelines for water requirements of recreational campgrounds in Utah	72
34	Design standards for recreational development in the State of Utah	72

PLATE IN POCKET

Plate 1. Seasonal Consumptive Use Factor F.

FOREWORD

Studies on the meteorological determinants of evapotranspiration were initiated at least as long ago as the 1920s and by the late 1940s had produced the Blaney-Criddle method for estimating crop consumptive use. The resulting ability to estimate water requirements by both location and crop added a new scientific dimension to water rights administration that was first introduced into the courts of Utah during adjudication of water rights in the Escalante Valley in 1949.

Application of the consumptive use concept to water rights administration and water resources planning, however, required a written reference. Technical Publication No. 8 entitled "Consumptive Use of Water and Irrigation Requirements of Crops in Utah" was published by the State Engineer in 1952.

By 1962, methods had been developed for going beyond agriculture to estimate water requirements for municipal, industrial, and recreational uses. Technical Publication No. 8 was revised and published under the title "Consumptive Use and Water Requirements for Utah."

Continuing advancements in water requirements estimation have occurred over the last 20 years. The present revision, Technical Publication No. 75, updates estimation of agricultural, municipal, recreational, and industrial water uses. It presents an isogram of potential consumptive use that permits the determination of crop water requirements at any point within the state.

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INTRODUCTION

Need for Water Use Standards

Reliable guides or standards for estimating water requirements are essential for the planning, design, and operation of any water using enterprise. Particularly in a state like Utah, where water demands are high relative to the availability of supplies, and where it is imperative that as many uses as possible be satisfied, it is important that water requirements in various uses be accurately quantified. If the achievement of laudable social and economic goals are not to be water limited, there must be authoritative water use standards to guide in making water allocations and in monitoring water transfers and changes in use that occur over time. Cost-effective management of water in any use is both fostered and maintained on the basis of soundly conceived and properly applied water requirements information.

Recognizing the widespread importance of information on unit water use, water administrators, planners, and managers have sought to obtain reliable values of water need, particularly for the major uses such as irrigated agriculture, municipal, and industrial. Concomitant with the establishment of the Office of the State Engineer have been efforts to determine the "duty of water" in various uses. Historically and presently, water use for irrigated agriculture has been the predominant use of water in Utah. Therefore, much research emphasis has been placed on determining water requirements of various crops grown in different regions of the state. A most significant distillation of water use information and guide to its use was Technical Publication No. 8, "Consumptive Use of Water and Irrigation Requirements of Crops in Utah" published by the State Engineer in 1952. This popular publication has been widely used in Utah and elsewhere as a basis for estimating crop water requirements. An updated and expanded version of the 1952 publication was issued in 1962 under the title "Consumptive Use and Water Requirements for Utah." The revised edition included information about water requirements in municipal, industrial, and recreational uses as well as agricultural. A further updating reflecting the state of the art in research and the accumulation of additional data upon which water requirements in various uses are derived constitutes this present report. A note-worthy improvement is the incorporation of techniques to permit the calculation of agricultural consumptive use at any geographic point of interest without going through some complicated extrapolation from a particular weather station location.

Water Requirements in Single and Aggregated Uses

As previously mentioned, unit water requirement estimates are essential in planning, operating, and evaluating performance of an individual water using enterprise. If they are to have meaningful utility for regional water resources planning, management, and administration, unit water use values must be applied in a river basin perspective. In other words, values of water requirement in particular individual uses must be applied within the conceptual framework of a hydrologic flow system recognizing that all uses are related through the unifying interconnection of all surface and subsurface waters of a basin or watershed. What one user does with and to water in the use process imparts an impact which may be felt by subsequent users downstream. The impact may be substantial or imperceptible and may be in terms of either quantity or quality or both. Important to appreciate is that different uses made from a common supply are not "homogeneous" or directly "convertible" in a hydrologic sense. For example, water use by crops is largely "consumptive"; meaning that liquid water is changed to a vapor in the use process and expelled into the atmosphere, thereby resulting in a depletion from the liquid manageable water supply of the basin. Water use in the generation of hydropower is "nonconsumptive"; meaning that water remains in the liquid state in the use process and is discharged in that form back into the general system, thereby causing no noticeable depletion from the stream system itself. Most water uses are comprised of both consumptive and nonconsumptive components. Municipalities, for example, may return to their sewer system up to 90 percent of the water diverted and delivered through their supply distribution systems. Thus, while different water uses may be expressed in terms of a common unit of water measure, that does not constitute a common denominator of convertibility in a hydrologic sense. This can be readily appreciated by considering the third party impacts of changing a "nonconsumptive use" entitlement to a "consumptive use" entitlement. It should be kept in mind, therefore, that water requirement criteria described in this report are in terms of individual uses. In instances where a variety of water uses are aggregated and take place in parallel and sequence, reasonable care may need to be exercised so as to maintain the hydrologic integrity of any calculation or projection involving water use criterion tabulated herein.

AGRICULTURAL WATER REQUIREMENTS

Agricultural water requirements are of special significance in arid areas where water needs must be met largely through irrigation. Unlike dryland agriculture, irrigated agriculture entails the diversion, regulation, conveyance, and distribution of water from streams and rivers. Therefore, irrigation water requirement becomes a key standard in the allocation and management of water, in the administering of water rights, and in the design of large and small irrigation projects.

Irrigation water requirement is a term used to denote the volume and regimen of flow that must be delivered at some specified point for subsequent distribution and placement in the soil where it can be used to satisfy the evapotranspirational needs of crops. Irrigation water requirement is thus composed of a basic potential consumptive use requirement (which is principally a function of climate) adjusted as appropriate by 1) incremental additions of water which improve the rooting environment, and to make up for unavoidable losses of water in the process of getting the proper amount placed in the crop root zone; and 2) incremental reductions from the basic consumptive use in those instances where precipitation, groundwater, or water from some other nonirrigation source satisfies a portion of the potential water need.

Selection of a Potential Consumptive Use Formula

Standards of potential consumptive use or evapotranspiration for various crops are determined from carefully controlled experiments. Measured quantities of water are placed in a controlled crop root zone and time changes in root zone moisture storage are carefully monitored. At the same time, climatic and physiologic factors that influence the evapotranspirational process are measured. Then the climatic and physiologic factors are correlated with water changes and formulae are developed which can be used for estimating evapotranspiration under given climatic and crop regimes. A comparison of seasonal and annual predictions of consumptive use compared to actual consumptive use in lysimeters containing a deep rooted grass-legume crop is shown in Table 1 (McGuinness and Bordne 1972). Other investigators have made more recent comparisons (Samani 1981); some of which have been based on Utah data. Testing and refinement of consumptive use formulas continues and improvements will undoubtedly be made.

After analyzing the more commonly used equations, their derivations, and their performance in various situations, the Blaney-Criddle formula as modified by the USDA (1967) was selected for estimating consumptive use in Utah. This formula utilizes data available or derivable in compatible time-increments throughout the state. The Blaney-Criddle method of determining agricultural water requirements has been thoroughly tested over time and has gained scientific credibility and, hence, widespread legal acceptance where water use disputes have been litigated.

Table 1. Seasonal and yearly comparison of average of 15 years evapotranspiration estimates, Ohio.

Method	Average April-October Seasonal ET		Average Yearly ET	
	Inches	Percent Difference	Inches	Percent Difference
Lysimeter	35.16	0	40.14	0
Blaney-Criddle	35.01	-0.4	37.79	-5.9
Thornthwaite	25.83	-26.5	26.61	-33.7
Hamon	23.22	-34.0	26.47	-34.3
Papadakis	21.73	-38.2	26.21	-34.7
Grassi	39.16	11.4	49.71	23.8
Stephen-Stewart	22.69	-35.5	24.48	-39.0
Turc	30.82	-12.3	32.55	-18.9
Jensen-Haise	35.99	2.4	38.05	-5.2
Makkink	26.18	-25.5	31.06	-22.6
Christiansen	34.00	-3.3	40.30	0.4
Penman	31.21	-11.2	37.62	-6.3
Van Bavel	33.65	-4.3	42.45	5.8
Weather Bureau (Pan)	35.94	2.2	43.35	8.0

Source: McGuinnes and Bordne (1972)

The Blaney-Criddle formula for computing consumptive use incorporates a climatic parameter called the consumptive use factor, F, and a physiologic parameter called the crop coefficient, K. Consumptive use over the crop growing season is expressed by the simple empirical relation

$$U = KF \qquad (1)$$

in which

U = the growing season consumptive use of water by the crop in inches
K = the consumptive use coefficient for the given crop for the growth period
F = the growing season consumptive use factor

The growing season consumptive use factor, F, is calculated as the sum of monthly and part-month consumptive use factors, f, where f = a monthly (or short period) consumptive use factor found by multiplying the mean monthly temperature, t, by the monthly percent of annual daytime hours, p

Since t and p are monthly values rather than growing season values, monthly consumptive use can be calculated when corresponding values of the consumptive use coefficient, k, are available. Hence,

$$u = kf = k\frac{tp}{100} \quad \ldots \quad (2)$$

and

$$U = \Sigma u$$
$$= \sum_{i=1}^{i=n} r_i k_i \frac{t_i p_i}{100} \quad \ldots \quad (3)$$

in which

r_i = the fraction of the month i in which crop growth occurs
n = the number of months of the year falling partly or entirely within the growing season
k_i = the consumptive use coefficient for the crop of interest for month i

The monthly consumptive use coefficient, k_i, has been further disaggregated into two components in order to separate the local climatic effects, k_{t_i}, from the crop growth stage or physiological effects, k_{c_i}. The crop growth stage coefficient thus becomes a general and universally applicable coefficient independent of local conditions. Accordingly,

$$k_i = k_{c_i} k_{t_i} \quad \ldots \quad (4)$$

in which

k_{c_i} is a coefficient reflecting the stage of crop growth representing month i, and
k_{t_i} is a climatic coefficient which is related to the mean air temperature, t_i, by:

$$k_{t_i} = 0.300 \text{ for } t_i < 35.5°F$$
$$= 0.0173\, t_i - 0.314 \text{ for } t_i \geq 35.5°F \quad \ldots \quad (5)$$

With these modifications, the Blaney-Criddle equation for calculating consumptive use for a growing season becomes

$$U = \sum_{i=1}^{i=n} r_i k_{c_i} k_{t_i} \frac{t_i p_i}{100} \quad \ldots \quad (6)$$

This equation has been used to determine the values of consumptive use by agricultural crops reported herein.

Calculating Potential Consumptive Use

The calculation of potential evapotranspiration or consumptive use for any particular crop at a location of interest requires information about 1) when the growing period begins and ends, 2) the mean monthly temperatures for the growing period, 3) the monthly percent of the possible yearly daytime hours for the months involved, 4) the monthly crop growth stage coefficients, and 5) the monthly climate or temperature coefficients. These are the factors represented by the Blaney-Criddle expression given as Equation 6.

The length of the potential growing season is commonly taken as the interval between the last killing freeze in the spring and the first killing freeze in the fall. In calculating potential consumptive use, the average date of the last 28°F temperature in the spring is normally used as the beginning date of the growing season. The average date of the first 28°F in the fall is considered the ending date of the growing season. These dates and the growing interval are shown in Table 2 for the 130 weather stations in Utah having long term continuous temperature records. These 28°F freeze dates are needed to determine the fraction of the month (r) for which growth occurs for those crops whose growth either begins or ends according to freeze temperatures. For other crops, dates of planting and harvest are needed in order to determine part month growth periods. Approximate planting and harvesting dates for annual crops as a function of the seasonal consumptive use factor, F, applicable to the location are shown in Table 3.

In order to determine the appropriate percentage of yearly daytime hours, p, for use in Equation 6, the latitude of the station whose weather data are being used in the calculation of consumptive use must be known. Monthly values of p for the latitudes which span Utah are given in Table 4.

For the set of long term weather stations in Utah the monthly percent of possible yearly daytime hours, p, has been determined and tabulated for convenient use in Table 5.

Mean monthly temperature, t, for the set of long term weather stations in Utah are provided in Table 6.

Values of the climatic coefficient, k_t, for any given mean temperature, t, for month i can be calculated by use of Equation 5 or obtained directly from Table 7.

For the commonly grown crops in Utah, the crop growth stage coefficient, k_c, can be obtained from the figures provided in the Appendix. The crop stage coefficient curves in the Appendix were developed by the U.S. Department of Agriculture and included in the 1970 revision of Technical Release No. 21. With annual crops, such as corn and small grains, the values of the growth stage coefficients are plotted against the growing period expressed in terms of percent of total growing period. For perennial crops, such as alfalfa, permanent pasture, and orchards,

Table 2. Data for weather stations in Utah having continuous records of 15 years or more.

No.	Station	Elevation (Feet)	Latitude (Deg-Min)	Longitude (Deg-Min)	Blaney-Criddle Seasonal F	Mean 28°F Freeze Dates Spring	Fall	Interval (Days)	Mean Annual Precipitation (Inches)	Mean Annual Temperature (DEG(F))
1	Altamont	6380	40-22	110-17	29.80	May 7	Oct 13	159	8.44	43.6
2	Alton	7040	37-26	112-29	25.95	May 19	Oct 5	139	16.38	45.4
3	Antelope Island	4225	40-56	112-10	40.42	Apr 13	Oct 31	201	15.57	51.9
4	Bear River Refuge	4208	41-28	112-16	38.64	Apr 15	Oct 25	193	11.97	50.4
5	Beaver	5920	38-17	112-38	26.69	May 18	Sep 29	134	11.33	47.5
6	Bingham Canyon	6095	40-32	112-09	36.34	Apr 20	Nov 2	196	21.22	47.9
7	Birdseye	5740	39-52	111-32	18.39	Jun 6	Sep 7	93	13.49	42.5
8	Black Rock	4895	38-43	112-57	28.61	May 11	Sep 27	139	8.61	48.6
9	Blanding	6036	37-37	109-28	34.30	Apr 28	Oct 19	174	11.82	49.7
10	Bluff	4315	37-17	109-33	42.60	Apr 5	Nov 1	210	7.55	54.6
11	Bonanza	5450	40-01	109-11	35.01	Apr 25	Oct 13	171	8.22	48.5
12	Boulder	6580	37-55	111-24	32.84	May 1	Oct 18	170	10.20	48.2
13	Brigham City	4335	41-29	112-02	38.64	Apr 16	Oct 25	192	19.31	51.1
14	Bryce Canyon FAA AP	7595	37-42	112-09	16.91	Jun 11	Sep 11	92	11.79	40.0
15	Bryce Canyon NP HDQ	7915	37-39	112-10	16.67	Jun 11	Sep 11	92	15.83	38.4
16	Capitol Reef NT MON	5500	38-17	111-16	36.78	Apr 25	Oct 18	176	7.24	53.2
17	Castle Dale	5660	39-13	111-01	28.72	May 13	Oct 4	144	8.00	46.0
18	Cedar City FAA AP	5601	37-42	113-06	33.13	Apr 30	Oct 13	166	10.33	49.8
19	Cedar City PH	5980	37-40	113-02	35.76	Apr 23	Oct 23	183	11.96	50.7
20	Cedar Point	6780	37-43	109-05	28.50	May 12	Oct 2	143	13.47	46.7
21	Circleville	6000	38-10	112-16	27.95	May 13	Oct 1	141	8.01	47.2
22	Coalville	5550	40-55	111-24	21.10	May 30	Sep 14	107	14.78	44.2
23	Corinne	4230	41-33	112-07	34.19	Apr 26	Oct 12	169	15.62	48.9
24	Cottonwood Weir	4950	40-37	111-47	42.83	Apr 5	Nov 4	213	22.69	53.7
25	Cove Fort	5980	38-36	112-35	27.56	May 15	Sep 27	135	13.01	47.5
26	Deer Creek Dam	5270	40-24	111-32	22.61	May 25	Sep 16	114	21.33	43.4
27	Delta	4630	39-21	112-34	35.41	Apr 23	Oct 13	173	7.77	50.1
28	Deseret	4585	39-17	112-39	32.17	May 3	Oct 8	158	6.92	49.2
29	Desert Exp R	5252	38-36	113-45	31.21	May 5	Oct 5	153	6.09	48.9
30	Duchesne	5510	40-10	110-24	28.40	May 14	Oct 3	142	8.71	45.3
31	Dugway	4340	40-11	112-56	39.04	Apr 14	Oct 23	192	6.67	51.1
32	Echo Dam	5500	40-58	111-26	25.95	May 17	Sep 25	131	13.81	45.3
33	Elberta	4690	39-57	111-57	34.60	Apr 26	Oct 14	171	10.93	50.2
34	Emery	6200	38-55	111-15	28.33	May 13	Oct 8	148	7.55	46.0
35	Enterprise Beryl Jct	5200	37-45	113-39	25.24	May 20	Sep 21	124	9.19	47.7
36	Ephraim Sorn FD	5580	39-21	111-35	30.52	May 6	Oct 8	155	10.46	46.8
37	Escalante	5810	37-46	111-36	30.34	May 8	Oct 9	154	11.22	48.6
38	Fairfield	4876	40-16	112-05	26.04	May 19	Sep 24	128	10.61	46.5
39	Farmington USU	4340	41-01	111-54	38.38	Apr 16	Oct 25	192	19.96	51.5
40	Ferron	5925	39-06	111-08	33.94	Apr 29	Oct 18	172	8.15	47.5
41	Fillmore	5160	38-57	112-19	38.12	Apr 16	Oct 24	191	14.78	51.6
42	Fish Spg Ref	4335	39-51	113-24	41.56	Apr 7	Oct 29	205	5.30	53.0
43	Flaming Gorge	6270	40-56	109-25	26.22	May 17	Sep 28	134	12.45	44.0
44	Fort Duchesne	4990	40-17	109-52	28.70	May 12	Sep 30	141	7.23	44.9
45	Garfield	4310	40-43	112-12	44.23	Mar 30	Nov 13	228	15.58	52.9
46	Garland	4350	41-44	112-10	34.09	Apr 27	Oct 14	170	15.14	48.0
47	Garrison	5275	38-56	114-02	33.20	Apr 29	Oct 10	164	7.13	49.8
48	Geneva Steel	4550	40-18	111-44	38.88	Apr 15	Oct 26	194	11.46	51.4
49	Green River AVN	4070	39-00	110-10	38.81	Apr 16	Oct 20	187	6.11	52.1
50	Gunnison	5145	39-09	111-49	25.74	May 19	Sep 20	124	7.99	47.8
51	Hanksville	4308	38-22	110-43	41.85	Apr 8	Oct 29	204	5.20	53.1
52	Hanna	6780	40-26	110-48	22.41	May 28	Sep 22	117	11.72	42.3
53	Hardware Ranch	5560	41-36	111-34	11.16	Jun 22	Aug 17	56	15.44	41.7
54	Heber	5580	40-31	111-25	22.90	May 26	Sep 19	116	15.82	44.1
55	Hiawatha	7230	39-29	111-01	31.34	May 4	Oct 18	167	14.15	45.5
56	Hovenweep Mon	5400	37-23	109-04	36.66	Apr 20	Oct 17	180	10.45	51.3
57	Ibapah	5280	40-02	113-59	22.53	May 26	Sep 13	110	10.70	45.1
58	Jensen	4720	40-22	109-21	29.15	May 10	Sep 28	141	7.94	45.5
59	Kamas Ranger St	6495	40-39	111-17	22.43	May 28	Sep 20	115	17.67	43.4
60	Kanab	4985	37-03	112-32	38.69	Apr 16	Oct 23	190	12.21	54.9
61	Koosharem	6950	38-31	111-53	21.07	Jun 1	Sep 18	109	9.25	43.4
62	Lake Town	5988	41-49	111-19	22.62	May 26	Sep 21	118	11.58	42.1
63	LaSal	6960	38-19	109-15	29.45	May 9	Oct 10	154	12.88	46.7
64	LaVerkin	3450	37-12	113-16	42.41	Apr 9	Oct 26	200	9.66	58.3
65	Levan	5300	39-33	111-52	33.92	Apr 28	Oct 16	171	14.66	49.1

Table 2. Continued.

No.	Station	Elevation (Feet)	Latitude (Deg-Min)	Longitude (Deg-Min)	Blaney-Criddle Seasonal F	Mean 28°F Freeze Dates Spring	Mean 28°F Freeze Dates Fall	Interval (Days)	Mean Annual Precipitation (Inches)	Mean Annual Temperature (DEG(F))
66	Lewiston	4480	41-58	111-50	28.17	May 12	Sep 30	141	17.64	45.4
67	Loa	7045	38-24	111-39	19.21	Jun 5	Sep 13	100	7.48	43.0
68	Logan KVNU	4504	41-46	111-50	32.25	May 2	Oct 10	161	15.01	46.6
69	Logan USU	4785	41-45	111-49	36.57	Apr 19	Oct 26	190	17.59	48.0
70	Logan USU Exp Sta	4608	41-46	111-49	31.93	May 4	Oct 11	160	16.47	47.3
71	Manila	6420	41-00	109-43	24.87	May 22	Sep 25	126	9.71	44.1
72	Manti	5585	39-15	111-38	30.73	May 7	Oct 12	158	12.93	47.6
73	Marysvale	5975	38-27	112-14	26.56	May 18	Sep 27	132	9.28	47.9
74	Mexican Hat	4270	37-09	109-52	45.62	Mar 31	Nov 3	217	5.95	57.2
75	Milford WSO	5028	38-26	113-01	32.60	May 2	Oct 9	160	8.40	49.2
76	Moab 4 NW	3965	38-36	109-36	44.26	Apr 5	Oct 31	209	7.94	56.3
77	Modena	5460	37-48	113-55	31.46	May 4	Oct 10	159	9.48	48.9
78	Monticello	6980	37-52	109-20	30.43	May 7	Oct 17	163	13.81	46.4
79	Monument Valley	5220	37-01	110-12	39.98	Apr 21	Oct 24	186	7.12	56.1
80	Morgan	5070	41-02	111-41	25.52	May 19	Sep 24	128	17.08	45.4
81	Moroni	5525	39-32	111-35	27.98	May 12	Oct 1	142	9.70	46.6
82	Mountain Dell Dam	5420	40-45	111-43	27.55	May 15	Oct 2	140	23.48	46.4
83	Myton	5030	40-12	110-04	32.79	May 1	Oct 12	164	6.80	45.8
84	Neola	6000	40-25	110-03	28.85	May 12	Oct 9	150	8.14	44.0
85	Nephi	5133	39-43	111-50	35.77	Apr 22	Oct 15	176	13.89	51.1
86	New Harmony	5290	37-29	113-18	34.83	Apr 25	Oct 20	178	16.55	51.4
87	Oak City	5075	39-23	112-20	39.36	Apr 14	Oct 26	195	12.06	52.2
88	Ogden Pioneer PH	4400	41-15	111-57	39.58	Apr 13	Oct 28	198	20.11	51.4
89	Ogden Sugar FCT	4280	41-14	112-02	37.62	Apr 17	Oct 23	189	16.19	50.7
90	Orderville	5460	37-16	112-38	29.81	May 9	Oct 1	145	14.50	50.5
91	Ouray	4670	40-08	109-38	32.02	May 4	Oct 3	152	6.35	46.6
92	Panguitch	6720	37-49	112-27	20.09	Jun 4	Sep 17	105	9.90	43.6
93	Park Valley	5570	41-48	113-20	32.37	May 1	Oct 14	166	10.47	46.7
94	Partoun	4750	39-39	113-53	32.28	May 3	Oct 4	154	6.15	49.9
95	Parowan	5975	37-51	112-50	31.80	May 5	Oct 12	160	12.25	50.0
96	Pine View Dam	4940	41-15	111-50	30.61	May 5	Oct 8	156	28.59	45.2
97	Piute Dam	5900	38-19	112-11	30.43	May 8	Oct 9	154	8.60	48.5
98	Pleasant Grove	4668	40-22	111-44	35.13	Apr 24	Oct 16	175	15.35	50.5
99	Price Warehouses	5680	39-37	110-50	34.63	Apr 26	Oct 17	174	9.88	48.8
100	Provo KOVO	4470	40-13	111-40	31.03	May 5	Oct 4	152	14.20	49.2
101	Richfield Radio KSVC	5270	38-46	112-05	28.86	May 11	Oct 1	143	8.16	48.7
102	Richmond	4680	41-54	111-49	30.56	May 7	Oct 6	152	18.52	47.5
103	Riverdale PH	4390	41-09	112-00	37.62	Apr 18	Oct 24	189	17.50	50.7
104	Roosevelt	5094	40-18	109-59	31.17	May 6	Oct 6	153	7.44	46.5
105	St. George	2760	37-07	113-34	50.83	Mar 18	Nov 16	243	7.56	61.5
106	Salina	5190	38-57	111-52	30.72	May 7	Oct 3	149	10.30	49.3
107	Saltair Salt PL	4210	40-46	112-06	42.08	Apr 4	Nov 14	224	12.00	50.6
108	SLC WSFO	4220	40-46	111-58	38.50	Apr 15	Oct 25	193	15.17	51.0
109	Santaquin	5100	39-57	111-47	36.03	Apr 23	Oct 21	181	19.66	50.1
110	Scipio	5306	39-15	112-06	28.59	May 13	Oct 2	142	12.34	47.4
111	Scofield Dam	7630	39-47	111-07	17.59	Jun 10	Sep 14	96	16.84	38.1
112	Silver L Brighton	8740	40-36	111-35	15.10	Jun 18	Sep 13	87	43.81	36.4
113	Snake Creek PH	5950	40-33	111-30	22.74	May 26	Sep 21	118	23.30	43.2
114	Snowville	4560	41-58	112-43	25.38	May 18	Sep 22	127	11.82	44.7
115	Soldier Summit	7470	39-55	111-05	16.04	Jun 13	Sep 7	86	14.77	38.7
116	Spanish Fork PH	4711	40-05	111-36	38.18	Apr 17	Oct 24	190	18.22	51.7
117	Strawberry RES E P	7606	40-10	111-11	16.22	Jun 7	Sep 6	91	20.62	35.6
118	Thompson	5150	38-58	109-43	40.84	Apr 11	Oct 27	199	8.92	53.0
119	Timpanogas Cave	5600	40-26	111-43	36.15	Apr 21	Oct 24	186	23.84	49.1
120	Tooele	4820	40-32	112-18	40.23	Apr 10	Nov 5	209	16.31	51.0
121	Tropic	6235	37-37	112-05	27.44	May 15	Oct 3	141	12.75	47.8
122	U of U	4730	40-46	111-51	42.67	Apr 5	Nov 7	216	16.93	52.9
123	Utah Lake Lehi	4497	40-22	111-54	33.04	Apr 29	Oct 12	166	10.75	48.7
124	Vernal Airport	5280	40-27	109-31	27.70	May 14	Sep 29	138	7.82	44.5
125	Veyo PH	4600	37-21	113-39	36.08	Apr 23	Oct 15	175	12.01	53.9
126	Wah Wah Ranch	4960	38-29	113-25	33.61	Apr 29	Oct 7	161	6.49	50.8
127	Wanship Dam	5940	40-48	111-24	21.51	May 31	Sep 18	110	15.68	43.6
128	Wendover WSO	4237	40-44	114-02	42.78	Apr 3	Nov 5	216	4.88	52.2
129	Woodruff	6343	41-32	111-09	16.85	Jun 12	Sep 9	89	9.26	38.6
130	Zions National Park	4050	37-13	112-59	50.65	Mar 17	Nov 16	244	14.36	61.2

Table 3. Approximate planting dates[a] and length of growing season for annual crops in Utah.

Crop	Approximate Days to Harvest	Seasonal Consumptive Use Factor, F[b]									
		20	24	28	32	36	40	44	52	56	60
Beans	90	-	6/17	6/8	5/29	5/19	5/9	4/29	4/18	4/10	4/1
Corn[c]	120	6/4	5/25	5/18	5/7	4/21	4/13	3/31	3/22	3/12	3/2
Grain, spring	100	5/1	4/24	4/16	4/9	4/1	3/21	3/15	3/9	3/1	2/21
Peas	90	-	-	5/26	5/15	5/3	4/24	4/14	4/2	3/26	3/22
Potatoes[d]	120	6/10	5/31	5/20	5/9	4/29	4/19	4/9	4/2	3/14	3/4
Small truck	90	6/15	6/5	5/26	5/17	5/8	4/30	4/13	4/7	4/5	4/4
Sorghum	135	-	-	-	-	-	-	-	6/11	6/19	6/23
Sugar Beets	150	-	-	-	4/18	4/8	3/28				
Tomatoes	150	-	-	5/20	5/10	4/30	4/20	4/10	4/1	3/22	3/17

[a] Planting dates will vary with the soil temperature for some crops. Freeze-free dates would allow earlier planting than shown here.

[b] Total seasonal consumptive use factor (F) for the period when the temperatures stay about 28°F.

[c] Corn grown in Utah is largely for silage. It will not mature when the seasonal consumptive use factor is less than 30, and except in the hottest areas of the state, getting the grain sufficiently dry for safe storage is difficult.

[d] When the consumptive use factor is less than 25, potatoes seldom mature but are grown for seed purposes.

Table 4. Monthly percentage of daytime hours (p) of the year for latitudes 36° to 43° north of the equator.

Latitude North	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
36°	6.98	6.85	8.35	8.85	9.80	9.82	9.99	9.41	8.36	7.85	6.93	6.81
37°	6.92	6.82	8.34	8.87	9.85	9.89	10.05	9.44	8.37	7.83	6.88	6.74
38°	6.87	6.79	8.33	8.89	9.90	9.96	10.11	9.47	8.37	7.80	6.83	6.68
39°	6.81	6.75	8.33	8.91	9.95	10.03	10.16	9.51	8.38	7.78	6.78	6.61
40°	6.75	6.72	8.32	8.93	10.01	10.09	10.22	9.55	8.39	7.75	6.73	6.54
41°	6.68	6.68	8.31	8.96	10.07	10.16	10.29	9.59	8.39	7.72	6.68	6.47
42°	6.61	6.65	8.30	8.99	10.13	10.24	10.35	9.62	8.40	7.70	6.62	6.39
43°	6.55	6.61	8.30	9.02	10.19	10.31	10.42	9.66	8.40	7.67	6.56	6.31

Table 5. Average percentage of daylight hours for principal weather station locations in Utah.

NO	STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1	Altamont	6.72	6.71	8.32	8.94	10.03	10.12	10.25	9.56	8.39	7.74	6.71	6.51	100.00
2	Alton	6.90	6.81	8.34	8.88	9.87	9.92	10.08	9.45	8.37	7.82	6.86	6.71	100.00
3	Antelope Island	6.68	6.68	8.31	8.96	10.07	10.16	10.29	9.59	8.39	7.72	6.68	6.47	100.00
4	Bear River Refuge	6.65	6.67	8.31	8.97	10.10	10.20	10.32	9.60	8.39	7.71	6.65	6.43	100.00
5	Beaver	6.85	6.78	8.33	8.90	9.91	9.98	10.12	9.48	8.37	7.79	6.82	6.66	100.00
6	Bingham Canyon	6.71	6.70	8.31	8.95	10.04	10.13	10.26	9.57	8.39	7.73	6.70	6.50	100.00
7	Birdseye	6.76	6.72	8.32	8.93	10.00	10.08	10.21	9.54	8.39	7.75	6.74	6.55	100.00
8	Black Rock	6.83	6.76	8.33	8.90	9.94	10.01	10.15	9.50	8.38	7.79	6.79	6.63	100.00
9	Blanding	6.89	6.80	8.33	8.88	9.88	9.93	10.09	9.46	8.37	7.81	6.85	6.70	100.00
10	Bluff	6.91	6.81	8.34	8.88	9.86	9.91	10.07	9.45	8.37	7.82	6.87	6.72	100.00
11	Bonanza	6.75	6.72	8.32	8.93	10.01	10.09	10.22	9.55	8.39	7.75	6.73	6.54	100.00
12	Boulder	6.87	6.79	8.33	8.89	9.90	9.95	10.11	9.47	8.37	7.80	6.83	6.69	100.00
13	Brigham City	6.65	6.67	8.31	8.97	10.10	10.20	10.32	9.60	8.39	7.71	6.65	6.43	100.00
14	Bryce Canyon FAA AP	6.88	6.80	8.33	8.88	9.88	9.94	10.09	9.46	8.37	7.81	6.84	6.70	100.00
15	Bryce Canyon NP HDQ	6.89	6.80	8.33	8.88	9.88	9.94	10.09	9.46	8.37	7.81	6.85	6.70	100.00
16	Capitol Reef NT MON	6.85	6.78	8.33	8.90	9.91	9.98	10.12	9.48	8.37	7.79	6.82	6.66	100.00
17	Castle Dale	6.80	6.74	8.33	8.91	9.96	10.04	10.17	9.52	8.38	7.77	6.77	6.59	100.00
18	Cedar City FAA AP	6.89	6.80	8.33	8.88	9.88	9.94	10.09	9.46	8.37	7.81	6.84	6.70	100.00
19	Cedar City PH	6.89	6.80	8.33	8.88	9.88	9.94	10.09	9.46	8.37	7.81	6.85	6.70	100.00
20	Cedar Point	6.88	6.80	8.33	8.88	9.89	9.94	10.09	9.46	8.37	7.81	6.84	6.70	100.00
21	Circleville	6.86	6.78	8.33	8.89	9.91	9.97	10.12	9.48	8.37	7.80	6.82	6.67	100.00
22	Coalville	6.69	6.68	8.31	8.96	10.07	10.15	10.28	9.59	8.39	7.72	6.68	6.48	100.00
23	Corinne	6.64	6.66	8.30	8.98	10.10	10.20	10.32	9.61	8.40	7.71	6.65	6.43	100.00
24	Cottonwood Weir	6.71	6.70	8.31	8.95	10.05	10.13	10.26	9.57	8.39	7.73	6.70	6.50	100.00
25	Cove Fort	6.83	6.77	8.33	8.90	9.93	10.00	10.14	9.49	8.38	7.79	6.80	6.64	100.00
26	Deer Creek Dam	6.72	6.70	8.32	8.94	10.03	10.12	10.25	9.57	8.39	7.74	6.71	6.51	100.00
27	Delta	6.79	6.74	8.33	8.92	9.97	10.05	10.18	9.52	8.38	7.77	6.76	6.59	100.00
28	Deseret	6.79	6.74	8.33	8.92	9.97	10.05	10.18	9.52	8.38	7.77	6.77	6.59	100.00
29	Desert Exp R	6.83	6.77	8.33	8.90	9.93	10.00	10.14	9.49	8.38	7.79	6.80	6.64	100.00
30	Duchesne	6.74	6.71	8.32	8.93	10.02	10.10	10.23	9.56	8.39	7.74	6.72	6.53	100.00
31	Dugway	6.74	6.71	8.32	8.94	10.02	10.10	10.23	9.56	8.39	7.74	6.72	6.53	100.00
32	Echo Dam	6.68	6.68	8.31	8.96	10.07	10.16	10.29	9.59	8.39	7.72	6.68	6.47	100.00
33	Elberta	6.75	6.72	8.32	8.93	10.01	10.09	10.22	9.55	8.39	7.75	6.73	6.54	100.00
34	Emery	6.81	6.75	8.33	8.91	9.95	10.02	10.16	9.51	8.38	7.78	6.78	6.62	100.00
35	Enterprise Beryl Jct	6.88	6.80	8.33	8.88	9.89	9.94	10.10	9.46	8.37	7.81	6.84	6.70	100.00
36	Ephraim Sorn FD	6.79	6.74	8.33	8.92	9.97	10.05	10.18	9.52	8.38	7.77	6.76	6.59	100.00
37	Escalante	6.88	6.80	8.33	8.89	9.89	9.94	10.10	9.46	8.37	7.81	6.84	6.69	100.00
38	Fairfield	6.73	6.71	8.32	8.94	10.03	10.11	10.24	9.56	8.39	7.74	6.72	6.52	100.00
39	Farmington USU	6.68	6.68	8.31	8.96	10.07	10.16	10.29	9.59	8.39	7.72	6.68	6.47	100.00
40	Ferron	6.80	6.75	8.33	8.91	9.96	10.04	10.17	9.51	8.38	7.78	6.77	6.60	100.00
41	Fillmore	6.81	6.75	8.33	8.91	9.95	10.03	10.16	9.51	8.38	7.78	6.78	6.61	100.00
42	Fish Spg Ref	6.76	6.72	8.32	8.93	10.00	10.08	10.21	9.54	8.39	7.75	6.74	6.55	100.00
43	Flaming Gorge	6.68	6.68	8.31	8.96	10.07	10.16	10.29	9.59	8.39	7.72	6.68	6.47	100.00
44	Fort Duchesne	6.73	6.71	8.32	8.94	10.03	10.11	10.24	9.56	8.39	7.74	6.72	6.52	100.00
45	Garfield	6.70	6.69	8.31	8.95	10.05	10.14	10.27	9.58	8.39	7.73	6.69	6.49	100.00
46	Garland	6.63	6.66	8.30	8.98	10.11	10.22	10.33	9.61	8.40	7.71	6.64	6.41	100.00
47	Garrison	6.81	6.75	8.33	8.91	9.95	10.03	10.16	9.51	8.38	7.78	6.78	6.61	100.00
48	Geneva Steel	6.73	6.71	8.32	8.94	10.03	10.11	10.24	9.56	8.39	7.74	6.71	6.52	100.00
49	Green River AVN	6.81	6.75	8.33	8.91	9.95	10.03	10.16	9.51	8.38	7.78	6.78	6.61	100.00
50	Gunnison	6.80	6.75	8.33	8.91	9.96	10.04	10.17	9.52	8.38	7.78	6.77	6.60	100.00
51	Hanksville	6.85	6.78	8.33	8.90	9.92	9.99	10.13	9.48	8.37	7.79	6.81	6.65	100.00
52	Hanna	6.72	6.70	8.32	8.94	10.04	10.12	10.25	9.57	8.39	7.74	6.71	6.51	100.00
53	Hardware Ranch	6.64	6.66	8.30	8.98	10.11	10.21	10.33	9.61	8.40	7.71	6.64	6.42	100.00
54	Heber	6.71	6.70	8.31	8.95	10.04	10.13	10.26	9.57	8.39	7.73	6.70	6.50	100.00
55	Hiawatha	6.78	6.74	8.33	8.92	9.98	10.06	10.19	9.53	8.38	7.77	6.76	6.58	100.00
56	Hovenweep Mon	6.90	6.81	8.34	8.88	9.87	9.92	10.07	9.45	8.37	7.82	6.86	6.72	100.00
57	Ibapah	6.75	6.72	8.32	8.93	10.01	10.09	10.22	9.55	8.39	7.75	6.73	6.54	100.00
58	Jensen	6.72	6.71	8.32	8.94	10.03	10.12	10.25	9.56	8.39	7.74	6.71	6.51	100.00
59	Kamas Ranger St	6.70	6.69	8.31	8.95	10.05	10.14	10.27	9.58	8.39	7.73	6.70	6.49	100.00
60	Kanab	6.92	6.82	8.34	8.87	9.85	9.89	10.05	9.44	8.37	7.83	6.88	6.74	100.00
61	Koosharem	6.84	6.77	8.33	8.90	9.93	10.00	10.14	9.49	8.38	7.79	6.80	6.64	100.00
62	Lake Town	6.62	6.66	8.30	8.98	10.12	10.23	10.34	9.61	8.40	7.70	6.63	6.40	100.00
63	LaSal	6.85	6.78	8.33	8.90	9.92	9.98	10.13	9.48	8.37	7.79	6.81	6.66	100.00
64	LaVerkin	6.91	6.81	8.34	8.87	9.86	9.90	10.06	9.45	8.37	7.82	6.87	6.73	100.00
65	Levan	6.78	6.73	8.32	8.92	9.98	10.06	10.19	9.53	8.39	7.76	6.75	6.57	100.00

Table 5. Continued.

NO	STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
66	Lewiston	6.61	6.65	8.30	8.99	10.13	10.24	10.35	9.62	8.40	7.70	6.62	6.39	100.00
67	Loa	6.85	6.77	8.33	8.90	9.92	9.99	10.13	9.49	8.37	7.79	6.81	6.65	100.00
68	Logan KVNU	6.63	6.66	8.30	8.98	10.12	10.22	10.34	9.61	8.40	7.70	6.63	6.41	100.00
69	Logan USU	6.63	6.66	8.30	8.98	10.12	10.22	10.34	9.61	8.40	7.71	6.63	6.41	100.00
70	Logan USU Exp Sta	6.63	6.66	8.30	8.98	10.12	10.22	10.34	9.61	8.40	7.70	6.63	6.41	100.00
71	Manila	6.68	6.68	8.31	8.96	10.07	10.16	10.29	9.59	8.39	7.72	6.68	6.47	100.00
72	Manti	6.80	6.74	8.33	8.91	9.97	10.04	10.17	9.52	8.38	7.77	6.77	6.59	100.00
73	Marysvale	6.84	6.77	8.33	8.90	9.92	9.99	10.13	9.49	8.37	7.79	6.81	6.65	100.00
74	Mexican Hat	6.91	6.82	8.34	8.87	9.86	9.90	10.06	9.44	8.37	7.83	6.87	6.73	100.00
75	Milford WSO	6.84	6.77	8.33	8.90	9.92	9.99	10.13	9.49	8.37	7.79	6.81	6.65	100.00
76	Moab 4 NW	6.83	6.77	8.33	8.90	9.93	10.00	10.14	9.49	8.38	7.79	6.80	6.64	100.00
77	Modena	6.88	6.80	8.33	8.89	9.89	9.95	10.10	9.46	8.37	7.81	6.84	6.69	100.00
78	Monticello	6.88	6.79	8.33	8.89	9.89	9.95	10.10	9.47	8.37	7.80	6.84	6.69	100.00
79	Monument Valley	6.92	6.82	8.34	8.87	9.85	9.89	10.05	9.44	8.37	7.83	6.88	6.74	100.00
80	Morgan	6.68	6.68	8.31	8.96	10.07	10.16	10.29	9.59	8.39	7.72	6.68	6.47	100.00
81	Moroni	6.78	6.73	8.32	8.92	9.98	10.06	10.19	9.53	8.39	7.76	6.75	6.57	100.00
82	Mountain Dell Dam	6.70	6.69	8.31	8.95	10.06	10.14	10.27	9.58	8.39	7.73	6.69	6.49	100.00
83	Myton	6.74	6.71	8.32	8.94	10.02	10.10	10.23	9.56	8.39	7.74	6.72	6.53	100.00
84	Neola	6.72	6.70	8.32	8.94	10.03	10.12	10.25	9.57	8.39	7.74	6.71	6.51	100.00
85	Nephi	6.77	6.73	8.32	8.92	9.99	10.07	10.20	9.54	8.39	7.76	6.74	6.56	100.00
86	New Harmony	6.90	6.81	8.34	8.88	9.87	9.92	10.08	9.45	8.37	7.82	6.86	6.71	100.00
87	Oak City	6.79	6.74	8.33	8.92	9.97	10.05	10.18	9.53	8.38	7.77	6.76	6.58	100.00
88	Ogden Pioneer PH	6.66	6.67	8.31	8.97	10.09	10.18	10.30	9.60	8.39	7.71	6.67	6.45	100.00
89	Ogden Sugar FCT	6.66	6.67	8.31	8.97	10.08	10.18	10.30	9.60	8.39	7.72	6.67	6.45	100.00
90	Orderville	6.91	6.81	8.34	8.88	9.86	9.91	10.07	9.45	8.37	7.82	6.87	6.72	100.00
91	Ouray	6.74	6.71	8.32	8.93	10.02	10.10	10.23	9.56	8.39	7.75	6.92	6.63	100.00
92	Panguitch	6.88	6.80	8.33	8.89	9.89	9.95	10.10	9.46	8.37	7.81	6.84	6.69	100.00
93	Park Valley	6.62	6.66	8.30	8.98	10.12	10.22	10.34	9.61	8.40	7.70	6.63	6.41	100.00
94	Partoun	6.77	6.73	8.32	8.92	9.99	10.07	10.20	9.54	8.39	7.76	6.75	6.56	100.00
95	Parowan	6.88	6.79	8.33	8.89	9.89	9.95	10.10	9.47	8.37	7.80	6.84	6.69	100.00
96	Pine View Dam	6.66	6.67	8.31	8.97	10.09	10.18	10.30	9.60	8.39	7.71	6.67	6.45	100.00
97	Piute Dam	6.85	6.78	8.33	8.90	9.92	9.98	10.13	9.48	8.37	7.79	6.81	6.66	100.00
98	Pleasant Grove	6.72	6.71	8.32	8.94	10.03	10.12	10.25	9.56	8.39	7.74	6.71	6.51	100.00
99	Price Warehouses	6.77	6.73	8.32	8.92	9.99	10.07	10.20	9.53	8.39	7.76	6.75	6.57	100.00
100	Provo KOVO	6.73	6.71	8.32	8.94	10.02	10.11	10.24	9.56	8.39	7.74	6.72	6.52	100.00
101	Richfield Radio KSVC	6.82	6.76	8.33	8.91	9.94	10.01	10.15	9.50	8.38	7.78	6.79	6.63	100.00
102	Richmond	6.62	6.65	8.30	8.99	10.12	10.23	10.34	9.62	8.40	7.70	6.63	6.40	100.00
103	Riverdale PH	6.67	6.68	8.31	8.96	10.08	10.17	10.30	9.59	8.39	7.72	6.67	6.46	100.00
104	Roosevelt	6.73	6.71	8.32	8.94	10.03	10.11	10.24	9.56	8.39	7.74	6.71	6.52	100.00
105	St. George	6.91	6.82	8.34	8.87	9.86	9.90	10.06	9.44	8.37	7.83	6.87	6.73	100.00
106	Salina	6.81	6.75	8.33	8.91	9.95	10.03	10.16	9.51	8.38	7.78	6.78	6.61	100.00
107	Saltair Salt PL	6.70	6.69	8.31	8.95	10.06	10.14	10.27	9.58	8.39	7.73	6.69	6.49	100.00
108	SLC WSFO	6.70	6.69	8.31	8.95	10.06	10.14	10.27	9.58	8.39	7.73	6.69	6.49	100.00
109	Santaquin	6.75	6.72	8.32	8.93	10.01	10.09	10.22	9.55	8.39	7.75	6.73	6.54	100.00
110	Scipio	6.80	6.74	8.33	8.91	9.97	10.04	10.17	9.52	8.38	7.77	6.77	6.59	100.00
111	Scofield Dam	6.76	6.73	8.32	8.93	10.00	10.08	10.21	9.54	8.39	7.76	6.74	6.56	100.00
112	Silver L. Brighton	6.71	6.70	8.31	8.95	10.05	10.13	10.26	9.57	8.39	7.73	6.70	6.50	100.00
113	Snake Creek PH	6.71	6.70	8.31	8.95	10.04	10.13	10.26	9.57	8.39	7.73	6.70	6.50	100.00
114	Snowville	6.61	6.65	8.30	8.99	10.13	10.24	10.35	9.62	8.40	7.70	6.62	6.39	100.00
115	Soldier Summit	6.75	6.72	8.32	8.93	10.00	10.09	10.21	9.55	8.39	7.75	6.73	6.55	100.00
116	Spanish Fork PH	6.74	6.72	8.32	8.93	10.01	10.10	10.23	9.55	8.39	7.75	6.73	6.53	100.00
117	Strawberry RES E P	6.74	6.71	8.32	8.93	10.02	10.10	10.23	9.56	8.39	7.74	6.72	6.53	100.00
118	Thompson	6.81	6.75	8.33	8.91	9.95	10.03	10.16	9.51	8.38	7.78	6.78	6.61	100.00
119	Timpanogas Cave	6.72	6.70	8.32	8.94	10.04	10.12	10.25	9.57	8.39	7.74	6.71	6.51	100.00
120	Tooele	6.71	6.70	8.31	8.95	10.04	10.13	10.26	9.57	8.39	7.73	6.70	6.50	100.00
121	Tropic	6.89	6.80	8.33	8.88	9.88	9.93	10.09	9.46	8.37	7.81	6.85	6.70	100.00
122	U of U	6.70	6.69	8.31	8.95	10.06	10.14	10.27	9.58	8.39	7.73	6.69	6.49	100.00
123	Utah Lake Lehi	6.72	6.71	8.32	8.94	10.03	10.12	10.25	9.56	8.39	7.74	6.71	6.51	100.00
124	Vernal Airport	6.72	6.70	8.32	8.94	10.04	10.12	10.25	9.57	8.39	7.74	6.71	6.51	100.00
125	Veyo PH	6.90	6.81	8.34	8.88	9.87	9.91	10.07	9.45	8.37	7.82	6.86	6.72	100.00
126	Wah Wah Ranch	6.84	6.77	8.33	8.90	9.92	9.99	10.13	9.49	8.37	7.79	6.81	6.65	100.00
127	Wanship Dam	6.69	6.69	8.31	8.95	10.06	10.15	10.28	9.58	8.39	7.73	6.69	6.48	100.00
128	Wendover WSO	6.70	6.69	8.31	8.95	10.05	10.14	10.27	9.58	8.39	7.73	6.69	6.49	100.00
129	Woodruff	6.64	6.66	8.30	8.98	10.10	10.20	10.32	9.61	8.40	7.71	6.65	6.43	100.00
130	Zions National Park	6.91	6.81	8.34	8.87	9.86	9.91	10.06	9.45	8.37	7.82	6.87	6.73	100.00

Table 6. Mean monthly temperatures in degrees Fahrenheit for Utah weather station.

NO	STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1	Altamont	17.5	24.0	33.1	43.5	52.8	60.8	67.9	65.6	57.3	46.4	32.8	21.1	43.6
2	Alton	27.1	29.7	33.2	42.2	50.5	58.4	66.2	64.5	58.0	48.2	36.9	29.5	45.4
3	Antelope Island	28.5	33.7	40.4	48.9	59.1	68.2	78.7	76.5	65.7	53.4	39.5	30.2	51.9
4	Bear River Refuge	24.6	30.5	38.8	49.9	59.7	66.9	76.0	73.6	64.1	52.4	38.5	29.3	50.4
5	Beaver	27.7	31.7	36.9	45.3	53.9	61.8	69.3	67.6	60.0	48.9	36.8	29.6	47.5
6	Bingham Canyon	27.5	30.7	35.3	44.7	54.2	62.0	72.0	69.7	61.6	50.3	37.4	29.8	47.9
7	Birdseye	20.5	25.3	33.0	40.7	50.4	57.7	65.0	63.3	54.0	45.1	33.3	21.9	42.5
8	Black Rock	25.4	32.3	39.8	47.3	56.1	64.7	72.5	69.3	61.0	49.2	37.5	26.8	48.6
9	Blanding	27.7	32.9	38.3	47.4	56.9	65.8	73.3	70.8	63.3	51.7	38.2	29.8	49.7
10	Bluff	31.1	38.2	44.9	54.2	63.2	71.7	78.7	76.4	67.8	55.5	41.7	32.3	54.6
11	Bonanza	19.7	26.2	37.2	48.5	59.0	67.2	75.1	72.4	63.6	51.6	36.2	24.9	48.5
12	Boulder	26.7	31.4	37.6	44.5	55.0	64.4	71.3	68.9	61.3	50.8	37.6	28.9	48.2
13	Brigham City	26.9	32.6	39.3	49.3	59.3	66.9	76.9	74.3	64.3	52.9	39.4	30.5	51.1
14	Bryce Canyon FAA AP	19.8	23.2	28.7	37.7	46.2	54.1	61.6	59.9	52.9	42.8	30.7	22.4	40.0
15	Bryce Canyon NP HDQ	17.9	21.0	30.3	34.3	45.8	55.2	60.7	58.3	50.8	39.7	27.3	20.6	38.4
16	Capitol Reef NT MON	29.7	35.4	42.7	52.1	61.2	69.6	76.9	74.4	67.3	55.6	41.5	31.7	53.2
17	Castle Dale	19.7	26.8	37.5	45.9	55.2	64.2	70.4	68.1	59.1	48.0	34.2	23.8	46.0
18	Cedar City FAA AP	28.7	33.1	38.4	47.1	56.2	65.0	73.2	71.3	63.2	51.5	38.8	30.8	49.8
19	Cedar City PH	30.2	34.1	39.9	47.7	56.9	66.6	73.6	71.4	63.7	52.1	40.1	31.7	50.7
20	Cedar Point	25.6	28.9	35.2	43.7	54.0	64.0	70.4	68.0	60.7	48.4	35.8	26.7	46.7
21	Circleville	27.4	31.1	36.9	43.7	53.5	62.3	70.5	68.0	59.2	48.9	37.1	28.0	47.2
22	Coalville	23.4	27.8	33.7	43.2	51.6	57.8	65.7	63.8	56.0	46.8	34.6	26.3	44.2
23	Corinne	24.5	30.2	37.8	48.0	57.4	64.6	73.9	71.6	62.0	50.6	37.4	28.5	48.9
24	Cottonwood Weir	31.0	35.9	41.6	50.9	60.3	68.6	79.5	77.5	68.5	56.0	41.7	33.0	53.7
25	Cove Fort	29.0	29.2	35.9	43.7	53.6	62.5	71.9	70.1	61.2	49.3	35.4	28.9	47.5
26	Deer Creek Dam	19.6	23.3	31.2	42.4	51.5	58.6	67.1	65.6	56.5	46.1	33.8	25.4	43.4
27	Delta	25.5	32.1	39.4	48.3	58.2	67.0	76.3	74.1	63.9	51.6	37.2	28.4	50.1
28	Deseret	25.5	32.2	39.3	47.9	57.0	64.6	73.9	71.6	62.0	50.4	37.0	28.4	49.2
29	Desert Exp R	26.6	32.7	37.3	46.0	56.0	64.4	73.7	71.6	62.1	50.4	38.0	28.3	48.9
30	Duchesne	17.9	24.6	34.9	45.9	55.4	62.8	70.2	67.9	59.3	48.1	33.6	22.5	45.3
31	Dugway	27.6	33.9	40.1	48.7	59.4	68.8	77.3	75.9	66.6	53.3	37.9	29.2	51.1
32	Echo Dam	23.1	27.6	33.7	43.8	52.7	59.6	68.4	66.8	58.0	47.9	35.0	26.5	45.3
33	Elberta	27.3	32.7	39.4	48.6	57.6	65.4	74.4	72.7	63.3	51.6	39.0	30.1	50.2
34	Emery	24.3	29.0	35.7	44.7	53.5	61.1	68.3	66.1	58.7	48.5	35.4	27.2	46.0
35	Enterprise Beryl Jct	26.7	32.5	38.0	45.3	54.6	62.5	70.2	68.8	59.9	48.6	36.2	28.6	47.7
36	Ephraim Sorn FD	23.8	28.5	36.1	44.0	54.1	63.3	70.3	69.3	60.3	49.8	35.8	26.0	46.8
37	Escalante	26.9	32.5	38.7	47.2	55.8	63.7	70.8	68.4	61.4	50.7	38.2	29.2	48.6
38	Fairfield	24.3	29.7	36.9	44.8	54.0	62.2	70.1	68.1	59.1	48.0	34.8	25.7	46.5
39	Farmington USU	28.7	34.3	40.6	49.8	58.9	66.3	75.7	74.0	64.4	53.6	40.2	31.6	51.5
40	Ferron	22.2	26.9	35.1	45.8	56.4	65.4	72.4	69.7	63.9	50.4	36.3	26.5	47.5
41	Fillmore	29.0	34.2	40.4	49.3	58.4	66.8	76.2	74.3	65.8	53.8	40.1	31.3	51.6
42	Fish Spg Ref	28.7	36.3	42.5	49.6	61.2	70.0	80.0	77.5	66.1	53.5	40.7	29.6	53.0
43	Flaming Gorge	21.2	26.0	36.2	41.2	51.7	60.3	67.9	66.0	56.6	46.1	33.5	23.8	44.0
44	Fort Duchesne	14.6	22.2	34.2	46.2	55.9	63.5	70.8	68.8	59.8	48.2	33.2	20.9	44.9
45	Garfield	29.4	34.3	41.3	49.8	60.8	70.0	79.7	77.1	66.2	53.6	40.8	31.3	52.9
46	Garland	22.8	28.9	37.0	46.4	56.5	64.6	73.6	71.5	61.4	49.6	36.9	26.8	48.0
47	Garrison	28.2	33.7	40.1	47.9	56.6	65.5	74.2	71.9	62.4	50.3	38.9	29.4	49.8
48	Geneva Steel	28.6	33.7	41.0	48.5	59.2	68.0	76.9	74.5	65.0	53.1	38.6	30.2	51.4
49	Green River AVN	24.1	33.6	42.0	52.4	62.2	70.3	78.2	75.8	66.2	53.5	38.3	28.0	52.1
50	Gunnison	25.7	31.6	38.4	44.9	55.4	64.1	71.3	69.2	59.7	49.3	36.5	26.8	47.8
51	Hanksville	26.1	33.9	42.5	52.9	62.9	71.9	79.4	76.9	67.6	54.7	39.4	28.9	53.1
52	Hanna	20.5	25.0	31.3	39.5	49.8	57.5	65.2	63.1	55.0	45.3	32.4	22.9	42.3
53	Hardware Ranch	21.1	24.7	30.9	39.4	48.5	55.7	62.2	61.1	51.6	43.5	32.5	22.3	41.7
54	Heber	20.7	25.5	33.2	43.2	51.9	58.4	66.9	65.3	57.1	47.4	34.5	25.2	44.1
55	Hiawatha	23.7	27.5	32.9	43.2	52.6	61.2	69.2	66.9	59.6	48.5	34.1	26.1	45.5
56	Hovenweep Mon	25.2	34.1	41.2	49.1	59.9	69.0	76.6	74.1	65.2	53.2	39.9	28.2	51.3
57	Ibapah	25.1	30.1	36.7	44.3	52.1	60.5	69.0	67.3	57.7	46.6	25.8	25.6	45.1
58	Jensen	14.8	22.4	35.0	47.1	57.1	64.4	72.1	69.5	60.3	48.5	33.7	21.1	45.5
59	Kamas Ranger St	23.7	26.0	30.7	39.8	49.7	57.9	66.2	64.3	55.8	46.1	33.9	27.3	43.4
60	Kanab	35.2	39.3	43.9	52.1	60.6	69.1	76.4	74.4	68.0	57.3	45.1	36.9	54.9
61	Koosharem	24.9	27.3	33.4	40.0	49.8	58.5	65.3	63.3	55.5	44.5	33.7	24.7	43.4
62	Lake Town	21.2	22.9	28.3	40.2	49.9	56.4	65.0	63.3	55.0	44.7	32.8	24.9	42.1
63	LaSal	23.5	28.3	35.2	43.4	53.2	62.3	68.9	67.1	59.0	48.1	35.9	25.6	46.7
64	LaVerkin	38.1	43.5	48.9	55.7	64.5	73.4	80.1	78.4	70.8	59.9	47.1	38.9	58.3
65	Levan	26.0	31.2	38.1	47.4	56.1	64.1	73.1	71.3	62.9	51.6	38.4	29.4	49.1

Table 6. Continued.

NO	STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
66	Lewiston	21.0	26.5	34.2	45.1	54.2	60.8	69.5	67.6	58.2	47.4	34.9	25.3	45.4
67	Loa	23.2	27.3	32.3	41.0	49.7	57.3	64.4	62.3	55.2	45.3	33.0	24.7	43.0
68	Logan KVNU	22.1	28.7	30.5	45.7	55.8	63.8	72.2	70.4	59.7	48.5	35.9	25.6	46.6
69	Logan USU	24.0	28.9	36.1	46.9	56.3	63.1	72.9	71.4	62.0	50.7	36.7	27.5	48.0
70	Logan USU Exp Sta	24.1	28.5	36.2	45.7	55.7	63.4	71.5	69.9	60.4	49.7	36.5	26.2	47.3
71	Manila	22.2	26.2	34.1	41.7	50.9	60.1	67.8	65.8	57.1	46.4	33.6	23.5	44.1
72	Manti	25.8	30.2	37.1	46.1	54.7	62.3	70.1	68.6	60.6	50.0	37.0	28.5	47.6
73	Marysvale	28.5	32.8	37.6	44.7	54.7	63.3	69.5	67.7	59.6	49.6	37.3	29.2	47.9
74	Mexican Hat	33.3	39.0	46.1	56.0	66.1	75.3	82.3	79.7	72.3	57.8	43.5	35.4	57.2
75	Milford WSO	25.7	31.4	38.1	47.2	56.5	65.2	74.3	72.6	63.0	50.7	37.3	28.6	49.2
76	Moab 4 NW	30.5	37.8	46.1	56.5	66.2	74.2	81.3	78.7	70.1	57.6	43.2	33.3	56.3
77	Modena	27.8	32.8	38.0	46.4	55.0	63.7	72.0	70.2	62.1	50.7	38.1	29.9	48.9
78	Monticello	25.9	29.5	34.6	44.1	52.9	61.2	68.6	66.3	59.5	49.1	36.3	28.3	46.4
79	Monument Valley	31.5	38.4	46.1	52.7	64.7	74.2	80.5	78.1	70.5	57.7	44.0	34.4	56.1
80	Morgan	22.9	27.9	34.7	44.5	53.4	60.3	68.5	66.7	57.5	47.7	34.5	26.1	45.4
81	Moroni	23.5	32.8	37.2	44.4	52.9	61.7	69.0	68.3	58.1	49.4	36.1	26.2	46.6
82	Mountain Dell Dam	25.8	29.5	35.0	44.7	53.5	59.9	68.8	67.4	58.8	48.7	36.3	28.2	46.4
83	Myton	14.9	23.6	35.1	47.1	56.8	65.2	72.1	70.2	61.3	48.9	33.5	23.7	45.8
84	Neola	17.9	24.5	34.1	43.2	54.0	61.9	68.5	66.7	57.3	46.8	31.8	21.6	44.0
85	Nephi	28.7	32.9	39.4	48.5	57.5	66.2	76.1	73.1	65.0	53.6	40.1	31.5	51.1
86	New Harmony	33.1	36.6	41.1	48.1	54.8	66.6	73.8	68.9	64.6	54.3	40.4	34.2	51.4
87	Oak City	28.9	34.4	40.6	49.6	59.1	67.8	78.0	75.8	66.4	54.7	40.1	31.5	52.2
88	Ogden Pioneer PH	27.8	33.1	39.7	49.6	59.3	66.9	76.9	74.7	65.1	53.3	39.4	30.8	51.4
89	Ogden Sugar FCT	27.4	32.8	39.4	49.1	58.4	65.8	75.3	73.2	63.6	52.5	39.3	31.1	50.7
90	Orderville	30.5	34.7	39.1	46.8	56.3	65.5	72.6	70.5	63.1	52.4	40.3	32.1	50.5
91	Ouray	14.9	23.3	37.2	48.0	59.2	67.8	74.6	71.9	61.3	49.0	33.3	19.2	46.6
92	Panguitch	23.5	27.7	33.4	42.1	50.1	57.6	64.6	62.9	55.8	45.8	34.1	25.6	43.6
93	Park Valley	24.4	29.0	34.8	44.0	53.5	60.7	71.8	69.9	60.4	49.1	35.6	27.0	46.7
94	Partoun	27.0	33.1	39.0	47.4	57.3	66.6	75.3	73.0	62.7	50.9	37.8	28.1	49.9
95	Parowan	29.6	34.1	38.7	47.3	56.2	64.6	72.0	69.8	62.8	52.1	40.0	32.2	50.0
96	Pine View Dam	19.7	24.4	32.6	44.8	54.3	61.1	70.5	68.5	59.5	48.6	33.8	24.2	45.2
97	Piute Dam	27.5	31.9	37.2	46.0	54.8	63.1	71.3	69.7	61.3	50.5	38.6	30.1	48.5
98	Pleasant Grove	29.1	34.1	40.2	48.3	57.7	65.7	74.3	71.9	62.8	52.0	39.5	30.7	50.5
99	Price Warehouses	23.0	30.7	39.5	47.8	57.5	65.4	73.4	71.4	62.7	51.4	36.5	26.8	48.8
100	Provo KOVO	26.5	32.5	40.3	48.3	56.7	64.6	72.4	70.3	60.9	50.1	38.8	28.9	49.2
101	Richfield Radio KSVC	28.1	32.8	38.9	47.0	55.5	63.2	70.7	69.2	60.8	50.0	38.0	30.2	48.7
102	Richmond	25.3	28.3	36.9	46.0	54.6	62.4	71.3	70.1	60.1	49.0	37.1	28.0	47.5
103	Riverdale PH	27.7	33.0	39.6	49.2	58.2	65.9	75.3	73.3	63.8	52.7	39.4	30.8	50.7
104	Roosevelt	17.0	24.3	36.3	47.7	57.3	64.8	72.4	70.1	61.1	49.3	34.7	22.4	46.5
105	St. George	39.9	45.9	51.6	60.1	68.9	77.1	84.3	82.6	74.9	62.9	49.2	40.9	61.5
106	Salina	29.3	31.0	39.5	48.5	56.9	65.5	73.1	71.1	62.3	49.1	37.2	28.5	49.3
107	Saltair Salt PL	26.5	33.4	39.7	47.7	56.6	71.8	76.6	74.0	63.0	51.0	38.9	29.8	50.6
108	SLC WSFO	28.0	33.4	39.6	49.2	58.3	66.2	76.7	74.5	64.8	52.4	39.1	30.3	51.0
109	Santaquin	27.7	32.1	38.3	47.9	57.2	65.3	74.8	73.0	64.1	52.0	38.7	30.1	50.1
110	Scipio	24.4	30.2	37.2	45.9	54.7	62.3	71.2	69.5	60.3	49.2	36.2	27.8	47.4
111	Scofield Dam	13.6	17.3	25.0	35.7	45.7	54.3	61.1	59.3	52.2	41.5	27.9	17.2	38.1
112	Silver L Brighton	19.0	20.4	23.5	32.2	41.2	49.2	57.9	56.3	48.9	39.2	27.5	21.2	36.4
113	Snake Creek PH	22.0	25.7	31.9	42.0	50.7	57.7	65.3	63.7	55.8	45.9	33.0	25.1	43.2
114	Snowville	21.7	26.5	34.7	43.9	51.9	60.6	68.2	66.5	57.1	46.3	34.7	24.2	44.7
115	Soldier Summit	17.5	20.3	28.1	37.7	46.4	53.7	61.1	59.9	51.5	40.7	28.2	19.5	38.7
116	Spanish Fork PH	28.8	33.7	40.2	49.7	59.0	67.4	76.0	74.0	65.2	53.9	40.5	31.6	51.7
117	Strawberry RES E P	11.3	15.8	22.4	32.8	43.8	51.5	58.4	56.9	49.0	40.0	28.6	16.7	35.6
118	Thompson	27.2	34.2	41.6	51.9	61.9	70.8	78.5	76.0	67.7	55.8	40.6	30.3	53.0
119	Timpanogas Cave	26.1	32.8	38.1	46.4	56.3	64.3	73.3	71.5	63.2	51.6	36.7	28.3	49.1
120	Tooele	28.9	33.3	39.3	48.8	58.2	66.2	76.1	74.0	64.4	52.2	39.2	31.0	51.0
121	Tropic	28.3	32.5	37.4	45.5	53.9	61.7	68.7	66.2	59.6	50.3	38.5	30.7	47.8
122	U of U	29.8	35.1	41.2	47.9	58.7	67.9	77.1	74.4	77.2	53.5	41.1	31.3	52.9
123	Utah Lake Lehi	26.1	31.5	38.1	47.4	56.4	64.0	72.3	70.6	61.0	49.8	37.5	29.2	48.7
124	Vernal Airport	16.1	23.3	34.1	45.5	54.9	62.2	69.6	67.6	58.9	47.4	33.1	21.2	44.5
125	Veyo PH	34.0	38.7	43.4	50.1	59.8	69.3	75.8	74.0	66.1	55.8	43.5	36.0	53.9
126	Wah Wah Ranch	28.0	34.4	40.5	47.4	58.1	67.9	76.0	73.5	63.7	51.6	38.3	29.6	50.8
127	Wanship Dam	23.3	27.0	33.1	41.4	50.9	58.3	65.0	64.0	55.2	45.7	33.9	25.6	43.6
128	Wendover WSO	27.4	34.2	41.1	50.8	60.8	69.2	79.3	76.7	66.2	52.8	38.6	29.7	52.2
129	Woodruff	14.9	18.7	26.2	38.4	47.5	54.4	62.2	60.4	51.7	41.5	28.5	19.1	38.6
130	Zions National Park	40.2	44.6	49.3	58.0	67.5	76.7	84.2	81.8	75.7	64.0	50.4	41.6	61.2

Table 7. Values of the climatic coefficient, k_t, for various mean monthly air temperatures, t.[a]

t °F	k_t	t °F	k_t	t °F	k_t
36	0.31	61	0.74	86	1.17
37	0.33	62	0.76	87	1.19
38	0.34	63	0.78	88	1.21
39	0.36	64	0.79	89	1.23
40	0.38	65	0.81	90	1.24
41	0.40	66	0.83	91	1.26
42	0.41	67	0.85	92	1.28
43	0.43	68	0.86	93	1.30
44	0.45	69	0.88	94	1.31
45	0.46	70	0.90	95	1.33
46	0.48	71	0.91	96	1.35
47	0.50	72	0.93	97	1.36
48	0.52	73	0.95	98	1.38
49	0.53	74	0.97	99	1.40
50	0.55	75	0.98	100	1.42
51	0.57	76	1.00		
52	0.59	77	1.02		
53	0.60	78	1.04		
54	0.62	79	1.05		
55	0.64	80	1.07		
56	0.66	81	1.09		
57	0.67	82	1.11		
58	0.69	83	1.12		
59	0.71	84	1.14		
60	0.72	85	1.16		

[a]Values of k_t are based on the formula, $k_t = 0.173\ t - 0.314$, for mean monthly temperatures less than 36°, use $k_t = 0.300$.

where plant cover is not so variable with stage of growth, the values of the coefficient, k_c, are best plotted against the actual months.

Example calculations of seasonal consumptive use by use of Equation 6 are shown in Tables 8 and 9. An annual crop, corn, grown near Logan, Utah, is used for the first example. A perennial crop, alfalfa, grown near Milford, Utah, is used for the second example. For the set of long term weather stations, calculations of the mean monthly consumptive use factor, f, have been made and are tabulated in Table 10. Thus, for these

Table 8. Sample calculation of average daily, monthly, and seasonal consumptive use by corn at Logan, Utah.

(1) Growing Period by Month	(2) Days in Period	(3) Percent of Growing Season to Midpoint of Period	(4) Fraction of Month Crop is Growing, r	(5) Mean Air Temperature °F, t	(6) Percent Daylight Hours, p	(7) B-C Consumptive Use Factor, f	(8) Climatic Coefficient, k_t	(9) Crop Growth Stage Coefficient, k_c	(10) B-C Consumptive Use Coefficient, k	(11) Average Monthly CU Inches, u	(12) Average Period CU Inches	(13) Average Daily CU Inches/Day
(Table 3)				(Table 6)	(Table 5)	((4) x (5) x (6) ÷ 100)	(Table 7)	(Col. 3 and Figure A-3)	((8) x (9))	((7) x (10))	((4) x (11))	((12) ÷ (2))
May 7-31	24	10.0	0.77	56.3	10.12	4.39	0.66	0.43	0.28	1.23	0.95	0.04
June 1-30	30	32.5	1.00	63.1	10.22	6.45	0.78	0.64	0.50	3.23	3.23	0.11
July 1-31	31	57.9	1.00	72.9	10.34	7.53	0.94	1.02	0.96	7.22	7.22	0.23
Aug. 1-31	31	84.6	1.00	71.4	9.61	6.86	0.92	1.02	0.94	7.08	7.08	0.23
Sept. 1-4	4	98.3	0.13	62.0	8.40	0.67	0.82	0.89	0.73	0.49	0.38	0.10
Growing Season Total	120										18.86	0.16

Table 9. Sample calculation of average daily, monthly, and seasonal consumptive use by alfalfa at Milford, Utah.

(1) Growing Period by Month	(2) Days in Period (Table 2)	(3) Date of Midpoint of Period	(4) Fraction of Month Crop is Growing, r	(5) Mean Air Temperature ^oF, t (Table 6)	(6) Percent Daylight Hours, p (Table 5)	(7) B-C Consumptive Use Factor, f ((4) x (5) x (6) ÷ 100)	(8) Climatic Coefficient, k_t (Table 7)	(9) Crop Growth Stage Coefficient, k_c (Col. 3 + Figure A-2)	(10) B-C Consumptive Use Coefficient, k ((8) x (9))	(11) Average Monthly CU Inches, u ((7) x (10))	(12) Average Period CU Inches ((4) x (11))	(13) Average Daily CU Inches/Day ((12) ÷ (2))
May 2-31	29	May 16	0.94	56.5	9.92	5.61	0.66	1.08	0.71	3.98	3.74	0.13
June 1-30	30	June 15	1.00	65.2	9.99	6.51	0.81	1.13	0.92	5.99	5.99	0.20
July 1-31	31	July 15	1.00	74.3	10.13	7.53	0.97	1.11	1.08	8.13	8.13	0.26
August 1-31	31	Aug. 15	1.00	72.6	9.49	6.89	0.94	1.06	1.00	6.89	6.89	0.22
Sept. 1-30	30	Sept. 15	1.00	63.0	8.37	5.28	0.78	0.99	0.77	4.07	4.07	0.14
Oct. 1-9	9	Oct. 5	0.29	50.7	7.79	3.95	0.56	0.94	0.53	2.09	0.61	0.07
Growing Season Total	160			65.59		32.63			0.90		29.43	0.18

Table 10. Average monthly consumptive use factors, f, Utah stations.

NO	STATION	AV(28F)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	Altamont	29.80	1.18	1.61	2.75	3.89	5.30	6.15	6.96	6.27	4.81	3.59	2.20	1.37
2	Alton	25.95	1.87	2.02	2.77	3.75	4.99	5.79	6.67	6.10	4.85	3.77	2.53	1.98
3	Antelope Island	40.42	1.91	2.25	3.36	4.38	5.95	6.93	8.09	7.33	5.51	4.12	2.64	1.96
4	Bear River Refuge	38.64	1.64	2.03	3.22	4.48	6.03	6.82	7.84	7.07	5.38	4.04	2.56	1.88
5	Beaver	26.69	1.90	2.15	3.07	4.03	5.34	6.17	7.02	6.41	5.02	3.81	2.51	1.97
6	Bingham Canyon	36.34	1.85	2.06	2.94	4.00	5.44	6.28	7.39	6.67	5.17	3.89	2.51	1.94
7	Birdseye	18.39	1.39	1.70	2.75	3.63	5.04	5.82	6.64	6.04	4.53	3.50	2.24	1.43
8	Black Rock	28.61	1.73	2.18	3.32	4.21	5.57	6.48	7.36	6.58	5.11	3.83	2.55	1.78
9	Blanding	34.30	1.91	2.24	3.19	4.21	5.62	6.54	7.39	6.70	5.30	4.04	2.62	2.00
10	Bluff	42.60	2.15	2.60	3.74	4.81	6.23	7.11	7.92	7.22	5.67	4.34	2.86	2.17
11	Bonanza	35.01	1.33	1.76	3.09	4.33	5.91	6.78	7.68	6.91	5.34	4.00	2.44	1.63
12	Boulder	32.84	1.84	2.13	3.13	3.96	5.44	6.41	7.20	6.52	5.13	3.96	2.57	1.93
13	Brigham City	38.64	1.79	2.17	3.26	4.42	5.99	6.82	7.94	7.14	5.40	4.08	2.62	1.96
14	Bryce Canyon FAA AP	16.91	1.36	1.58	2.39	3.35	4.57	5.38	6.22	5.67	4.43	3.34	2.10	1.50
15	Bryce Canyon NP HDQ	16.67	1.23	1.43	2.53	3.05	4.53	5.48	6.12	5.51	4.25	3.10	1.87	1.38
16	Capitol Reef NT MON	36.78	2.04	2.40	3.56	4.63	6.07	6.95	7.79	7.05	5.63	4.33	2.83	2.11
17	Castle Dale	28.72	1.34	1.81	3.12	4.09	5.50	6.45	7.16	6.48	4.95	3.73	2.32	1.57
18	Cedar City FAA AP	33.13	1.98	2.25	3.20	4.18	5.56	6.46	7.39	6.75	5.29	4.02	2.66	2.06
19	Cedar City PH	35.76	2.08	2.32	3.32	4.24	5.62	6.62	7.43	6.75	5.33	4.07	2.75	2.12
20	Cedar Point	28.50	1.76	1.96	2.93	3.88	5.34	6.36	7.11	6.43	5.08	3.78	2.45	1.79
21	Circleville	27.95	1.88	2.11	3.07	3.89	5.30	6.21	7.13	6.44	4.96	3.81	2.53	1.87
22	Coalville	21.10	1.56	1.86	2.80	3.87	5.19	5.87	6.76	6.12	4.70	3.61	2.31	1.70
23	Corinne	34.19	1.63	2.01	3.14	4.31	5.80	6.59	7.63	6.88	5.21	3.90	2.49	1.83
24	Cottonwood Weir	42.83	2.08	2.40	3.46	4.55	6.06	6.95	8.16	7.42	5.75	4.33	2.79	2.14
25	Cove Fort	27.56	1.98	1.98	2.99	3.89	5.32	6.25	7.29	6.66	5.13	3.84	2.41	1.92
26	Deer Creek Dam	22.61	1.32	1.56	2.59	3.79	5.17	5.93	6.88	6.28	4.74	3.57	2.27	1.65
27	Delta	35.41	1.73	2.16	3.28	4.31	5.80	6.73	7.77	7.06	5.36	4.01	2.52	1.87
28	Deseret	32.17	1.73	2.17	3.27	4.27	5.68	6.49	7.52	6.82	5.20	3.92	2.50	1.87
29	Desert Exp R	31.21	1.82	2.21	3.11	4.09	5.56	6.44	7.47	6.80	5.20	3.93	2.58	1.88
30	Duchesne	28.40	1.21	1.65	2.90	4.10	5.55	6.34	7.18	6.49	4.98	3.73	2.26	1.47
31	Dugway	39.04	1.86	2.28	3.34	4.35	5.95	6.95	7.91	7.25	5.59	4.13	2.55	1.91
32	Echo Dam	25.95	1.54	1.84	2.80	3.92	5.31	6.05	7.04	6.41	4.87	3.70	2.34	1.72
33	Elberta	34.60	1.84	2.20	3.28	4.34	5.76	6.60	7.60	6.94	5.31	4.00	2.63	1.97
34	Emery	28.33	1.66	1.96	2.97	3.98	5.32	6.12	6.94	6.28	4.92	3.77	2.40	1.80
35	Enterprise Beryl Jct	25.24	1.84	2.21	3.17	4.02	5.40	6.21	7.09	6.51	5.01	3.79	2.48	1.91
36	Ephraim Sorn FD	30.52	1.62	1.92	3.01	3.92	5.39	6.36	7.16	6.60	5.06	3.87	2.42	1.71
37	Escalante	30.34	1.85	2.21	3.22	4.19	5.52	6.33	7.15	6.47	5.14	3.96	2.61	1.95
38	Fairfield	26.04	1.64	1.99	3.07	4.00	5.41	6.29	7.18	6.51	4.96	3.72	2.34	1.66
39	Farmington USU	38.38	1.92	2.29	3.37	4.46	5.93	6.74	7.79	7.10	5.40	4.14	2.68	2.04
40	Ferron	33.94	1.51	1.81	2.92	4.08	5.62	6.56	7.36	6.63	5.36	3.92	2.46	1.75
41	Fillmore	38.12	1.98	2.31	3.37	4.39	5.81	6.70	7.74	7.06	5.51	4.19	2.72	2.07
42	Fish Spg Ref	41.56	1.94	2.44	3.54	4.43	6.12	7.06	8.17	7.40	5.54	4.15	2.74	1.94
43	Flaming Gorge	26.22	1.42	1.74	3.01	3.69	5.20	6.12	6.98	6.33	4.75	3.56	2.24	1.54
44	Fort Duchesne	28.70	0.98	1.49	2.84	4.13	5.61	6.42	7.25	6.58	5.02	3.73	2.23	1.36
45	Garfield	44.23	1.97	2.30	3.43	4.46	6.11	7.10	8.19	7.39	5.55	4.14	2.73	2.03
46	Garland	34.09	1.51	1.92	3.07	4.17	5.71	6.60	7.61	6.87	5.16	3.82	2.45	1.72
47	Garrison	33.20	1.92	2.28	3.34	4.27	5.63	6.57	7.54	6.84	5.23	3.91	2.64	1.94
48	Geneva Steel	38.88	1.92	2.26	3.41	4.34	5.94	6.88	7.88	7.12	5.45	4.11	2.59	1.97
49	Green River AVN	38.81	1.64	2.27	3.50	4.67	6.19	7.05	7.95	7.21	5.55	4.16	2.60	1.85
50	Gunnison	25.74	1.75	2.13	3.20	4.00	5.52	6.43	7.25	6.59	5.00	3.83	2.47	1.77
51	Hanksville	41.85	1.79	2.30	3.54	4.71	6.24	7.18	8.04	7.29	5.66	4.26	2.68	1.92
52	Hanna	22.41	1.38	1.68	2.60	3.53	5.00	5.82	6.68	6.04	4.61	3.50	2.17	1.49
53	Hardware Ranch	11.16	1.40	1.65	2.57	3.54	4.90	5.69	6.42	5.87	4.33	3.35	2.16	1.43
54	Heber	22.90	1.39	1.71	2.76	3.86	5.21	5.91	6.86	6.25	4.79	3.67	2.31	1.64
55	Hiawatha	31.34	1.61	1.85	2.74	3.85	5.25	6.16	7.05	6.38	5.00	3.77	2.30	1.72
56	Hovenweep Mon	36.66	1.74	2.32	3.43	4.36	5.91	6.84	7.72	7.00	5.46	4.16	2.74	1.89
57	Ibapah	22.53	1.69	2.02	3.05	3.96	5.22	6.11	7.05	6.43	4.84	3.61	1.74	1.67
58	Jensen	29.15	1.00	1.50	2.91	4.21	5.73	6.51	7.39	6.65	5.06	3.74	2.26	1.37
59	Kamas Ranger St	22.43	1.59	1.74	2.55	3.56	4.99	5.87	6.80	6.16	4.68	3.56	2.27	1.77
60	Kanab	38.69	2.43	2.68	3.66	4.62	5.97	6.84	7.68	7.02	5.69	4.49	3.10	2.49
61	Koosharem	21.07	1.70	1.85	2.78	3.56	4.94	5.85	6.62	6.01	4.65	3.47	2.29	1.64
62	Lake Town	22.62	1.40	1.52	2.35	3.61	5.05	5.77	6.72	6.09	4.62	3.44	2.17	1.59
63	LaSal	29.45	1.61	1.92	2.93	3.86	5.28	6.22	6.98	6.36	4.94	3.75	2.45	1.70
64	LaVerkin	42.41	2.63	2.96	4.08	4.94	6.36	7.27	8.06	7.41	5.93	4.69	3.24	2.62
65	Levan	33.92	1.76	2.10	3.17	4.23	5.60	6.45	7.45	6.80	5.27	4.01	2.59	1.93

Table 10. Continued.

NO	STATION	AV(28F)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
66	Lewiston	28.17	1.39	1.76	2.84	4.05	5.49	6.22	7.19	6.50	4.89	3.65	2.31	1.62
67	Loa	19.21	1.59	1.85	2.69	3.65	4.93	5.72	6.52	5.91	4.62	3.53	2.25	1.64
68	Logan KVNU	32.25	1.46	1.91	2.53	4.11	5.64	6.52	7.46	6.77	5.01	3.74	2.38	1.64
69	Logan USU	36.57	1.59	1.92	3.00	4.21	5.69	6.45	7.53	6.86	5.21	3.91	2.44	1.76
70	Logan USU Exp Sta	31.93	1.60	1.90	3.01	4.11	5.63	6.48	7.39	6.72	5.07	3.83	2.42	1.68
71	Manila	24.87	1.48	1.75	2.83	3.74	5.13	6.11	6.98	6.31	4.79	3.58	2.24	1.52
72	Manti	30.73	1.75	2.04	3.09	4.11	5.45	6.26	7.13	6.53	5.08	3.89	2.50	1.88
73	Marysvale	26.56	1.95	2.22	3.13	3.98	5.43	6.32	7.04	6.42	4.99	3.86	2.54	1.94
74	Mexican Hat	45.62	2.30	2.66	3.84	4.97	6.52	7.46	8.28	7.53	6.05	4.52	2.99	2.38
75	Milford WSO	32.60	1.76	2.13	3.17	4.20	5.61	6.51	7.53	6.89	5.28	3.95	2.54	1.90
76	Moab 4 NW	44.26	2.08	2.56	3.84	5.03	6.57	7.42	8.24	7.47	5.87	4.49	2.94	2.21
77	Modena	31.46	1.91	2.23	3.17	4.12	5.44	6.34	7.27	6.64	5.20	3.96	2.61	2.00
78	Monticello	30.43	1.78	2.00	2.88	3.92	5.23	6.09	6.93	6.28	4.98	3.83	2.48	1.89
79	Monument Valley	39.98	2.18	2.62	3.84	4.67	6.37	7.34	8.09	7.37	5.90	4.52	3.03	2.32
80	Morgan	25.52	1.53	1.86	2.88	3.99	5.38	6.13	7.05	6.40	4.82	3.68	2.30	1.69
81	Moroni	27.98	1.59	2.21	3.10	3.96	5.28	6.21	7.03	6.51	4.87	3.84	2.44	1.72
82	Mountain Dell Dam	27.55	1.73	1.97	2.91	4.00	5.38	6.08	7.07	6.46	4.93	3.76	2.43	1.83
83	Myton	32.79	1.00	1.58	2.92	4.21	5.69	6.59	7.38	6.71	5.14	3.79	2.25	1.55
84	Neola	28.85	1.20	1.64	2.84	3.86	5.42	6.26	7.02	6.38	4.81	3.62	2.13	1.41
85	Nephi	35.77	1.94	2.21	3.28	4.33	5.75	6.67	7.76	6.97	5.45	4.16	2.70	2.07
86	New Harmony	34.83	2.28	2.49	3.43	4.27	5.41	6.61	7.44	6.51	5.41	4.24	2.77	2.30
87	Oak City	39.36	1.96	2.32	3.38	4.42	5.89	6.82	7.94	7.22	5.57	4.25	2.71	2.07
88	Ogden Pioneer PH	39.58	1.85	2.21	3.30	4.45	5.98	6.81	7.92	7.17	5.46	4.11	2.63	1.99
89	Ogden Sugar FCT	37.62	1.83	2.19	3.27	4.40	5.89	6.70	7.76	7.03	5.34	4.05	2.62	2.01
90	Orderville	29.81	2.11	2.36	3.26	4.15	5.55	6.49	7.31	6.66	5.28	4.10	2.77	2.16
91	Ouray	32.02	1.00	1.56	3.09	4.29	5.93	6.85	7.63	6.87	5.14	3.80	2.24	1.25
92	Panguitch	20.09	1.62	1.88	2.78	3.74	4.96	5.73	6.52	5.95	4.67	3.57	2.33	1.71
93	Park Valley	32.37	1.62	1.93	2.89	3.95	5.41	6.21	7.42	6.72	5.07	3.78	2.36	1.73
94	Partoun	32.28	1.83	2.23	3.25	4.23	5.72	6.71	7.68	6.96	5.26	3.95	2.55	1.84
95	Parowan	31.80	2.04	2.32	3.22	4.20	5.56	6.43	7.27	6.61	5.26	4.07	2.73	2.15
96	Pine View Dam	30.61	1.31	1.63	2.71	4.02	5.48	6.22	7.27	6.57	4.99	3.75	2.25	1.56
97	Piute Dam	30.43	1.88	2.16	3.10	4.09	5.43	6.30	7.22	6.61	5.13	3.94	2.63	2.00
98	Pleasant Grove	35.13	1.96	2.29	3.34	4.32	5.79	6.65	7.61	6.88	5.27	4.02	2.65	2.00
99	Price Warehouses	34.63	1.56	2.07	3.29	4.26	5.74	6.58	7.48	6.81	5.26	3.99	2.46	1.76
100	Provo KOVO	31.03	1.78	2.18	3.35	4.32	5.68	6.53	7.41	6.72	5.11	3.88	2.61	1.89
101	Richfield Radio KSVC	28.86	1.92	2.22	3.24	4.19	5.52	6.33	7.17	6.57	5.09	3.89	2.58	2.00
102	Richmond	30.56	1.67	1.88	3.06	4.13	5.53	6.38	7.38	6.74	5.05	3.77	2.46	1.79
103	Riverdale PH	37.62	1.85	2.20	3.29	4.41	5.87	6.70	7.76	7.03	5.35	4.07	2.63	1.99
104	Roosevelt	31.17	1.14	1.63	3.02	4.26	5.75	6.55	7.41	6.70	5.13	3.82	2.33	1.46
105	St. George	50.83	2.76	3.13	4.30	5.33	6.79	7.63	8.48	7.80	6.27	4.92	3.38	2.75
106	Salina	30.72	2.00	2.09	3.29	4.32	5.66	6.57	7.43	6.76	5.22	3.82	2.52	1.88
107	Saltair Salt PL	42.08	1.77	2.23	3.30	4.27	5.69	7.28	7.87	7.09	5.29	3.94	2.60	1.93
108	SLC WSFO	38.50	1.87	2.23	3.29	4.40	5.86	6.72	7.88	7.14	5.44	4.05	2.62	1.97
109	Santaquin	36.03	1.87	2.16	3.19	4.28	5.72	6.59	7.64	6.97	5.38	4.03	2.61	1.97
110	Scipio	28.59	1.66	2.04	3.10	4.09	5.45	6.26	7.24	6.62	5.05	3.82	2.45	1.83
111	Scofield Dam	17.59	0.92	1.16	2.08	3.19	4.57	5.47	6.24	5.66	4.38	3.22	1.88	1.13
112	Silver L Brighton	15.10	1.27	1.37	1.95	2.88	4.14	4.98	5.94	5.39	4.10	3.03	1.84	1.38
113	Snake Creek PH	22.74	1.48	1.72	2.65	3.76	5.09	5.84	6.70	6.10	4.68	3.55	2.21	1.63
114	Snowville	25.38	1.43	1.76	2.88	3.95	5.26	6.20	7.06	6.40	4.80	3.57	2.30	1.55
115	Soldier Summit	16.04	1.18	1.36	2.34	3.37	4.64	5.42	6.24	5.72	4.32	3.16	1.90	1.28
116	Spanish Fork PH	38.18	1.94	2.26	3.34	4.44	5.91	6.80	7.77	7.07	5.47	4.18	2.72	2.06
117	Strawberry RES E P	16.22	0.76	1.06	1.86	2.93	4.39	5.20	5.98	5.44	4.11	3.10	1.92	1.09
118	Thompson	40.84	1.85	2.31	3.47	4.62	6.16	7.10	7.97	7.23	5.67	4.34	2.75	2.00
119	Timpanogas Cave	36.15	1.75	2.20	3.17	4.15	5.65	6.51	7.51	6.84	5.30	3.99	2.46	1.84
120	Tooele	40.23	1.94	2.23	3.27	4.37	5.84	6.70	7.81	7.08	5.40	4.04	2.63	2.02
121	Tropic	27.44	1.95	2.21	3.12	4.04	5.33	6.13	6.93	6.26	4.99	3.93	2.64	2.06
122	U of U	42.67	2.00	2.35	3.42	4.29	5.90	6.89	7.92	7.13	6.48	4.13	2.75	2.03
123	Utah Lake Lehi	33.04	1.76	2.11	3.17	4.24	5.66	6.47	7.41	6.75	5.12	3.85	2.52	1.90
124	Vernal Airport	27.70	1.08	1.56	2.84	4.07	5.51	6.30	7.14	6.47	4.94	3.67	2.22	1.38
125	Veyo PH	36.08	2.35	2.64	3.62	4.45	5.90	6.87	7.63	6.99	5.53	4.36	2.99	2.42
126	Wah Wah Ranch	33.61	1.92	2.33	3.37	4.22	5.77	6.79	7.70	6.97	5.33	4.02	2.61	1.97
127	Wanship Dam	21.51	1.56	1.81	2.75	3.71	5.12	5.92	6.68	6.13	4.63	3.53	2.27	1.66
128	Wendover WSO	42.78	1.84	2.29	3.42	4.55	6.11	7.02	8.15	7.35	5.55	4.08	2.58	1.93
129	Woodruff	16.85	0.99	1.25	2.18	3.45	4.80	5.55	6.42	5.80	4.34	3.20	1.89	1.23
130	Zions National Park	50.65	2.78	3.04	4.11	5.15	6.66	7.60	8.47	7.73	6.34	5.01	3.46	2.80

particular locations the values of f as shown in column 7 of Tables 8 and 9 can be obtained directly from Table 10 without the need for the data in columns 5 and 6.

For estimates of total seasonal consumptive use where precise estimates of the incremental (monthly) values are not required (as in Equation 6) Equation 1 can be used directly if appropriate values of K and F are available. Seasonal consumptive crop coefficients, K, are shown in Table 11. Values of F for crops whose growing season is between 28°F freeze dates can be obtained from Table 2 for the set of long term weather stations in Utah. F values for crops with shorter growing periods would have to be calculated by summing the appropriate full and part month f values in the manner shown in Tables 8 and 9 or by use of Table 10 with appropriate part month adjustments as dictated by beginning and ending growth dates.

Table 11. Seasonal consumptive-use crop coefficients (K) for irrigated crops.

Crop	Length of Normal Growing Season or Period[a]	Consumptive-use Coefficient (K)[b]
Alfalfa	Between frosts	0.80 to 0.90
Beans	3 months	0.60 to 0.70
Corn	4 months	0.75 to 0.85
Cotton	7 months	0.60 to 0.70
Grains, small	3 months	0.75 to 0.85
Grain, sorghums	4 to 5 months	0.70 to 0.80
Oilseeds	3 to 5 months	0.65 to 0.75
Orchard crops: Deciduous	Between frosts	0.60 to 0.70
Pasture crops:		
Grass	Between frosts	0.75 to 0.85
Ladino white clover	Between frosts	0.80 to 0.85
Potatoes	3 to 5 months	0.65 to 0.75
Soybeans	140 days	0.65 to 0.70
Sugar beet	6 months	0.65 to 0.75
Tomatoes	4 months	0.65 to 0.70
Truck crops, small	2 to 4 months	0.60 to 0.70
Vineyard	5 to 7 months	0.50 to 0.60

[a]Length of season depends largely on variety and time of year when the crop is grown. Annual crops grown during the winter period may take much longer than if grown in the summertime.

[b]The lower values of (K) for use in the Blaney-Criddle formula, U = KF, are for the more humid areas, and the higher values are for the more arid climates.

Geographical Variation in Consumptive Use

There is a potential need to estimate consumptive use and water requirements wherever water is applied to cropland. Water requirements often must be determined for individual farms for water management purposes. The administration of water rights as between and among individual water right holders sometimes requires the determination of consumptive use on very specific sites. The determination of crop consumptive use can be made by the procedure outlined in the previous section at locations where mean monthly air temperature data are available. However, such data are generally not available at individual farm locations. The only locations where temperature measurements have been made and recorded over time periods sufficiently long to establish reliable norms are the cooperator stations reported by the Weather Service. The proximity of such stations to any particular farm site of interest may be many miles. In the entire State of Utah there are only 67 climate stations with temperature records of 30 years or more. An additional 63 stations have 15 years or more of record as of 1982. Thus, there are 130 locations in Utah having data that permits reliable calculations of consumptive use. The question of interest is whether such information from particular climate stations can be extended or extrapolated spacially so as to provide reliable input values for the calculation of consumptive use at <u>any</u> geographic point of interest.

In areas of uniform and generally level terrain, temperature, or temperature indices at a particular measuring station may be quite representative of a large surrounding area. In Utah, however, most agricultural areas are characterized by valleys having "bench" and "bottom" lands and mountainous borders intermittently incised by canyons serving as air drainage conduits into the valley region. Under such situations, factors of topography, exposure, land slopes, elevation, and air drainage may create local differences in air temperature that would negate the assumption that temperature measurements at one site are a reasonable representation of temperatures over a relatively large region surrounding that site. To the extent that temperature extrapolations contain errors, so also will any calculation of consumptive use which employs temperature as a predominant factor.

While data from standard climate stations are the customary basis of any extrapolation of temperature to other ground locations of interest, Richardson (1968) has shown that extrapolations can also be made from atmospheric temperature measurements well above ground level. For example, there are long term measurements of temperature, temperature lapse rates with elevation, and elevation of the air at the 700 millibar level of atmospheric pressure.[1] An isogram of mean July upper air temperature at the 700 mb level and associated temperature lapse rates are shown in Figure 1. Since local topographic effects are essentially absent in the higher atmosphere, isolines of mean temperature are smooth and uniformly changing such that linear interpolations to points between isolines can describe a 700 mb surface over the entire state.

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[1]The 700 millibar temperature refers to the temperature at a point above the earth's surface where the atmospheric pressure is about 70 percent of the standard pressure at mean sea level. Mean sea level pressure is 1013 millibars or 1.013 bars (14.7 psi).

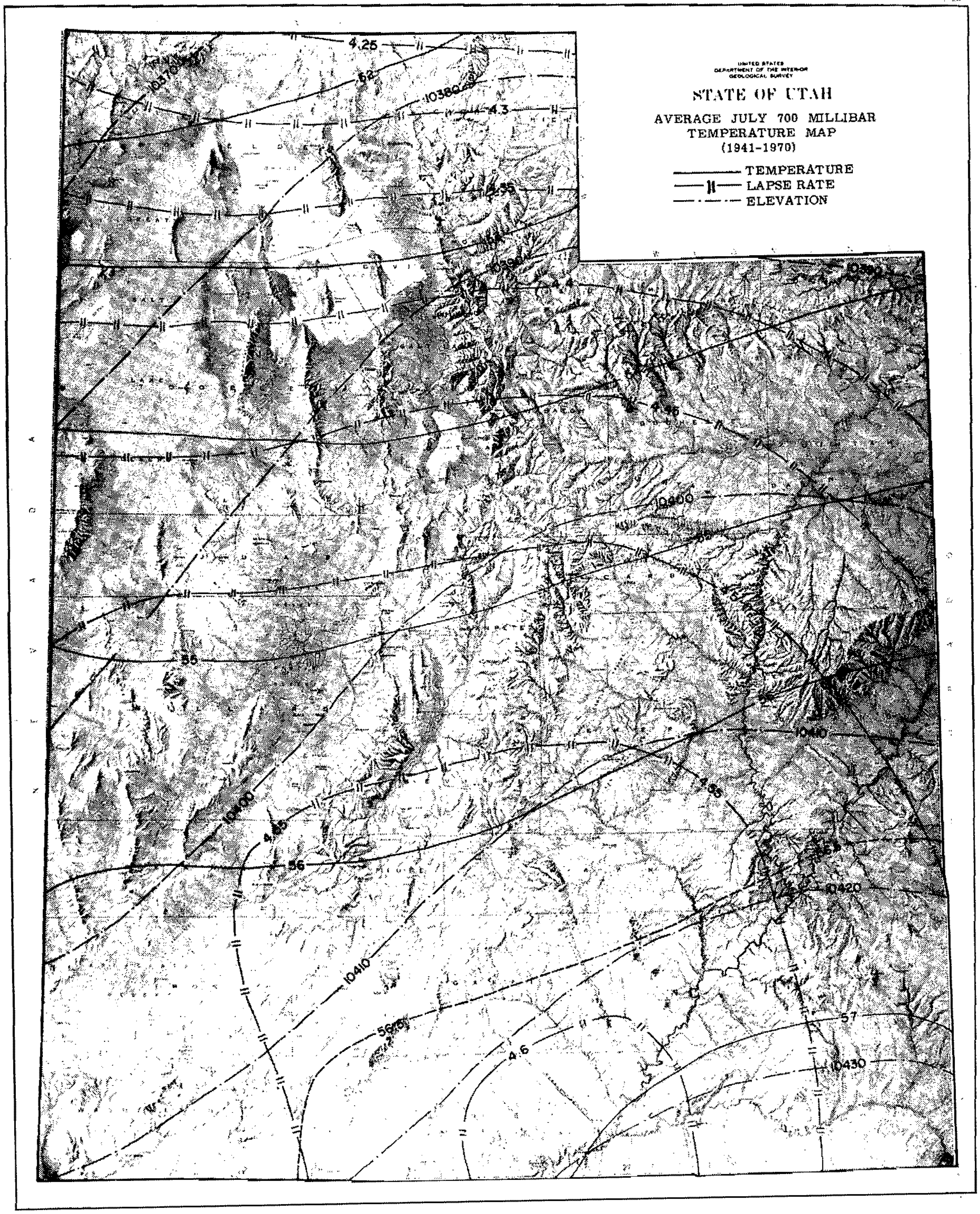

Figure 1. Average July 700 millibar temperature map for Utah.

From a map like Figure 1, temperature at a point on the 700 mb surface can be "lapsed" to estimate air temperatures directly below at the ground elevation. Thus, temperatures at grid points on the upper atmosphere surface can be projected vertically downward (using the temperature lapse with elevation relation) to points at ground elevations. The advantage of this kind of vertical extrapolation over a horizontal extrapolation based on existing weather service stations is that one can readily obtain a uniformly spaced set of ground elevation temperature estimates at far greater density than the existing nonuniformly spaced weather stations provide. Thus, using a 10,000 foot uniform grid pattern over the 700 millibar surface in the atmosphere, temperatures could be estimated at 22,000 points on the ground in a uniform spacing over the entire state. This geographic spacing of data points provides a much more dense network than is provided by the 130 nonuniformly spaced locations of existing ground stations.

Richardson's method of estimating mean temperature at the ground surface is given by the equation

$$t_s = t_{700} + \alpha (E_{700} - E_s) + t_\lambda \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (7)$$

in which

t_s = the mean air temperature in °F at the ground elevation, E_s
t_{700} = the mean temperature in °F at the 700 mb level
α = the temperature lapse rate in °F per 1000 ft
E_{700} = elevation at the 700 mb level in feet above mean sea level
E_s = elevation at a corresponding point at the ground surface in feet above msl
t_λ = adjustment factor incorporating the influence of local exposure, slope, and air drainage at the point of ground temperature determination

Values of t_s can then be used as t_i in Equation 6 to calculate crop consumptive use at the location of the t_s estimate.

The surface temperature as calculated from Equation 7 without the correction term, t_λ, gives a t_s estimate often referred to as the "free air temperature." At the present time, the functional relationship between t_λ and the factors of exposure, slope, and air drainage have not been perfected to the point that these functions of t_λ can be confidently substituted into Equation 7. For purposes of this study, the free air temperature value was used in generating the temperature values for the grid points at the ground surface. Slight adjustments to the calculated ground surface temperatures were made, drawing on the use of promising, but not fully proven, relations of the adjustment factor, t_λ, as well as local familiarity with the nature of geographic mean temperature variations with exposures, slopes, and air drainage.

Since Figure 1 gives the 700 millibar temperature only for the month of July, the ground surface temperature, t_s, for other months of the year were obtained by correlation. The mean monthly temperatures are highly correlated with the mean July temperature with the greatest variance occurring in the winter months which are not included in the growing season calculations. An illustration of how the various input variables are utilized in calculating seasonal consumptive use factor, f, at any given point is shown in Figure 2.

With the capability to get good estimates of temperature and, hence, consumptive use at any particular point (not just those points at which weather stations are located), it becomes possible to characterize the geographic variations in consumptive use quite accurately and in ways that simplify and amplify utility. Previously developed maps showing the geographic variation of consumptive use (i.e., Bagley et al. 1963, Jeppson et al. 1968) have used information available at ground based weather stations only. As has been indicated, the location and highly nonuniform spacing of the approximately 130 Utah stations required great spacial and elevational extrapolations in the construction of consumptive use isolines. Construction of consumptive use isolines based on 22,000 ground locations uniformly spaced and better balanced in the representation of elevation differences gives a very reliable depiction of the geographic variation in consumptive use. Displayed on a state map, a practitioner can obtain an estimate of consumptive use at any site of interest without any calculation whatsoever except for the possible need to extrapolate between isolines of consumptive use. However, a separate consumptive use map would be needed for each crop in order to permit this one-step determination of consumptive use. A two-step compromise which uses a single map to provide the site specificity and an accompanying table to provide the crop specificity, is an expeditious way of obtaining estimates of seasonal consumptive use. Plate 1 is a map showing the geographic distribution of the full growing season consumptive use factor, F, for Utah. Superimposed on the map is a table which accomplishes the two-way link of full season F with part season F, and of the correspondence of any F to particular crop growing periods. By use of Plate 1, a user can note the F value for the geographic site of interest, enter the table with the value obtained, and read off the value of growing season consumptive use for the crop of interest. Extrapolations between isolines of F will be necessary where the site of interest falls between isolines. Similarly, where the value of F as derived from the map falls between the F increments in the table, extrapolation between the two relevant columnar values of consumptive use for the crop of interest will be necessary.

Comparisons were made of consumptive use values calculated with measured temperature data at the existing 130 stations with consumptive use values calculated from 700 millibar level temperatures extrapolated to the site of the 130 stations. Correlation coefficients for all crops were high ranging from 0.949 to 0.965.

Irrigation Water Requirements

Crop consumptive use requirement, as determined by procedures outlined in the previous section, establishes the basic water need for normal crop

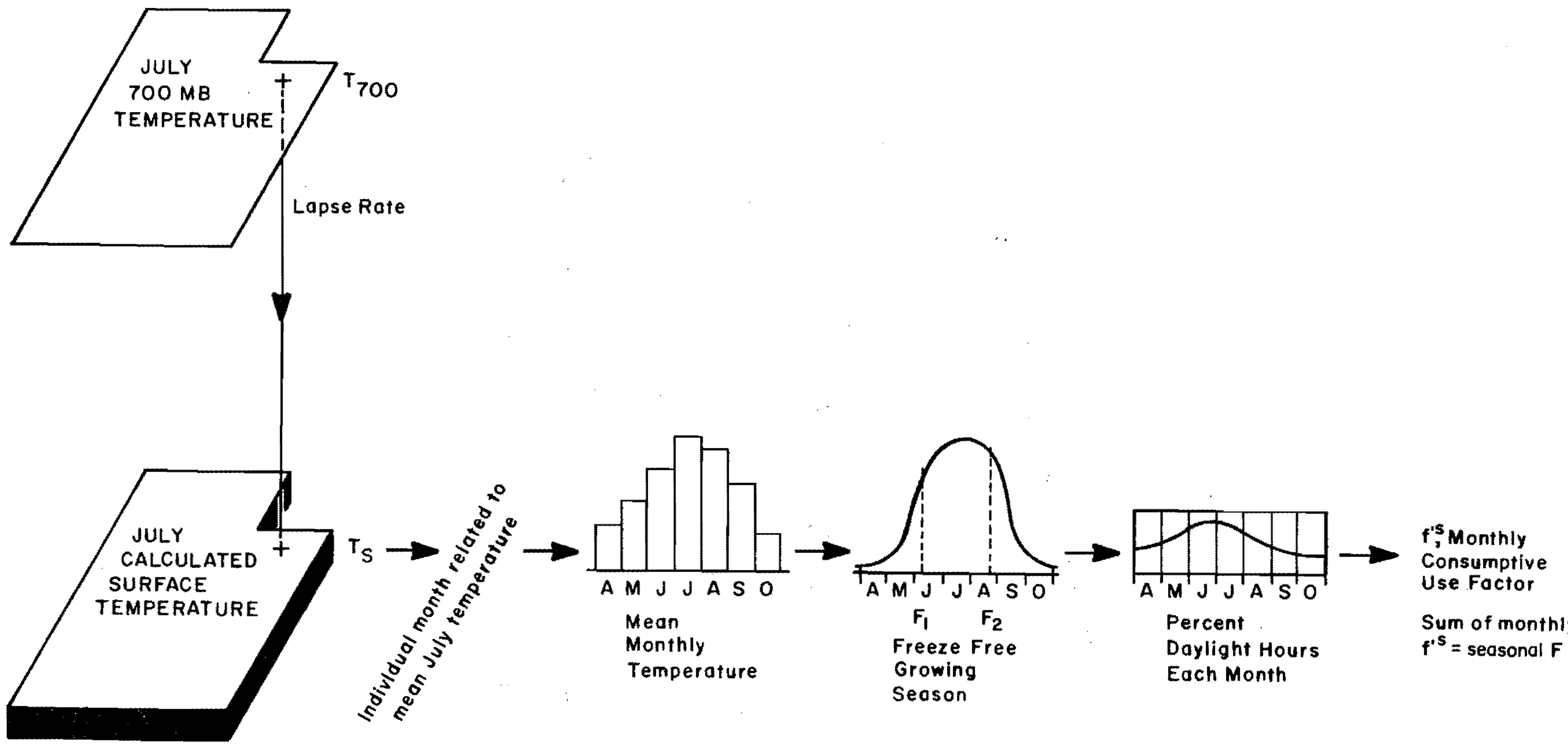

Figure 2. Input, information flow, and output of consumptive use factor model, F, presented schematically.

growth. The determination of an "irrigation water requirement" begins with the consumptive use requirement as the base or norm and then incorporates adjustments upward and/or downward according to the practicalities of placing the consumptive water requirement uniformly within the root zone of the crop, and whether and to what extent nonirrigation sources of water (such as rainfall or groundwater) provide a part of the total requirement.

The reader should be reminded that the consumptive use and irrigation requirements emphasized in this report are based on mean climatic conditions. Any great variance from the mean for any given year would tend to increase or decrease the actual consumptive use and irrigation requirement accordingly. The amounts reported are also independent of soil conditions, or in other words, presume that the fertility of soils is similar and that soil moisture conditions at the beginning and end of the growing season are approximately the same. Calculations also presume that annual crops begin their consumption at the beginning of the freeze-free period and that the growing period for perennial crops such as alfalfa, grass, and deciduous orchards is the same as the normal freeze-free period.

Upward adjustments to crop evapotranspirational needs

While meeting the consumptive needs of crops (discussed in the previous section) is the primary purpose of irrigation, there are situations that justify additions to the water required for replenishment of soil moisture. Seed germination, climate modification to delay bloom of fruit trees, frost protection, and fertilizer application are examples of beneficial water uses that can improve crop production. Allowance for such water needs over and above evapotranspirational needs would have to be made as site conditions warrant. However, unless such uses are perennial, one may choose to ignore their effect in the calculation of average irrigation requirement.

Poor quality water. The quality of the water available for irrigation can also influence the irrigation requirement. Where changing to a better quality supply or blending are not viable options, additional amounts of water may help to maintain full crop productivity. In the use of saline waters, for example, it is well known that equal amounts of different quality water do not provide "equivalent service." (See Figure 3 for an illustration of this concept.) The amount of water required to maintain a favorable salt balance, beyond that required for crop evapotranspiration, has been termed the leaching requirement. Applying certain simplifying assumptions, a steady state salt balance equation reduces to

$$V_D/V_I = C_I/C_D \quad (8)$$

where V_D, V_I, C_D, and C_I are respective volumes of the irrigation water applied to the soil profile and the drainage and the corresponding salt

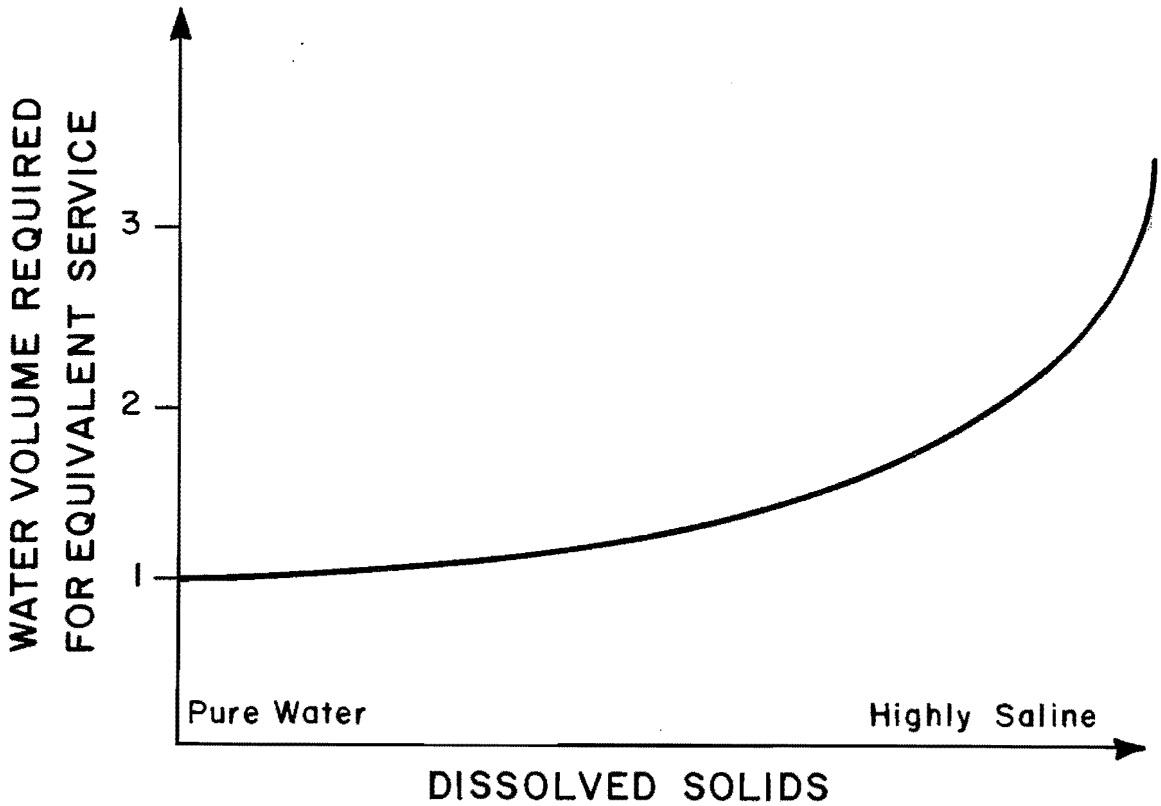

Figure 3. Illustration of increased volumes of water needed for equivalent service when salt concentration is increased.

concentrations (USDA Agr. Hdbk. 60 1954). Because the electrical conductivity (EC) of a water is generally a reliable index of total salt concentration, EC can be substituted for C in Equation 8 giving an approximate equality between the leaching fraction and salinity in the irrigation and drainage waters as

$$L_R = D_D/D_I = EC_I/EC_D \quad \ldots \ldots \ldots \ldots \ldots \quad (9)$$

where EC_I is the measured electrical conductivity of the irrigation water and EC_D is the measured electrical conductivity of water draining from the soil profile.

Some general guidelines for evaluating the suitability of waters for irrigation are given in Table 12. The reader should consult the original source for the basic assumptions for these guidelines if the water supply of interest is of such quality that it may suggest an upward adjustment in irrigation requirement.

Table 12. Guidelines for interpretation of water quality for irrigation.

Problem and Related Constituent (1)	Water Quality Guidelines: No Problem (2)	Increasing Problems (3)	Severe Problems (4)
Salinity[a]			
EC of irrigation water, in micromhos per centimeter	<750	750-3000	>3000
Permeability			
EC of irrigation water, in micromhos per centimeter	>500	<500	< 200
Sodium hazard, adj. SAR[b]	<6.0	6.0-9.0	>9.0
Specific Ion Toxicity[c] from ROOT absorption			
Sodium (by adj. SAR)	<3	3.0-9.0	>9[d]
Chloride			
Milliequivalents per liter	<4	4.0-10	>10
Milligrams per liter or parts per million	<142	142-355	>355
Boron, in milligrams per liter or parts per million	<0.5	0.5-2.0	2.0-10.0
FOLIAR absorption[e] sprinkers			
Sodium			
Milliequivalents per liter	<3.0	>3.0	-
Milligrams per liter or parts per million	<69	>69	-
Chloride			
Milliequivalents per liter	<3.0	>3.0	-
Milligrams per liter or parts per million	<106	>106	-
Miscellaneous[f]			
Nitrogen in milligrams per liter or parts per million, for sensitive crops	<5	5-30	>30
Bicarbonate (only with overhead sprinklers)			
Milliequivalents per liter	<1.5	1.5-8.5	>8.5
Milligrams per liter or parts per millions	<90	90-520	>520
pH	normal range = 6.5-8.4		-

[a]Assumes water for crop plus needed water for leaching requirement (LR) will be applied. Crops vary in tolerance to salinity.

[b]adj. SAR (Adjusted Sodium Adsorption Ratio) is calculated from a modified equation developed by U.S. Salinity Laboratory. The higher the salinity of the water, the less likely that permeability problems will occur.

[c]Most tree crops and woody ornamentals are sensitive to sodium and chloride (u values shown). Most annual crops are not sensitive.

[d]For shrinking-swelling type soils (montmorillonite type clay minerals); for others, higher values apply.

[e]Leaf areas wet by sprinklers (rotating heads) may show a leaf burn due to sodium or chloride absorption under low-humidity high-evaporation conditions. (Evaporation increases ion concentration in water films on leaves between rotations of sprinkler heads.)

[f]Excess N may affect production or quality of certain crops, e.g., sugar beets, apricots, and grapes. (1 mg/l NO_3-N = 2.72 lb N/acre-ft of applied water or 1 kg/1,000 m^3.) HCO_3 with overhead sprinkler irrigation may cause a white carbonate deposit to form on fruit and leaves.

Note: Interpretations are based on possible effects of constituents on crops or soils or both. Guidelines are flexible and should be modified when warranted by local experience or special conditions of crop, soil, and method of irrigation.

Irrigation efficiency. The process of distributing water over a field and getting the crop root zone uniformly filled is not simple. Soil characteristics, land slopes and topography, crop, method of irrigation, skill of the irrigator, and wind may all affect the uniformity and precision with which irrigation water can be stored in the soil as desired. As a practical matter, the assurance of an adequate water supply to all areas of an irrigated field results in an inevitable oversupply to some areas. Thus, the "efficiency" with which water can be placed in the rooting zone of crops must be taken into account when estimating irrigation water requirement. For example, if the field irrigation efficiency were 50 percent, then the irrigation water requirement would be double the calculated consumptive use requirement. The field irrigation efficiency applicable to a particular determination of irrigation water requirement is highly specific to site and situation factors. An indication of the relative adaptability of various irrigation systems to these site and situation factors can be seen in Table 13. Values of irrigation efficiency achievable with good practice for the various kinds of irrigation systems are also shown in the table.

An overall farm irrigation efficiency used in the estimation of irrigation water requirement should also include considerations of the efficiency of conveyance from the point of diversion to the field or farm if circumstances warrant. Losses in ditches of a given size vary widely but a useful approximation for larger ditches is given by the formula

$$S = 0.2\ C \sqrt{Q/V} \qquad (10)$$

where

S = seepage loss, in CFS per mile of canal
Q = discharge of canal, CFS
V = mean velocity of flow, FPS
C = cubic feet of water lost in 24 hours through each square foot of wetted area of canal prism

Values of the seepage coefficient "C" are given in Table 14.

Downward adjustments to crop evapotranspirational needs

Although soil moisture carryover and an occasional inadvertent "flooding" may modify the irrigation need in specific instances, perhaps the more important factors to consider in terms of long term average irrigation requirement are the contributions from groundwater and from precipitation occurring during the growing period.

Groundwater contributions. In areas where the water table is sufficiently high that capillary movement into the root zone occurs, plants may receive a part or all of their consumptive needs directly from groundwater. Where such conditions exist, it becomes necessary to estimate the

Table 13. Comparison of irrigation systems in relation to site and situation factors.

	Improved Surface Systems			Sprinkler Systems		Trickle System
Site and Situation Factors	Redesigned Surface Systems	Level Basins	Intermittent Mechanical Move	Continuous Mechanical Move	Solid Set and Permanent	Emitters and Porous Tubes
Infiltration rate	Moderate to low	Moderate	All	Medium to high	All	All
Topography	Moderate slopes	Small slopes	Level to rolling	Level to rolling	Level to rolling	All
Crops	All	All	Generally shorter crops	All but trees and vineyards	All	High value required
Water supply	Large streams	Very large streams	Small streams nearly continuous	Small streams nearly continuous	Small streams	Small streams, continuous and clean
Water quality	All but very high salts	All	Salty water may harm plants	Salty water may harm plants	Salty water may harm plants	All-can potentially use high salt waters
Efficiency	Average 60-70%	Average 80%	Average 70-80%	Average 80%	Average 70-80%	Average 80-90%
Labor requirement	High, training required	Low, some training	Moderate, some training	Low, some training	Low to seasonal high, little training	Low to high, some training
Capital requirement	Low to moderate	Moderate	Moderate	Moderate	High	High
Energy requirement	Low	Low	Moderate to high	Moderate to high	Moderate	Low to moderate
Management skill	Moderate	Moderate	Moderate	Moderate to high	Moderate	High
Machinery operations	Medium to long fields	Short fields	Medium field length, small interference	Some interference circular fields	Some interference	May have considerable interference
Duration of use	Short to long	Long	Short to medium	Short to medium	Long term	Long term, but durability unknown
Weather	All	All	Poor in windy conditions	Better in windy conditions than other sprinklers	Windy conditions reduce performance; good for cooling	All
Chemical application	Fair	Good	Good	Good	Good	Very good

Source: Fangmeier (1977).

Table 14. Values of seepage coefficient "C".

Type of Material	Value of C
Cemented gravel and hardpan with sand loam	0.34
Clay and clayey loam	0.41
Sandy loam	0.66
Volcanic ash	0.68
Volcanic ash with sand	0.98
Sand and volcanic ash or clay	1.20
Sandy soil with rock	1.68
Sandy and gravelly soil	2.20

proportion of the water need being met from such sources and deduct such amounts from quantities to be provided by irrigation.

Effective precipitation. Precipitation falling directly on the land during the growing period may be consumptively used by the crops and, therefore, decrease the irrigation requirement. However, there are factors which limit the full effectiveness of precipitation, and these should be considered in judging what portion of the growing season precipitation is stored in the soil and ultimately consumed by plants. The U.S. Department of Agriculture has discussed the factors that influence the effectiveness of rainfall in considerable detail (USDA 1970). From an analysis of 50 years of precipitation records at each of 22 Weather Bureau stations in the 48 contiguous states, the USDA developed a method of estimating monthly effective precipitation as a function of the monthly amount of precipitation, the monthly consumptive use rate, and the net depth of water applied in each irrigation. Although the functional relationship is somewhat cumbersome mathematically, it can be simplified so that the product of three factors (incorporating the effect of each variable) provides an estimate of effective precipitation. The factor or multiplier for monthly values of each variable can be obtained from Table 15. Effective precipitation is the product of the three multipliers. Examples of how the growing period effective precipitation is calculated are given in Table 16. Average monthly precipitation values for Utah weather station locations are given in Table 17.

Calculation of irrigation water requirement

Irrigation requirement is the amount of water that must be delivered to a cropped area to assure that the consumptive use requirement will indeed be met. Beginning with the calculated value of crop consumptive use, adjustments appropriate to specific site conditions and management

Table 15. Multipliers to use in calculating effective precipitation.

(a)

Average Monthly Precipitation (inches)	M_p Precipitation Factor
0.1106	0
0.15	0.0329
0.20	0.0727
0.25	0.1107
0.30	0.1474
0.35	0.1830
0.40	0.2177
0.45	0.2517
0.50	0.2850
0.60	0.3499
0.70	0.4130
0.80	0.4745
0.90	0.5346
1.00	0.5936
1.50	0.8750
2.00	1.140
2.50	1.394
3.00	1.638
3.50	1.876
4.00	2.107
5.00	2.556
6.00	2.990
7.00	3.410
8.00	3.820

(b)

Monthly Consumptive Use (inches)	M_μ Consumptive Use Factor
0	1.000
1	1.057
2	1.118
3	1.182
4	1.250
5	1.322
6	1.398
7	1.478
8	1.563
9	1.653
10	1.748

(c)

Net Depth of Water Applied (inches)	M_D Depth of Water Applied Factor
0.75	0.72
1.00	0.77
1.50	0.86
2.00	0.93
2.50	0.97
3.00	1.00
4.00	1.02
5.00	1.04
6.00	1.06
7.00	1.07

Adapted from USDA Technical Release No. 21, revised September 1970.

practicalities are applied. The previous example calculations of consumptive use for corn grown near Logan and alfalfa grown near Milford (see Tables 8 and 9) can provide the base for the extended calculations for estimating the average seasonal irrigation water requirement.

Table 16. Sample calculation of effective precipitation.

(1) Growing Period by Month (See Tables 8 and 9)	(2) Mean Monthly Precipitation (inches) (Table 17)	(3) M_P Precipitation Factor (Table 15)	(4) Average Monthly Consumptive Use (inches) (Tables 8,9)	(5) M_u Consumptive Use Factor (Table 15)	(6) M_D Depth of Water Applied Factor (Table 15)	(7) Average Monthly Effective Precipitation (inches) (Col 3 x Col 5 x Col 6)
LOGAN, UTAH						
May 7-31	1.44	0.8413	0.95	1.054	1.0	0.89
June 1-30	1.78	1.002	3.23	1.21	1.0	1.21
July 1-31	0.34	0.1759	7.22	1.50	1.0	0.26
Aug. 1-31	0.87	0.517	7.08	1.48	1.0	0.77
Sept. 1-4	0.13	0.0167	0.38	1.022	1.0	0.02
Total	4.56		18.86			3.15
MILFORD, UTAH						
May 2-31	0.57	0.3304	3.74	1.2323	0.93	0.38
June 1-30	0.56	0.3239	5.99	1.397	0.93	0.42
July 1-31	0.51	0.2915	8.13	1.575	0.93	0.43
Aug. 1-3	0.68	0.4020	6.89	1.393	0.93	0.52
Sept. 1-30	0.61	0.3562	4.07	1.255	0.93	0.42
Oct. 1-9	0.23	0.955	0.61	1.035	0.93	0.09
Total	3.16		29.43			2.26

Table 17. Average mean monthly precipitation for principal weather station locations in Utah.

NO	STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1	Altamont	0.53	0.51	0.54	0.67	0.78	0.75	0.65	0.95	0.84	0.97	0.50	0.75	8.44
2	Alton	1.90	1.49	1.48	1.25	0.78	0.64	1.43	1.94	1.23	1.19	1.26	1.79	16.38
3	Antelope Island	1.42	1.34	1.46	2.25	1.72	1.55	0.25	0.74	0.97	1.06	1.40	1.41	15.57
4	Bear River Refuge	1.07	0.87	0.93	1.38	1.33	1.48	0.24	0.55	0.84	0.99	1.17	1.12	11.97
5	Beaver	0.77	0.95	1.00	1.14	1.00	0.74	1.10	1.34	0.85	0.88	0.71	0.85	11.33
6	Bingham Canyon	1.90	1.82	2.21	2.52	2.10	2.01	1.09	1.29	0.93	1.52	1.73	2.10	21.22
7	Birdseye	1.47	1.26	1.28	1.05	0.94	0.93	0.91	1.18	0.80	1.04	1.08	1.55	13.49
8	Black Rock	0.57	0.67	0.92	1.00	0.88	0.48	0.72	0.69	0.67	0.85	0.64	0.52	8.61
9	Blanding	1.11	0.89	0.87	0.86	0.64	0.50	0.96	1.58	1.02	1.36	0.78	1.25	11.82
10	Bluff	0.61	0.58	0.54	0.52	0.35	0.29	0.67	1.00	0.73	0.99	0.51	0.76	7.55
11	Bonanza	0.52	0.45	0.50	0.81	0.76	0.85	0.48	0.86	0.98	1.05	0.48	0.48	8.22
12	Boulder	0.77	0.60	0.70	0.69	0.87	0.59	1.07	1.50	0.94	1.15	0.78	0.74	10.20
13	Brigham City	1.99	1.59	1.88	2.34	1.95	1.90	0.34	0.71	1.14	1.49	2.03	1.95	19.31
14	Bryce Canyon FAA AP	0.81	0.81	0.96	0.83	0.73	0.68	1.13	1.75	1.20	1.07	0.77	1.05	11.79
15	Bryce Canyon NP HDQ	1.28	1.21	1.42	1.19	0.85	0.73	1.30	2.41	1.50	1.50	1.05	1.39	15.83
16	Capitol Reef NT MON	0.28	0.22	0.41	0.56	0.60	0.56	0.96	1.20	0.63	0.99	0.43	0.40	7.24
17	Castle Dale	0.60	0.57	0.49	0.53	0.59	0.54	0.86	1.09	0.85	0.80	0.50	0.58	8.00
18	Cedar City FAA AP	0.65	0.76	1.12	1.05	0.68	0.54	0.96	1.22	0.72	0.89	0.96	0.78	10.33
19	Cedar City PH	0.79	0.95	1.28	1.14	0.79	0.49	1.21	1.33	0.92	1.14	1.01	0.91	11.96
20	Cedar Point	1.18	0.85	0.82	0.92	0.77	0.53	1.15	1.77	1.22	1.87	1.14	1.25	13.47
21	Circleville	0.57	0.37	0.65	0.60	0.69	0.61	0.78	1.12	0.72	0.74	0.53	0.63	8.01
22	Coalville	1.24	1.05	1.46	1.53	1.50	1.37	0.78	1.02	0.84	1.23	1.36	1.40	14.78
23	Corinne	1.55	1.29	1.40	1.75	1.84	1.53	0.39	0.61	0.87	1.06	1.61	1.72	15.62
24	Cottonwood Weir	2.01	1.91	2.69	2.96	2.31	1.63	0.67	1.23	1.11	1.84	2.06	2.27	22.69
25	Cove Fort	0.93	1.28	1.43	1.48	1.09	0.91	0.84	1.07	0.83	1.03	1.06	1.06	13.01
26	Deer Creek Dam	2.80	2.31	1.93	1.75	1.39	1.42	0.61	1.08	0.99	1.75	2.33	2.97	21.33
27	Delta	0.53	0.83	0.76	0.83	0.87	0.56	0.46	0.46	0.48	0.74	0.55	0.70	7.77
28	Deseret	0.49	0.41	0.69	0.87	0.74	0.50	0.36	0.60	0.44	0.66	0.57	0.59	6.92
29	Desert Exp R	0.27	0.28	0.45	0.60	0.66	0.48	0.83	0.77	0.40	0.62	0.37	0.36	6.09
30	Duchesne	0.50	0.46	0.58	0.66	0.82	1.01	0.76	1.05	0.81	0.93	0.49	0.64	8.71
31	Dugway	0.46	0.51	0.54	0.79	0.66	0.60	0.42	0.49	0.57	0.53	0.53	0.57	6.67
32	Echo Dam	1.05	0.89	1.26	1.44	1.47	1.57	0.69	0.95	0.79	1.27	1.17	1.26	13.81
33	Elberta	0.85	0.84	0.98	1.07	1.05	0.94	0.62	1.05	0.61	0.96	0.87	1.09	10.93
34	Emery	0.47	0.41	0.45	0.42	0.62	0.69	0.71	1.17	0.79	0.85	0.40	0.57	7.55
35	Enterprise Beryl Jct	0.61	0.67	0.89	0.88	0.53	0.50	0.97	1.11	0.55	0.92	0.86	0.70	9.19
36	Ephraim Sorn FD	0.88	0.92	0.99	1.11	0.91	0.72	0.61	0.72	0.87	0.87	0.85	1.01	10.46
37	Escalante	0.93	0.64	0.80	0.72	0.66	0.59	1.29	1.90	0.91	1.16	0.66	0.96	11.22
38	Fairfield	0.94	0.71	0.87	0.89	1.05	0.88	0.88	0.91	0.70	0.88	0.91	0.99	10.61
39	Farmington USU	2.01	1.73	2.03	2.65	2.06	1.73	0.40	1.09	0.93	1.54	1.90	1.89	19.96
40	Ferron	0.69	0.53	0.45	0.42	0.66	0.63	0.85	1.24	0.78	0.78	0.52	0.60	6.15
41	Fillmore	1.36	1.52	1.74	1.76	1.18	0.93	0.62	0.99	0.80	1.14	1.34	1.40	14.78
42	Fish Spg Ref	0.29	0.46	0.63	1.26	0.82	1.02	0.51	0.47	0.61	0.75	0.52	0.49	7.83
43	Flaming Gorge	0.45	0.62	0.85	1.65	1.54	1.41	1.14	0.92	1.13	1.33	0.70	0.71	12.45
44	Fort Duchesne	0.47	0.36	0.43	0.61	0.68	0.86	0.46	0.72	0.63	0.89	0.51	0.61	7.23
45	Garfield	1.09	1.10	1.51	2.35	1.61	1.31	0.59	0.68	1.10	1.37	1.51	1.36	15.58
46	Garland	1.27	1.24	1.48	1.58	1.72	1.49	0.63	0.70	1.16	1.35	1.17	1.35	15.14
47	Garrison	0.57	0.43	0.78	0.68	0.66	0.45	0.56	0.60	0.55	0.72	0.58	0.55	7.13
48	Geneva Steel	0.66	0.94	1.01	1.54	1.14	0.97	0.50	0.69	0.83	1.20	0.96	1.00	11.46
49	Green River AVN	0.33	0.35	0.38	0.49	0.51	0.50	0.42	0.97	0.56	0.77	0.39	0.44	6.11
50	Gunnison	0.63	0.53	0.75	0.92	0.75	0.57	0.41	0.63	0.84	0.78	0.68	0.50	7.99
51	Hanksville	0.22	0.20	0.30	0.44	0.33	0.38	0.46	1.02	0.48	0.71	0.33	0.33	5.20
52	Hanna	0.93	0.70	0.58	0.76	1.03	1.15	0.88	1.47	1.32	1.08	0.74	1.08	11.72
53	Hardware Ranch	1.62	1.61	1.22	1.68	1.30	1.49	0.46	0.95	0.97	1.14	1.42	1.58	15.44
54	Heber	1.97	1.43	1.28	1.34	1.15	1.25	0.68	1.05	0.85	1.29	1.61	1.92	15.82
55	Hiawatha	1.06	0.87	1.03	1.06	1.10	1.25	1.13	1.99	1.19	1.35	0.85	1.27	14.15
56	Hovenweep Mon	0.64	0.72	0.86	0.79	0.58	0.44	0.71	1.12	0.96	1.65	0.97	1.01	10.45
57	Ibapah	0.57	0.83	0.99	1.27	1.46	1.02	0.80	1.03	0.65	0.88	0.59	0.61	10.70
58	Jensen	0.50	0.48	0.52	0.75	0.61	0.95	0.38	0.79	0.72	0.99	0.51	0.74	7.94
59	Kamas Ranger St	1.56	1.78	1.57	1.85	1.53	1.22	0.94	1.07	1.17	1.60	1.70	1.68	17.67
60	Kanab	1.47	1.10	1.21	0.89	0.60	0.44	0.88	1.55	0.75	0.95	0.96	1.41	12.21
61	Koosharem	0.61	0.62	0.63	0.74	0.86	0.64	1.09	1.34	0.87	0.75	0.45	0.65	9.25
62	Lake Town	0.92	0.82	0.86	1.18	1.19	1.34	0.44	0.82	0.85	1.01	1.10	1.05	11.58
63	LaSal	0.88	0.90	0.81	1.02	0.92	0.74	1.39	1.56	1.21	1.53	0.86	1.06	12.88
64	LaVerkin	1.11	1.09	1.26	0.62	0.53	0.34	0.70	0.89	0.75	0.67	0.81	0.89	9.66
65	Levan	1.27	1.25	1.64	1.68	1.33	1.01	0.68	1.03	0.92	1.19	1.20	1.46	14.66

Table 17. Continued.

NO	STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
66	Lewiston	1.70	1.43	1.60	1.96	1.99	1.92	0.46	0.98	1.02	1.38	1.59	1.61	17.64
67	Loa	0.36	0.25	0.44	0.48	0.60	0.59	1.14	1.33	0.74	0.75	0.41	0.39	7.48
68	Logan KVNU	1.21	1.06	1.41	1.63	1.35	1.61	0.44	0.80	1.27	1.60	1.44	1.19	15.01
69	Logan USU	1.63	1.45	1.74	2.12	1.86	1.78	0.34	0.87	0.94	1.43	1.79	1.64	17.59
70	Logan USU Exp Sta	1.65	1.21	1.57	1.94	1.54	1.62	0.41	0.83	1.13	1.50	1.50	1.57	16.47
71	Manila	0.37	0.51	0.69	1.31	1.25	0.87	0.92	0.92	0.93	1.08	0.48	0.38	9.71
72	Manti	1.04	1.16	1.35	1.40	1.13	1.01	0.73	1.01	0.84	1.13	1.00	1.13	12.93
73	Marysvale	0.70	0.71	0.85	0.76	0.82	0.46	1.00	1.18	0.87	0.75	0.55	0.63	9.28
74	Mexican Hat	0.40	0.40	0.36	0.30	0.27	0.28	0.67	0.82	0.52	0.93	0.47	0.53	5.95
75	Milford WSO	0.61	0.70	1.04	0.90	0.61	0.56	0.51	0.68	0.61	0.78	0.67	0.73	8.40
76	Moab 4 NW	0.48	0.55	0.63	0.85	0.61	0.56	0.47	0.89	0.64	1.05	0.62	0.59	7.94
77	Modena	0.69	0.67	0.82	0.81	0.56	0.55	0.94	1.34	0.62	0.96	0.74	0.78	9.48
78	Monticello	0.93	0.78	0.96	0.99	0.91	0.58	1.57	2.18	1.21	1.64	0.84	1.22	13.81
79	Monument Valley	0.42	0.60	0.52	0.32	0.31	0.35	0.82	0.86	0.66	1.10	0.49	0.67	7.12
80	Morgan	1.66	1.45	1.75	1.84	1.64	1.55	0.42	0.96	0.87	1.39	1.68	1.87	17.08
81	Moroni	0.93	0.86	0.77	0.79	0.67	0.77	0.54	0.91	0.77	0.84	0.77	1.08	9.70
82	Mountain Dell Dam	2.19	2.19	2.41	2.74	2.37	1.82	0.72	1.11	1.15	2.05	2.18	2.55	23.48
83	Myton	0.41	0.30	0.41	0.53	0.58	0.85	0.52	0.80	0.61	0.73	0.46	0.60	6.80
84	Neola	0.58	0.41	0.51	0.65	0.90	0.94	0.54	0.70	0.65	1.05	0.61	0.60	8.14
85	Nephi	1.23	1.22	1.41	1.49	1.26	1.07	0.65	1.02	0.81	1.16	1.16	1.41	13.89
86	New Harmony	2.04	1.68	1.90	1.26	0.71	0.60	1.13	1.48	0.96	1.34	1.58	1.87	16.55
87	Oak City	1.01	1.01	1.27	1.37	1.14	0.91	0.44	0.93	0.70	1.05	1.07	1.16	12.06
88	Ogden Pioneer PH	2.13	1.67	2.01	2.44	2.01	1.79	0.56	0.96	1.01	1.61	1.89	2.03	20.11
89	Ogden Sugar FCT	1.41	1.19	1.35	2.09	1.75	1.68	0.49	0.81	0.96	1.37	1.59	1.50	16.19
90	Orderville	1.77	1.52	1.47	1.14	0.62	0.60	0.90	1.38	0.97	1.18	1.24	1.71	14.50
91	Ouray	0.35	0.41	0.22	0.58	0.61	0.71	0.45	0.61	0.84	0.71	0.40	0.46	6.35
92	Panguitch	0.53	0.56	0.72	0.73	0.65	0.69	1.49	1.56	0.94	0.81	0.63	0.59	9.90
93	Park Valley	0.95	0.77	0.70	0.78	1.16	1.28	0.79	0.99	0.56	0.61	0.96	0.92	10.47
94	Partoun	0.28	0.39	0.44	0.66	0.70	0.81	0.63	0.51	0.43	0.52	0.41	0.37	6.15
95	Parowan	0.84	1.05	1.48	1.26	0.88	0.63	1.11	1.39	0.69	0.92	1.01	0.99	12.25
96	Pine View Dam	3.26	2.84	3.13	3.07	2.47	2.13	0.56	1.24	1.31	2.23	3.07	3.28	28.59
97	Piute Dam	0.60	0.55	0.72	0.71	0.71	0.60	0.80	1.20	0.79	0.70	0.63	0.59	8.60
98	Pleasant Grove	1.58	1.27	1.45	1.80	1.42	1.04	0.58	0.81	0.83	1.61	1.29	1.67	15.35
99	Price Warehouses	0.76	0.67	0.69	0.62	0.64	0.79	0.97	1.24	1.07	1.03	0.53	0.87	9.88
100	Provo KOVO	1.44	1.48	1.44	1.48	1.34	0.78	0.59	0.79	0.95	1.36	1.15	1.40	14.20
101	Richfield Radio KSVC	0.57	0.65	0.79	0.79	0.72	0.61	0.78	0.72	0.69	0.66	0.59	0.59	8.16
102	Richmond	1.76	1.45	1.67	2.17	2.11	1.85	0.52	0.91	1.02	1.52	1.79	1.75	18.52
103	Riverdale PH	1.65	1.27	1.64	2.29	1.86	1.68	0.52	0.89	0.96	1.51	1.64	1.59	17.50
104	Roosevelt	0.52	0.37	0.49	0.62	0.59	0.91	0.43	0.81	0.67	0.90	0.46	0.67	7.44
105	St. George	0.88	0.83	0.90	0.52	0.38	0.19	0.61	0.64	0.48	0.57	0.69	0.87	7.56
106	Salina	0.94	0.83	1.05	1.09	0.93	0.82	0.67	0.76	0.70	0.85	0.82	0.84	10.30
107	Saltair Salt PL	0.65	0.73	1.07	1.89	1.24	1.18	0.49	0.63	1.04	1.23	0.98	0.87	12.00
108	SLC WSFO	1.27	1.19	1.63	2.12	1.49	1.30	0.70	0.93	0.68	1.16	1.31	1.39	15.17
109	Santaquin	1.76	1.76	2.25	2.30	1.71	1.41	0.81	1.34	0.95	1.76	1.71	1.90	19.66
110	Scipio	1.16	1.14	1.46	1.22	0.97	0.85	0.66	0.93	0.74	1.02	0.98	1.21	12.34
111	Scofield Dam	2.18	2.87	1.39	1.03	0.95	1.02	1.04	1.38	1.04	1.22	1.15	1.60	16.84
112	Silver L Brighton	5.35	4.80	5.53	4.50	2.87	2.65	1.28	1.95	1.74	3.05	4.75	5.34	43.81
113	Snake Creek PH	3.25	2.53	2.39	1.98	1.47	1.49	0.71	1.23	1.02	1.71	2.40	3.12	23.30
114	Snowville	1.16	0.89	1.12	1.26	1.54	1.02	0.51	0.55	0.74	0.98	1.00	1.05	11.62
115	Soldier Summit	1.53	1.67	1.57	1.07	1.11	0.62	1.18	1.31	0.99	1.10	1.08	1.54	14.77
116	Spanish Fork PH	1.77	1.56	1.97	2.05	1.56	1.39	0.62	1.03	1.03	1.61	1.65	1.95	18.22
117	Strawberry RES E P	2.78	2.02	2.22	1.41	1.40	1.13	1.35	1.50	1.51	1.71	1.52	2.07	20.62
118	Thompson	0.65	0.53	0.66	0.81	0.70	0.66	0.61	1.21	0.81	1.11	0.54	0.63	8.92
119	Timpanogas Cave	2.47	1.99	2.38	2.61	2.30	1.83	1.00	1.37	1.19	2.10	2.01	2.59	23.84
120	Tooele	1.14	1.34	1.84	2.20	1.64	1.35	0.70	0.93	0.72	1.44	1.51	1.50	16.31
121	Tropic	1.24	0.90	0.97	0.87	0.70	0.62	1.22	2.06	1.09	1.16	0.82	1.10	12.75
122	U of U	1.58	1.55	1.71	2.17	1.87	1.08	0.58	0.88	1.02	1.49	1.45	1.55	16.93
123	Utah Lake Lehi	0.81	0.75	1.08	1.18	1.03	0.93	0.60	0.89	0.60	0.95	0.90	1.03	10.75
124	Vernal Airport	0.54	0.42	0.52	0.73	0.62	0.96	0.45	0.76	0.66	0.90	0.55	0.71	7.82
125	Veyo PH	0.90	1.62	1.38	0.94	0.72	0.36	0.70	0.99	0.95	1.06	1.37	1.02	12.01
126	Wah Wah Ranch	0.29	0.38	0.58	0.62	0.55	0.42	0.66	1.00	0.55	0.66	0.49	0.29	6.49
127	Wanship Dam	1.13	1.16	1.28	1.81	1.48	1.28	0.88	1.05	1.29	1.37	1.35	1.60	15.68
128	Wendover WSO	0.29	0.31	0.41	0.44	0.68	0.73	0.22	0.36	0.27	0.45	0.40	0.32	4.88
129	Woodruff	0.48	0.50	0.65	0.87	1.02	1.29	0.69	0.88	0.74	0.91	0.62	0.61	9.26
130	Zions National Park	1.55	1.58	1.69	1.27	0.69	0.62	0.84	1.57	0.80	1.04	1.16	1.55	14.36

Given: Corn to be irrigated by the furrow method at Logan, Utah. Total dissolved solids content of irrigation water, 350 ppm (Specific Conductance of 590 micromhos per cm). No groundwater contribution. Net water applied is 3.0 inches/ irrigation.

Seasonal consumptive use (Table 8)	18.86 inches
Average growing season rainfall (Table 17)	4.56 inches
Average growing season effective rainfall (Table 16)	3.15 inches
Field application efficiency (Table 13)	60%

Calculation: Net field irrigation requirement is obtained by subtracting from the seasonal potential consumptive use that water supplied from natural sources, i.e. effective precipitation and groundwater. Thus, 18.86 - 3.15 = 15.71 inches. No additional water is needed to compensate for poor water quality. Gross irrigation requirement at the field is obtained by dividing the net field irrigation requirement by the irrigation efficiency. Thus, 15.71 inches ÷ 0.60 = 26.18 inches irrigation requirement.

Given: Alfalfa to be irrigated at Milford, Utah, by an intermittent mechanical move sprinkler system in moderate windy conditions. Water supplied from a deep well having 875 ppm (Specific Conductance of 1400 micromhos per cm) total dissolved solids. Net water applied per irrigation is 2.0 inches.

Seasonal consumptive use (Table 9)	29.43 inches
Average growing season rainfall (Table 17)	3.14 inches
Average growing season effective rainfall (Table 16)	2.26 inches
Field irrigation efficiency (Table 13)	70%

Calculation: Net field irrigation requirement is 29.43 inches - 2.26 inches = 27.17 inches. No water supplied from high water table condition but the specific conductance of the groundwater used as an irrigation source exceeds 1000 micromhos per centimeter, suggesting the possibility of mild problems where water is being applied by sprinkler. (See Table 12 and Figure 3).

If we use the lower value of irrigation efficiency (Table 13) because of moderate wind condition, the gross irrigation requirement is 27.17 inches ÷ 0.70 = 38.81 inches. Experience may suggest that this quantity may need to be increased somewhat to mitigate any adverse effects from water quality.

If there are on-farm conveyance losses these would have to be taken into account in estimating the irrigation requirement in terms of needed water delivery at the farm headgate. Water diversion requirement necessary to provide the farm irrigation requirement can be calculated by dividing the farm irrigation water requirement by the conveyance efficiency of the conveying channel.

WATER REQUIREMENTS OF DOMESTIC ANIMALS

Domestic animals play an important role in the economy of the State of Utah. Beef cattle, dairy herds, sheep, turkeys, chickens, and hogs represent a substantial part of the agricultural sector. This animal industry is dependent upon the local production of feed and upon an adequate supply of drinking water. During periods of drought, it is feed production that is most seriously injured, but the animals can be impaired if severely restricted in water consumption. It is important, therefore, to know how much water animals require and how to evaluate water rights acquired by watering animals, particularly on mountain or desert ranges.

Many factors influence the intake of water by livestock. In a general way, when animals are on prepared feeds, the water intake is proportional to the amount of dry matter in the feed. Cattle and sheep drink 3 to 4 pounds[1] of water to each pound of dry matter consumed. Pigs, horses, and fowl consume about 2 to 3 pounds of water per pound of dry matter. Water consumption tends to be higher when feed rations are high in protein content and also when rations contain high proportions of fiber.

When animals feed on pastures or ranges, the amount of drinking water is dependent upon the amount of water in the feed. Variations in water consumption due to this factor are most pronounced in cattle and sheep. Sheep on good pasture drink little or no water and can go for weeks without ever drinking water. Cattle eating succulent feeds will also substantially reduce their intake of water, but not to the same extent as that of sheep.

Another factor that affects the intake of water is environmental temperature. During periods of hot, dry weather, moisture is lost by evaporation from body surfaces. This is particularly true of horses, which sweat profusely. In order to keep a water balance in the animal tissue, the water intake by the animal must increase. Consumption of water will increase as temperature increases until a maximum temperature occurs. At that point the animal begins to eat less, production (milk, eggs) decreases and the animal begins to lose weight.

The level of production also affects water consumption. The total water intake of steers on maintenance rations averages about 36 pounds per day; on fattening rations, it is about 72 pounds per day. Dry Holstein cows take in about 90 pounds of water a day; when producing 20 to 50 pounds of milk a day they may consume 160 pounds of water per day. Cows producing 80 pounds of milk a day drink as much as 190 pounds of water a day. Lactating ewes need 30 to 50 percent more water than other ewes. A sow

[1]One gallon of water is 8.33 pounds.

may consume 38 pounds of water per day the week before farrowing and 45 pounds a day the week following farrowing. Nonpregnant sows consume about 20 pounds of water per day; when 77-114 days pregnant they consume about 30 pounds per day. The water consumption of mature pullets is about 25 to 33 pounds for each 100 birds; 100 laying hens need 41 to 62 pounds a day.

Tables 18 to 22 give normal levels of water consumption by cattle, sheep, pigs, turkeys, and chickens, respectively. The high values are reasonably consistent for animals eating dry feed during periods of warm temperature, but the values given at the lower end of the scale are subject to wider variation because of range and pasture conditions.

The horse population in Utah is high, despite the fact that horses are now seldom used as draft animals. Horses raised for sport or pleasure are normally fed in well watered pastures. The water consumption of horses will vary with the temperature, their activity, and the type of feed consumed. Water consumption will be between 65 and 100 pounds per horse per day.

Table 18. Water requirements of cattle.

Class of cattle	Condition	Water Consumption	
		Gallons/Day	Pounds/Day
			x 8.33
Holstein calves	4 weeks old	1.2 - 1.4	10 - 12
	8 weeks old	1.6	13
	12 weeks old	2.2 - 2.4	18 - 20
	16 weeks old	3.0 - 3.4	25 - 28
	20 weels old	3.8 - 4.3	32 - 36
	26 weeks old	3.9 - 5.7	33 - 47
Dairy heifers	pregnant	7.2 - 8.4	60 - 70
Steers	maintenance ration	4.2	35
	fattening ration	8.4	70
Range Cattle		4.2 - 12.2	35 - 102
Range Cattle, cow and calf		9.0 - 18.0	75 - 150
Jersey cows	milk production 5-30#/day	7.2 - 12.2	60 - 102
Holstein cows	milk production 20-50#/day	7.8 21.8	65 - 181
	milk production 80#/day	22.8	190
	dry	10.8	90

Source: Adapted from Sykes (1955).

Table 19. Water requirements of sheep.

Condition	Water consumption	
	gallons per day	pounds per day
On range or dry pasture	0.6 - 1.6	5 - 13
On range (salty feeds)	2.0	17
On rations of hay and grain, roots and grain	0.14 - 0.7	1.2 - 6
On good pasture	Very little if any	

Source: Adapted from Sykes (1955).

Table 20. Water requirements of pigs.

Condition	Water consumption	
	gallons per day	pounds per day
Body weight 30 pounds	0.6 - 1.2	5 - 10
Body weight 60 - 80 pounds	0.8	7
Body weight 75 - 125 pounds	1.9	16
Body weight 200 - 380 pounds	1.4 - 3.6	12 - 30
Pregnant sows	3.6 - 4.5	30 - 37
Lactating sows	4.8 - 6.0	40 - 50

Source: Adapted from Sykes (1955).

Table 21. Water requirements of turkeys.

Conditions	Water consumption gallons per 100 birds per day
1 - 3 weeks old	1.1 - 2.6
4 - 7 weeks old	3.7 - 8.4
9-13 weeks old	8.8 - 14.3
15-19 weeks old	16.7 - 16.9
21-26 weeks old	13.6 - 15.0

Source: Adapted from Sykes (1955).

Table 22. Water requirements of chickens.

Condition	Water consumption gallons per 100 birds per day
1-3 week old	0.4 - 2.0
3-6 weeks old	1.4 - 3.0
6-10 weeks old	3.0 - 4.0
9 - 13 weeks old	4.0 - 5.0
Pullets	3.0 - 4.0
Nonlaying hens	5.0
Laying hens, moderate temperature	5.0 - 7.5
Laying hens, temperature 90°F	9.0

Source: Adapted from Sykes (1955).

MUNICIPAL WATER REQUIREMENTS

General Considerations

Municipalities build water distribution systems for the safety and convenience of those persons who choose to reside in or maintain businesses within the municipal boundaries. The first municipal systems were built primarily for fire protection, but uses today in addition to fire fighting, include drinking water, and water for cooking, washing, bathing, flushing toilets, heating, cooling, watering lawns, filling swimming pools in summer and ice skating rinks in winter, street cleaning, car washing, laundries, dairies, fountains, bakeries, food processing plants, manufactories, and industries of various sorts. The total municipal need is the summation of the amounts needed for all uses. No two cities are exactly alike in use structure.

The water that is diverted from the supply source for municipal use is not all "consumed" as it is put to use, and it is difficult to measure how much water is transferred to vapor and how much is discharged through the wastewater facility in liquid form. Some studies (Hansen et al. 1979) indicate that anywhere from 35 to 90 percent of the water diverted is returned in liquid form to the sewer collection system and eventually back into the natural drainage source or river. Although the water returned or sewer effluent is of a lower quality (unless thoroughly treated) and is returned at a different point in the hydrologic system, it can be an important manageable part of the total hydrologic resource.

In considering the water requirements for municipal systems, it is necessary to look at historic uses and then to find techniques of extending that information to predict future needs.

In the period from 1958 to 1962, the State Engineer conducted a study of water uses and needs for municipalities along the Wasatch Front (Criddle et al. 1962). This study assembled information on the then current uses of 63 water agencies in Weber, Davis, and Salt Lake Counties and projected the needs of these agencies to the year 1975. The State Engineer used this study as a guide in processing pending applications to appropriate water for domestic uses.

Since 1960 the Utah Division of Water Rights has been monitoring water suppliers; and, beginning about 1975, other agencies have commissioned studies which have contributed to municipal water use information. Some of the results of these studies were published in 1979 by the Utah Water Research Laboratory and the Utah League of Cities and Towns (Hansen et al. 1979). This study tabulated water use for 50 Utah municipalities for the years 1960 to 1976 and made some projections for the state needs to the year 2020.

Both the 1960 inventory and the more recent 1979 inventory show that when expressing water use on an average per capita daily basis there is a large variability among systems. A bar graph of the average water use during 1974, 1975, and 1976 by 50 Utah municipalities is shown in Figure 4. The quantities vary from 93 to 505 gallons per capita per day. The total annual use figures reported by the municipalities were converted to a gallons per capita per day basis by dividing the total use by the total population and by 365 (the number of days in a year). These figures are reported in Table 23 and summarized by mean, minimum, and maximum values in Table 24. The time period represented is from 1960-1976.

The historic data on municipal water use have little meaning until the reasons for some of the variation among systems can be explained. A glance at the bar graph of Figure 4 will show that five municipalities, Bountiful, Centerville, North Ogden, South Ogden, and Washington Terrace, all have low withdrawal rates, 93-110 gpcd. The common element among these five communities is that all have dual water systems; that is, a separate pressurized water system exists in each to supply the outside or landscaping water needs. The municipal system supplies essentially no outside water. The Salt Lake City water system on the other hand supplies essentially 100 percent of outside use. Its average withdrawal rate is 287 gpcd. Salt Lake City is also the largest system in the state and has a higher population density than the other systems. It also has more multiple unit dwellings, apartments, and condominiums. The high outside use would tend to make the withdrawal rate high while the population density and multiple living units would tend to reduce the withdrawal rate. Other factors which affect the average rate of withdrawal are climate, market value of domestic residences, lot sizes, types of industry using municipal water, type of charges, use of meters, and condition of storage and conveyance system (pipe leakage and reservoir spills).

Those cities with high withdrawal rates (over 400 gpcd) are not necessarily the cities that supply 100 percent of their outside demand. The Cities of Delta, Fillmore, Hyrum, Logan, and Morgan all have high withdrawal rates but have different outside use indexes. The high withdrawal rate cannot be explained by price of water either, but may have something to do with population density, special industrial uses, and reservoir spills or leakage. An example of unusually high unit withdrawal rates is that of the little town of Amalga in Cache Valley. Amalga had in 1979 a population of 210 and an average withdrawal rate per capita of 1682 gallons per day. The explanation is that Amalga's water system supplies water to a large cheese manufacturing plant and several large dairy herds. About 85 percent of the total supply goes to these uses.

Planners for future water development have considered not only what has been needed in the past, but an apparent increasing per capita withdrawal rate to accommodate the increasing use of water using appliances and the trend toward more bathrooms per household, etc. It now appears that this increasing rate has leveled off and in the future may actually decrease. As the population density in a city increases and people crowd closer together in multiple living units, i.e., apartments, condominiums, etc., the unit use appears to stabilize. The Salt Lake metropolitan area appears to have a fairly constant per capita withdrawal rate between 250 and 300 gallons per day. The long term stability of unit withdrawal rates for four metropolitan cities can be seen in the graph of Figure 5.

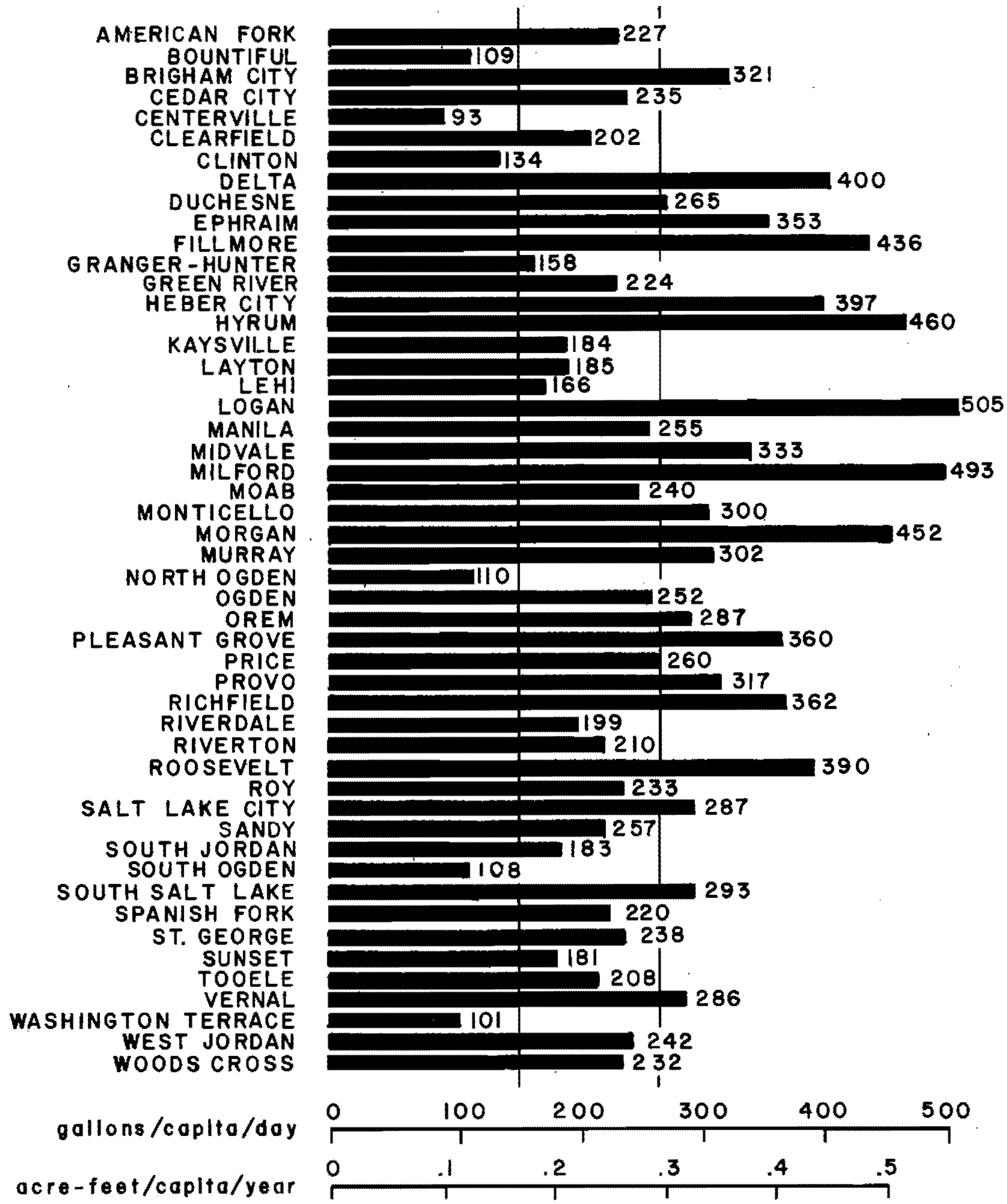

Figure 4. Daily per capita withdrawal rates for 50 Utah municipal systems: Average of 1974, 1975, and 1976. (Tooele has only 1 year of record, Duchesne has 2 years of record.)

Table 23. Estimated daily withdrawal rates per person (gcd) for 50 Utah municipal systems: 1960-1975

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	425	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	260	296	260	228	238
Woods Cross			176	177	199	175	163	168	158	162	152	164	191	223	265	196	235

Table 24. Per capita withdrawal rate (gcd) statistics for 50 Utah municipalities: 1960-1976.

Municipality	Years of Data	Statistics			
		Mean	Deviation	Minimum	Maximum
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

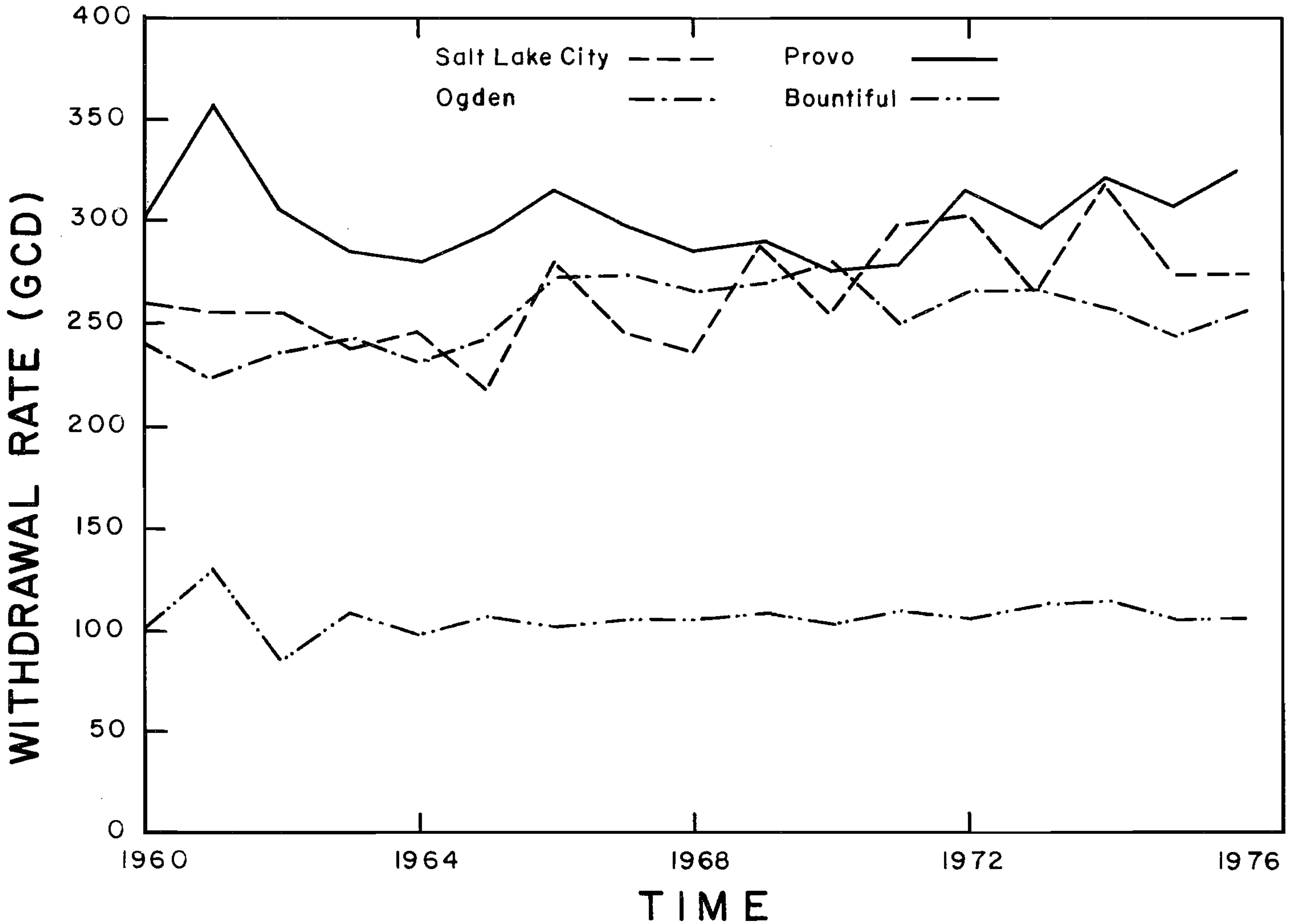

Figure 5. Daily per capita withdrawal rates (gcd) for Bountiful, Ogden, Provo, and Salt Lake City: 1960-1976.

The 1979 study on municipal uses in Utah did not attempt to project future needs of each water supplier. It did make the following conclusions:

(1) A good estimate of the municipal withdrawal rate for indoor use only is 100 gpcd.

(2) For short term planning, 262 gpcd is a good estimation of Utah's average per capita water needs (statewide).

(3) For long term planning, 262 gpcd is excessive. Per capita water usage in the future will decline for three reasons:

- (a) Water will become increasingly expensive.
- (b) Leakage will be controlled.
- (c) As Utahns move closer together, they will require less water on a per capita basis for outdoor use.

Design of Municipal Systems

The design parameters for new domestic water systems, subdivisions, and small rural domestic systems include:

(1) Average annual use, which is used to define the total amount of water needed at the source of supply, and is a measure of the water right appropriated.

(2) Instantaneous peak demand/fire flow, which is used to size the main supply pipelines.

(3) Peak daily flow, which is used to size the treatment plant, well pumps and equalizing reservoirs.

(4) Peak monthly flow, which is used to size the raw water reservoir or determine the amount of new water acquisitions needed.

Average annual use

As previously noted, when comparing one system with another, the average annual use from a domestic water system is variable. This is not cause for concern because usually the variations can be explained by the particular demands placed upon each system. Industrial uses peculiar to one system, variation in outside demands, and the cost of water to the users which reduces use for outside purposes are all reasons for differences. There must, however, be some basis to estimate average annual use for the design of new systems.

Average annual use is not a critical parameter for system design, but it does indicate the total amount of water needed at the source of supply, and is a measure of the water right appropriated. Beginning with the most elementary system, a single family domestic household, the Utah adjudication procedure has allowed 650 gallons per day. As a system increases to include many households and multiple dwelling units, such as apartments and condominiums, and as business uses are connected to the system, the average use per connection increases. For rural and small urban systems, the Utah State Department of Health recommends a design standard of 800 gallons per day. (Many large community systems exceed this. The Utah average use would be about 950 gallons per connection.)

Table 25 gives recommended design amounts for varying system demands.

Peak demands

A municipal water system must be able to conduct peak flows as well as provide the total seasonal quantity of water needed. Peak rates of flow information is important to the planning and design of systems because each type of peak determines either the size of the water right, the size of the pipe system, the size of the treatment plant, or the raw water storage facilities, along with capital and operating costs associated with each. The primary costs affected are summarized in Table 26.

Main line pipes are designed to handle instantaneous peak demands or fire flows, whichever is greater. Water treatment plants are designed to meet peak day demands. Storage reservoirs which deliver raw water to treatment plants are sized to provide seasonal or monthly peak demands.

Unfortunately, peak demand values are seldom measured by water utilities. The only generally available figure is the average daily demand (total annual use divided by 365 days). For distribution system design, peak day, peak month, and instantaneous peak demands are usually estimated by applying multipliers to the flow rate of average daily demand. The multipliers suggested by water supply textbooks usually give a range of values. For example, Clark and Viessman (1966) suggest a peak-day flow of 120 to 400 percent of average daily and an instantaneous peak flow of 150 to 1200 percent of average. These ranges are too great for design. The State Engineer in the past has used 220 percent of average daily flow as being a reasonable figure for peak daily flows. A more recent study (Hughes and Gross 1979) has derived the relationships for Utah systems reported below.

Instantaneous peak demand

Instantaneous demands are used to size main distribution lines and in-line booster pumps. Fire flows govern pipe sizes in distribution systems in central business districts and in residential areas where the pipe capacity is less than about 500 gpm (about 250 connections). One

Table 25. Average annual domestic water demand for design purposes.

Design conditions	Average demand gallons/person/day	Average demand gallons/connection/day
Urban systems with no outside use	100	365
Recreation homes occupied in summer season only	165	600
Single domestic residence	180	650
Rural or small urban communities	220	800

Table 26. Effects on municipal water system cost of different durations of flow peak.

Peak Flow Period	Costs Which are Primarly Effected	
	Capital Investment	Operating
Monthly	Raw Water Reservoir, Water Stock or Right Purchases	Monthly well, booster and treatment plant pumping costs, annual water purchase charges
Daily	Treatment Plant, Well Pumps, Transmission Conduits, Equalizing Reservoirs	Electrical demand charges for pumps Treatment plant start-up costs
Instantaneous	Distribution Mains (within ranges where fire flow does not govern), Service Lines, In-Line Booster Pumps	Booster Pumps

reason for providing for high instantaneous flow rates in the design of distribution systems is to reduce the possibility of low or negative line pressures resulting from high demand and low capacity. Negative pressures may cause contamination of the water supply if, for example, a hose end were lying in a puddle or if a leak in the pipeline were below the water table.

Instantaneous peak flow rates per connection decline, but at a decreasing rate, with a larger number of connections in a system. After 1000 connections the decline is so small as to be negligible, and a constant unit value of instantaneous flow can be used for design purposes. The shape of the curve used to represent flow rate per connection from 1 to 1000 connections has been somewhat arbitrary because measured flows were scarce. Recent studies by the Farmers Home Administration using data from Ohio (FmHA 1976) and by Hughes and Gross (1979) using Utah data have produced the curves shown in Figure 6. Recommendations for using the curves are:

1. The Utah demand curve (Figure 6) is recommended for low density rural systems where project cost is a critical issue and where no unusual characteristic (large landscaped lots, nonresidential use, or large leaks) would create higher peaks.

2. For systems where some factor suggests the possibility of high short term peaks or where pipe cost is less critical, a higher factor of safety could be achieved by using the FmHA average standard. For example, if the system serves a high value district with large landscaped lots, the FmHA average standard would be more suitable than the Utah demand function which was derived from systems which were in low to middle value districts. Also, if the size of the lawns to be irrigated is large or if a large percent of the households is to be unmetered, then the FmHA average standard should be used.

Peak day demand

The capacities of water supply facilities such as treatment plants, pump motors, equalizing reservoirs, etc., are determined by average demand during the peak 24-hour period. This peak day demand is often determined by applying a multiplier to the average daily use. The State Engineer has used 2.20 as being a reasonable multiplier. Hughes and Gross measured the flows in several Utah systems and developed regression equations to more closely approximate the relationship between average and peak demand. The correlations were very good (R^2 of 0.953 and 0.938, respectively). The equations for peak day demand as a function of average demand are given:

$$D_{pd/c} = 600 \text{ or } 84\ (D_{avg/c}) - 207 \quad \text{whichever is greater} \quad . \quad . \quad . \quad . \quad (11)$$

and

$$D_{pd/p} = 165 \text{ or } 2.5\ (D_{avg/p}) - 49 \quad \text{whichever is greater} \quad . \quad . \quad . \quad . \quad (12)$$

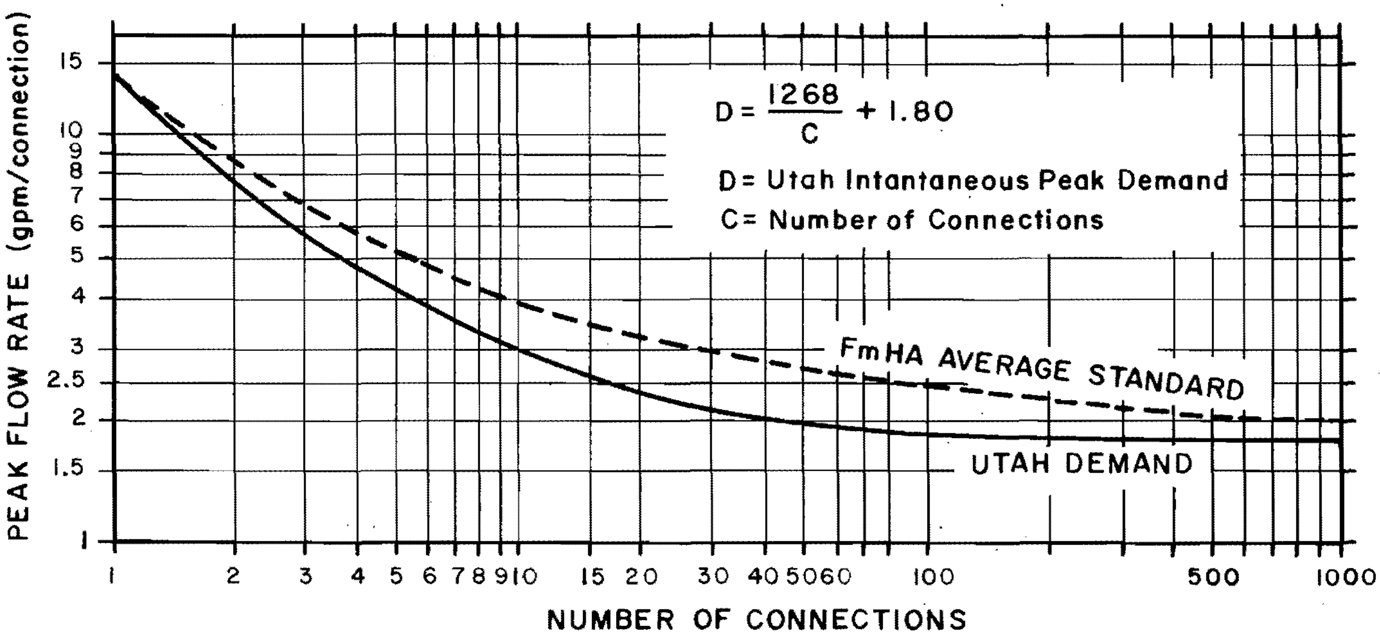

Figure 6. Peak instantaneous demands within municipal water systems in Utah: Utah demand function and Farmers Home Administration average standard.

in which

$D_{pd/c}$ = peak day demand in gallons per connection
$D_{avg/c}$ = average demand in thousand gallons per month per connection
$D_{avg/p}$ = average demand in gallons per person per day

These equations are plotted in Figure 7 and Figure 8. Both curves show minimum values to be used in situations with small average demand.

Outdoor water use index and peak day demand

It has long been known that outside use (principally yard irrigation) is a very important factor in summer water use and that this component of demand varies greatly among Utah systems. Some areas have supplemental pressure pipelines or ditch systems from which all or part of the outside demand is supplied. Landscaping varies greatly between rural and urban and between old and new residential areas. Still another factor is climatic variation between Utah's Dixie and the higher and wetter northern valleys.

A single, easy to use index which accounts for many factors which collectively determine outside demand from a municipal-domestic system is shown in Table 27. It associates an integer between 1 and 9 with each of nine outdoor use category descriptions. These descriptions, although somewhat subjective, are reproducible and provide a reasonably easy means for defining the index number. The index number 1 is used for a system which provides no outside water (such as Bountiful City), and the index number increases as outside irrigation increases up to a maximum of 9 which represents a city in which all of the outside demand is furnished by the municipal system and from which relatively large landscaped areas are irrigated in a hot-dry Utah climate (such as Monticello).

If the average daily demand for the system to be designed is not known, the peak day demand can be approximated by using the following equations based on regression analysis on Utah data, which relate peak day demand to the outdoor use index:

$$D_{pd/c} = 600 \text{ or } 345\,(I) - 82 \quad \text{whichever is greater} \qquad (13)$$

where peak day demand is in gallons per connection.

$$D_{pd/p} = 165 \text{ or } 92.5\,(I) - 21 \quad \text{whichever is greater} \qquad (14)$$

where peak day demand is in gallons per person and (I) is the outdoor use index. These equations are plotted in Figure 9 and Figure 10.

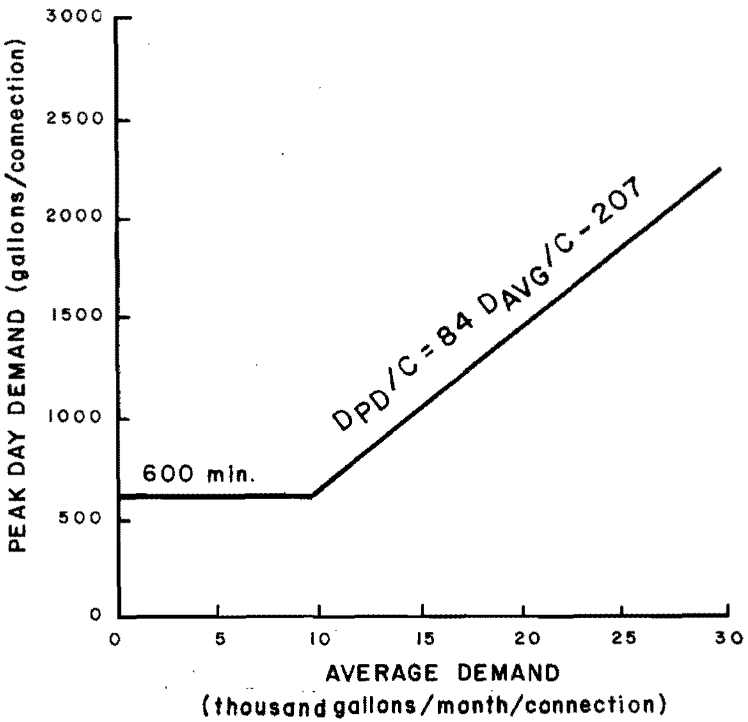

Figure 7. Peak day demand per connection as a function of average demand.

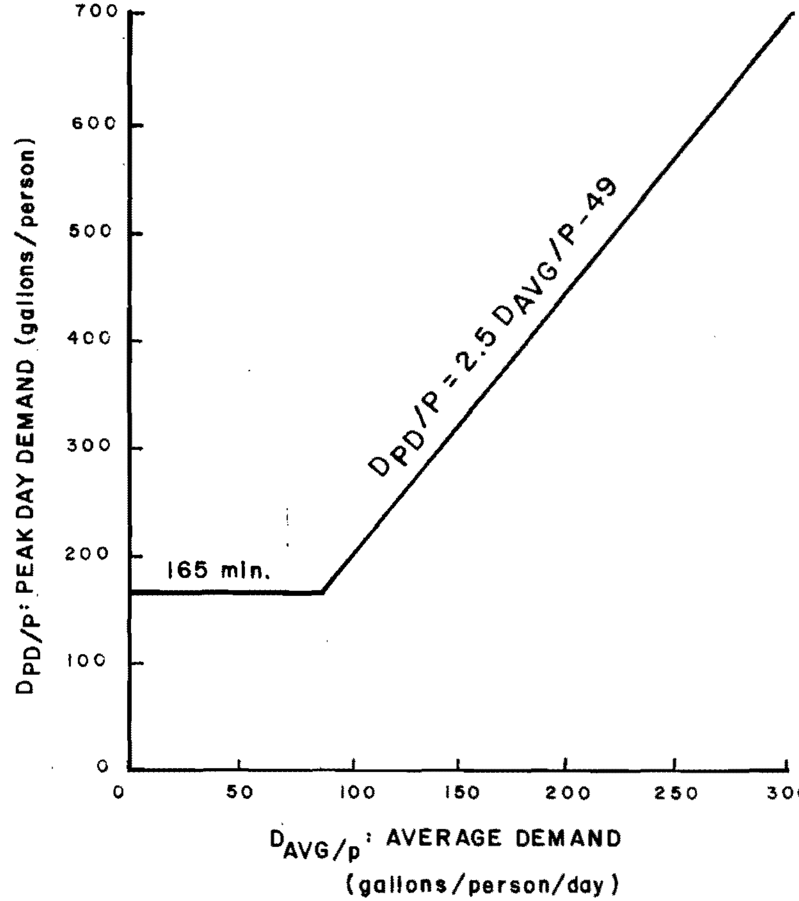

Figure 8. Peak day demand per person as a function of average demand.

Table 27. Outdoor use index (I).

Index (I)	Categories Indicating Extent of Outdoor Demand From Domestic System
1.	No outdoor use from domestic system--everyone has connection to pressurized dual system.
2.	Almost no irrigation from domestic system--supplementary system is available which services at least 85% of outside demand.
3.	Supplementary ditch system is available and landscaped areas are small (average less than 1500 square feet).
4.	No supplementary system is available but landscaped areas are small (average less than 1500 square feet).
5.	Ditch system available for gardens but lawns (over 60%) are irrigated from domestic system.
6.	Ditch or piped system available to some customers but most outside irrigation (over 75%) is from domestic system.
7.	All outside areas are irrigated from domestic system--moderate amount of landscaping, average Utah climate.
8.	Large amount of landscaping and all irrigated from domestic system--average Utah climate.
9.	Large amount of landscaping and all irrigated from domestic system--hot and dry Utah climate.

Peak month demand

Sustained periods of high demand are important in determining storage capacity or required sustained yield from wells. Peak month demand can be estimated from the following equations:

$$D_{pm/c} = 12 \text{ or } 2.96\,(D_{avg/c}) - 15 \quad \text{whichever is greater} \quad . . . \quad (15)$$

in which

$D_{pm/c}$ = peak demand month in thousand gallons per connection
$D_{avg/c}$ = average demand in thousand gallons per month per connection

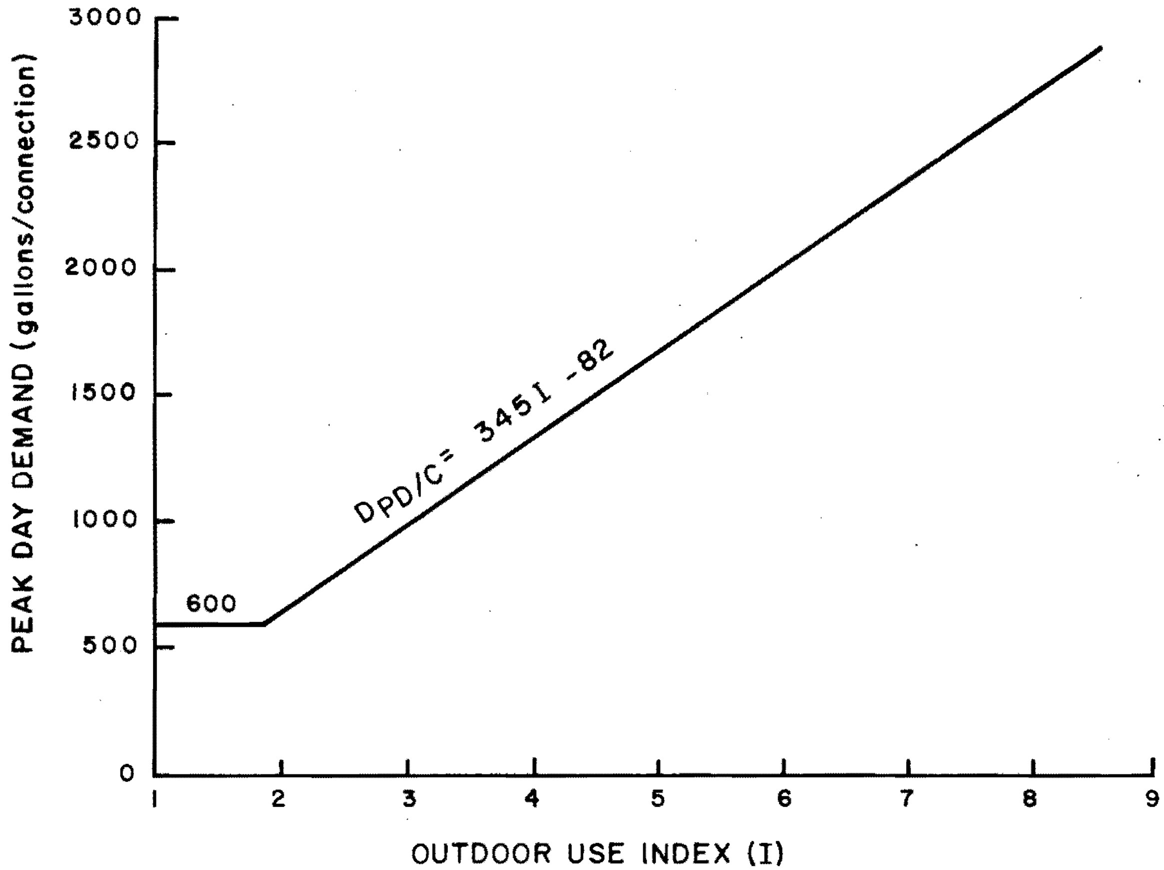

Figure 9. Peak day demand per connection as a function of outdoor use index.

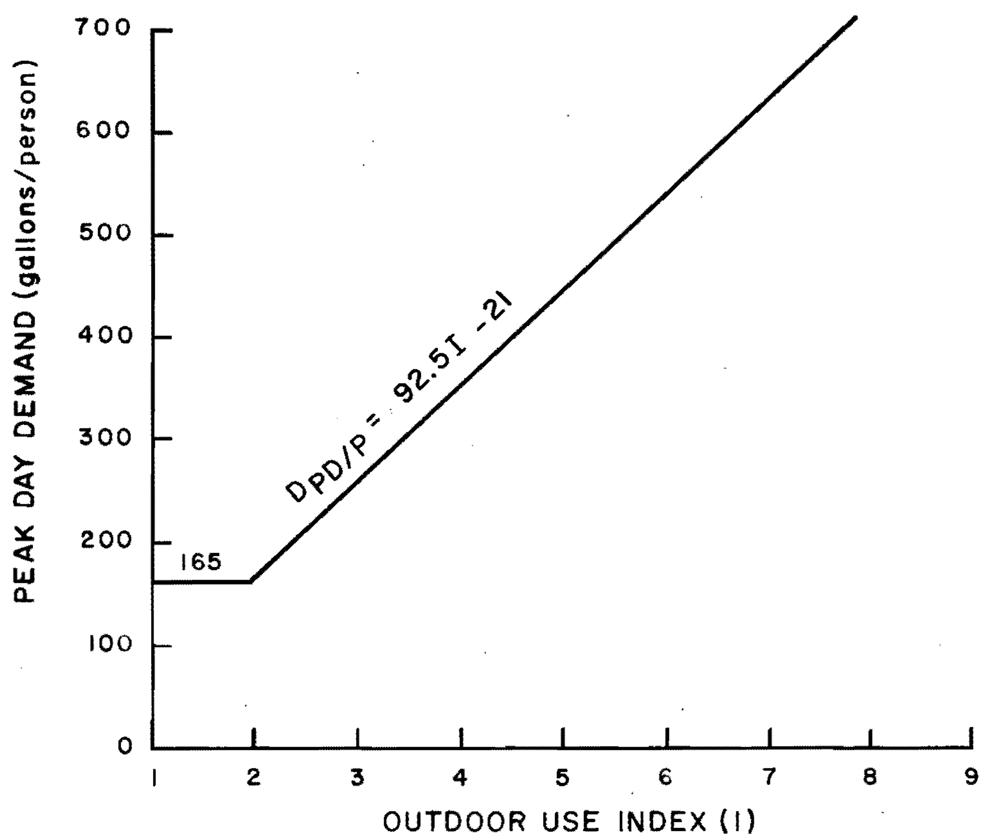

Figure 10. Peak day demand per person as a function of outdoor use index.

or

$$D_{pm/p} = 125 \text{ or } 2.92\ (D_{avg/p}) - 130 \text{ whichever is greater} \quad \ldots \quad (16)$$

in which

$D_{pm/p}$ = peak month demand in gallons per person per day
$D_{avg/p}$ = average demand in gallons per person per day

These equations are plotted in Figures 11 and 12.

Computing Demands - An Example

Using the Hughes and Gross (1979) expression for peak day demand as a function of average demand, and solving for average demand, the expressions are:

$$D_{avg/c} = \frac{D_{pd/c} + 207}{84} \quad \ldots\ldots\ldots\ldots \quad (17)$$

and

$$D_{avg/p} = \frac{D_{pd/p} + 49}{2.5} \quad \ldots\ldots\ldots\ldots \quad (18)$$

As input to these equations, the peak day demand is estimated using Equations 13 and 14 and the appropriate outdoor use index. As an example of how these equations can be used to estimate design flows for community water systems, consider a community water system to accommodate 450 connections and a population of about 1700 persons. There is to be no supplementary outside water and landscaped areas are less than 1500 square feet per connection (outside use index = 4, Table 27). Find: 1) the instantaneous flow rate for main line pipe design; 2) peak day demand; 3) average demand and total water supply needed; and 4) peak month demand. Solving for these four flows:

(1) The instantaneous peak flow rate can be determined from Figure 6 using the Utah standard expressed by equation. The calculated value is

$$D_{inst} = \frac{12.68}{450} + 1.80 = 1.83 \text{ GPM per connection}$$

Total flow is:

450 connections x 1.83 = 823 GPM

In a low valued, small lot residential area or in a recreational development this design flow may be used, otherwise use the FmHA curve on Figure 6 to read 2 GPM per connection or 900 GPM for main line capacity.

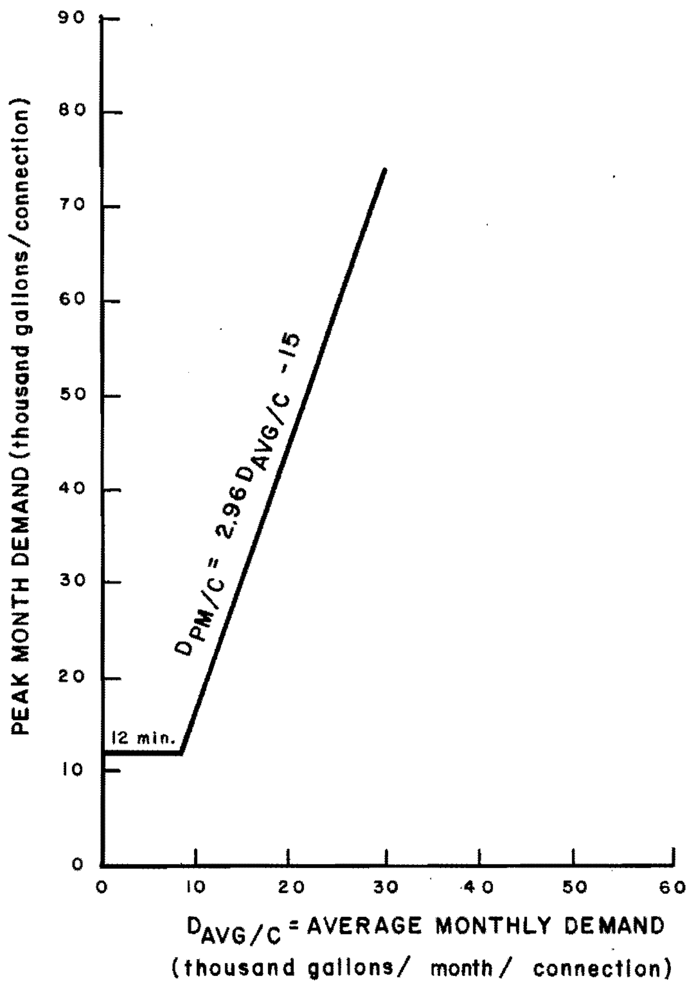

Figure 11. Peak month demand per connection as a function of average demand.

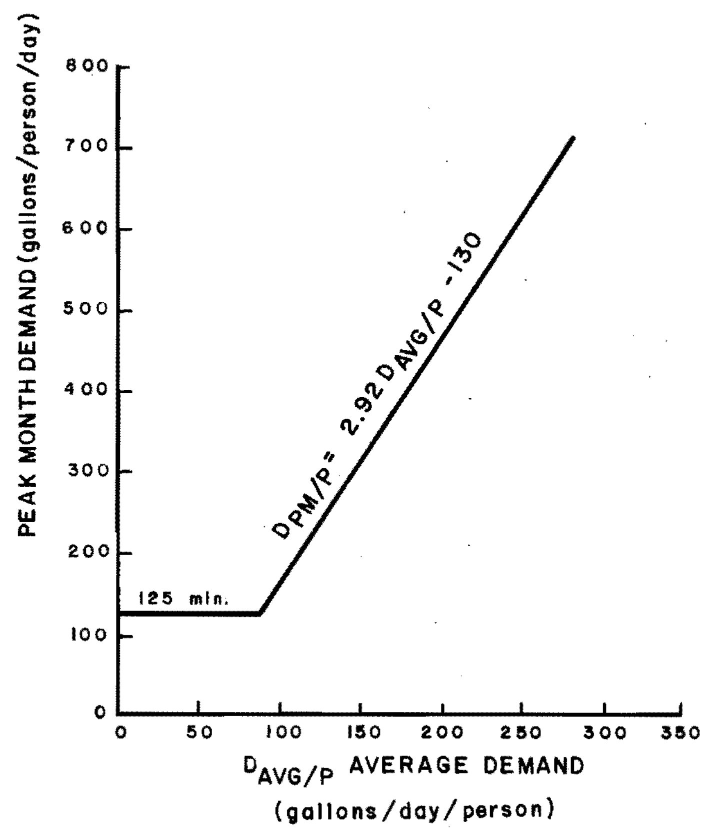

Figure 12. Peak month demand per person as a function of average demand.

(2) The peak day demand can be estimated from Equations 13 and 14 or from the graphs in Figures 9 and 10.

$$D_{pd/c} = 345(I) - 82$$

$$= 345(4) - 82 = 1298 \text{ gallons per connection per day}$$

$$D_{pd/p} = 92.5(I) - 21$$

$$= 92.5(4) - 21 = 349 \text{ gallons per person per day}$$

(3) Average demand can be computed from Equations 17 or 18.

$$D_{avg/c} = \frac{D_{pd/c} + 207}{84}$$

$$= \frac{1298 + 207}{84} = 17{,}900 \text{ gallons/month/connection}$$

$$D_{avg/p} = \frac{D_{pd/p} + 49}{2.5}$$

$$= \frac{349 + 49}{2.5} = 159 \text{ gallons per day/person}$$

Total annual water supply needed:

gallons per month x 12 x No. of connections =

17,900 x 12 x 450 = 96.66 million gallons/year

(4) Peak month demands can be estimated from Equations 15 and 16 or from graphs in Figure 11 and Figure 12.

$$D_{pm/c} = 2.96 - 15 \times D_{avg/c}$$

$$= 2.96 - 15\ (17.9) = 38{,}000 \text{ gallons/connection}$$

$$D_{pm/p} = 2.92 - 130\ D_{avg/p}$$

$$= 2.92 - 130\ (159) = 334 \text{ gallons/person per day}$$

The above computations are summarized in Table 28.

Table 28. A summary of flows computed in design example.

Item	Unit Use gallons per connection	Unit Use gallons per person	Total Use million gallons	Average flow rate gallons per minute
Average demand	17,900/mo.	160/day	97/year	185
Peak month demand	38,000/mo.	334/day	17/month	387
Peak day demand	1,298/day	350/day	0.6/day	405
Instantaneous Demand				900

INDUSTRIAL WATER REQUIREMENTS

Water has economic value because of its physical properties. It's what water does when used as a secondary medium in causing or allowing changes or processes to occur that makes it a valuable resource. The weight and fluid motion of water can cause a turbine to turn and electricity to be generated. Heating water with coal, oil, or nuclear energy can transform liquid to vapor and the expanding vapor can be harnessed for many kinds of useful work. The thermal properties of water can be used in manufacturing processes such as quenching heated metals to temper them, or storing or transporting heat to warm, cool, or maintain temperatures necessary in certain processes. As a fluid of given density, water can be used to separate metals, from the panning of gold to the flotation of copper. Water can be used to control dust, assure soil compaction, wash foods and transport solids; and because energy is absorbed to cause evaporation, water can be used as a cooling agent.

Industrial water uses are process and site specific, and therefore it is difficult to make general assessments of water required for industry. Also, few measurements are available as to how much water is used or where the water is needed and for what purpose. It is also difficult to normalize industrial use in units that are meaningful when extrapolating to other conditions. Water consumed per employee per day or water consumed per pound of product are not valid methods of comparison where the bulk of the water is used in a process unrelated to number of employees or to pound of product finished.

To obtain the relative magnitudes of industrial water use in Utah, a survey was made covering the years 1974, 1975, and 1976. It was determined that industrial uses can be grouped into five major categories:

(1) energy conversion, including

- (a) hydroelectric
- (b) steam-electric
- (c) oil extraction from tar sand and shales
- (d) geothermal
- (e) coal extraction
- (f) oil extraction, oil wells
- (g) natural gas extraction
- (h) uranium extraction
- (i) coal gasification
- (j) coal liquefaction
- (k) refineries, petroleum

(2) primary metals

- (a) copper
- (b) steel

(3) inorganic chemicals

(4) hydraulic cement

(5) food products

A listing of some energy conversion related activities with estimates of the water required is given in Table 29. New technologies and new processes could alter these estimates.

Within each of the above categories water serves at least three major functions: 1) water needed in the manufacture of a product, 2) water needed as a cooling agent, and 3) water needed for sanitary purposes including the needs of workers in the plant. The survey tabulated the percent of water used in each of these three functions for several different industries. These values are shown on Table 30. The table also indicates the percentage of water returned to streams.

An attempt was made to normalize the water requirements of various industries by computing the water used per employee per day ged Table 30. These values are shown but should be recognized as approximations as industrial use is not necessarily proportional to the number of employee days. The magnitude of the values do, however, have some comparative consistency as can be seen from similarities among plants of a given type. Average water use for selected industries is plotted in Figure 13. Water for the generation of electric energy has been omitted in these comparisons.

Perhaps the greatest industrial use of water in Utah is for energy conversion. There are several ways in which water can be used. The greatest volume of water is probably used in hydrogeneration of electricity. This is a nonconsumptive use of water, and 100 percent of the flow is returned to the resource stream. Most Utah streams are small with steep gradients, so power generation usually entails the diversion from and drying up of a portion of the natural stream.

Steam-generation of electricity diverts less water than does hydrogeneration. The difference is that the water converted to steam is not returned to the stream, but, after many condensation and recirculation cycles, eventually exits as vapor. A major use of water in steam generation is that used to cool and condense the steam for recirculation. The volume of water needed for this use is dependent upon whether an open or closed cooling system is used. Open systems are once-through type where large volumes of cold water are circulated through the condenser and returned to the natural stream. The closed system returns the heated water to a cooling tower or pond, from which it is later withdrawn and reused. As the water is reused, the dissolved solids become concentrated and eventually the water has to be replaced with fresh water. New technology is making available systems which can use water of extremely high salt concentration, and hence less total volume of water consumed.

Water is also used in developing fossil fuel resources. The extraction of mineral fuels such as coal and oil requires water as does the refining of oil into combustible fuels. Amounts depend on processes used and the care exercised in water management. Newer technologies to produce fuels from coal gasification or coal liquefaction or to extract crude from tar sands and oil shales will also require water.

Table 29. Water use rates for energy conversion industries.

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 extraction	$\geq$ 20.9 gallons/ton
Oil extraction	$\geq$ 171 gallons/barrell
Natural gas extraction	$\geq$ 2.9 mg/bcf
Uranium extraction	$\geq$ 0.184 mg/ton

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

Table 30. Utah industrial water withdrawal rates (ged) for major water using industries: average of 1974, 1975, and 1976.

	*	% of Withdrawal Rate				Withdrawal Rate	Return Flow
		Product Manufacture	Cooling	Employee Sanitation	Other	ged	(% of withdrawal)
Meat Packing	1	79	17	3	1	453	80
	2	95	4	1	0	1484	N.A.[a]
Poultry Processing	1	70	25	5	0	1194	100
Cheese	1	97	2	1	0	2486	98
	2	69	20	1	10	288	90
Ice Cream	1	N.A.	N.A.	N.A.	N.A.	507	N.A.
	2	N.A.	N.A.	N.A.	N.A.	322	N.A.
Fluid Milk	1	N.A.	N.A.	N.A.	N.A.	873	N.A.
Canned Vegetables	1	N.A.	N.A.	N.A.	N.A.	4851	N.A.
Flour	1	85	10	5	0	639	50
Bread	1	80	10	10	0	633	70
Candy	1	N.A.	N.A.	N.A.	N.A.	578	N.A.
	2	N.A.	N.A.	N.A.	N.A.	312	N.A.
Soft Drinks	1	N.A.	N.A.	N.A.	N.A.	278	N.A.
Inorganic Chemicals	1	82	15	1	2	8908	15
Petroleum Refining	1	33	65	T[b]	T	11760	N.A.
	2	30	67	3	0	7860	N.A.
	3	45	55	T	0	11738	N.A.
Hydraulic Cement	1	97	T	3	0	3260	3
	2	95	0	T	5	3668	2
Steel Works	1	33	56	6	5	5109	10
Copper Smelting	1	92	6	1	1	67231	N.A.

[a]Not available.
[b]Less than one percent.
*Plant number where different plants were surveyed in the same industry.

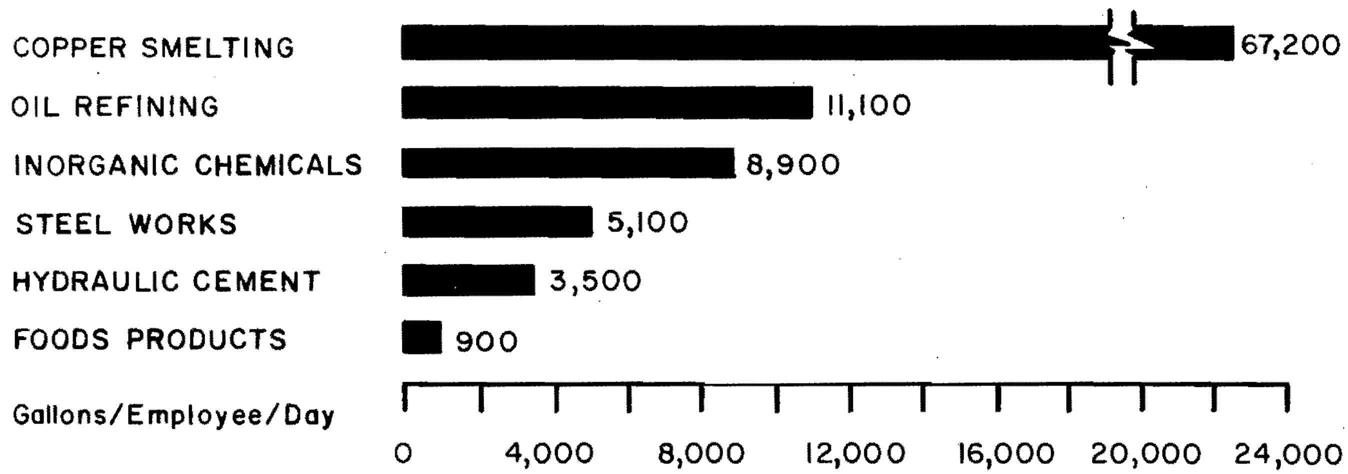

Figure 13. Normalized water use rates for Utah's major water using industries. (Hydro and steam electric generation excluded.)

RECREATIONAL WATER REQUIREMENTS

Water requirements for recreational purposes are treated differently than water requirements for agricultural, municipal, or industrial purposes because the benefit comes not by diverting the water from the stream, but by keeping and preserving it in its natural course and setting. Water has value for recreational uses because it is there, because it has certain flow characteristics favoring the biologic environment, because it has the necessary geometry (surface area, depth, width, etc.), and because it has the proper quality (temperature, clarity, taste, odor, etc.).

Unlike other water users, the recreationist does not extract or withdraw water from the source, except for drinking on site and for sanitary purposes. (This small amount of withdrawn water is in reality a domestic use in a recreational area.) To the recreationist this water has value because it is not diverted, but left in the stream, and it is the recreationist that is mobile and can move to the site of choice for a specific type of activity.

Many recreational activities on streams and lakes (reservoirs) have been created or enhanced by water development for other purposes. Dams have created numerous reservoirs in Utah which attract many recreational visitors, and the water regulation provided by the reservoir has often enhanced fishing in the stream below because of decreased variability in flow. Some opportunities for river and stream recreation have been lost, however, because of changes in flow regimen and temperature which have diminished the habitat suitability for fish. As life styles change and as public preference for outdoor recreation increases, the future may see legislative changes in the law which favor in-stream uses. The dependence of society upon agriculture and energy may, however, dictate which direction water use goes.

Types of Water Related Recreation Activities

Water related recreational activities can be grouped as follows:

(1) Proximity uses: sightseeing, nature study, picnicking, camping, summer homes.

(2) Fishing, both flowing water and ponded water fishing employing such means as: wading, canoeing, low-power boating, and bank fishing.

(3) Personal water contact: includes swimming, wading, tubing, water skiing, and scuba diving.

(4) Tranquil water boating, both rivers and lakes, includes canoeing, rowing, sailing, low-power boats, and high-power boats.

(5) Nontranquil water boating, includes rafts, drift boats, canoes, and kayaks.

(6) Waterfowl hunting, relegated mostly to marshlands which support migratory birds such as ducks and geese.

Most of the activities enumerated above depend upon the geometry of the water source and the dynamics of the system, that is whether the water is still as in ponded surfaces or moving as in flowing rivers. When moving the velocity also has importance in determining a recreational use.

A subjective evaluation as to whether a specific activity is good, fair, or poor is based on the area required for the sport. Some of these activities are given in Table 31. Swimming and canoe-fishing on flowing streams are dependent upon stream velocity and water depth. High velocities and shallow depths preclude the use of streams for these activities. The probability of using streams for swimming and canoe-fishing increase as the depth increase and velocity decreases as shown in Figure 14.

Evaluating Changes in Recreation Opportunities

Where water is preserved in the natural streams for recreational purposes other legitimate uses which depend on regulation and diversion of natural flow must be sacrificed. Since water allocated to a specific use may preclude other uses, there is always a tradeoff in determining the most beneficial use. Striking a balance which most fully serves the identified objectives of a dynamic society with respect to in-stream and off-stream water uses is difficult because the value of recreational water use is so difficult to quantify.

Fishing is an important recreational sport in Utah but determining the amount of water needed to support fisheries is difficult. The ideal water-site combination of quantity, velocity, depth, temperature and accessibility to create the best habitat for fish is seldom obtainable under natural conditions and is most often too costly to provide by creating conditions. Because economic uses of water for agriculture and industry take precedence in the public interest, fishing as a sport must be a shared use and exist where it can best be included in project plans. Ponded water fishing, which in some respects is more productive than flowing water fishing, is created when reservoirs are built, and flowing water fishing is often enhanced when dams are operated to reduce the variability of flow below the dam. Some developments do, however, destroy fisheries and "cost" to the fishing must be evaluated in terms of lost public recreation. Sometimes concessions can be made to maintain in-stream flows to support fisheries and still support traditional water uses. The problem is not to be able to determine the water requirements for ideal fish habitat but to evaluate the conditions which will exist before and after a contemplated change and to assess the relative costs to the fishery. If these costs are unreasonable, the project should probably be altered or omitted.

Table 31. Outdoor water recreational areas rated by amount of water surface area available.

ACTIVITY	SURFACE AREA (acres)	REMARKS
*Advanced Swimming	4	Good
	1	Fair
	.2	Poor
*Recreational Swimming	4	Good
	1	Fair
	.1	Poor
Water Skiing	520	Good
	250	Fair
	150	Poor
Pleasure Boating	520	Good
	250	Fair
	150	Poor
Low-power Boating	150	Good
	75	Fair
	20	Poor
Non-power Boating	25	Good
	10	Fair
	5	Poor
Ice Skating	5	Good
	.3	Fair
	.3	Poor
Sailing	300	Good
	150	Fair
	20	Poor

*Advanced Swimming (depth > 5') generally limited to lakes.
Recreation Swimming (depth < 5') limited to rivers, streams, etc.

Fish may be affected by changes in the stream environment during any of four life history stages: egg, fry, juvenile, and adult. Furthermore, what might be considered the "ideal" stream flow conditions for one stage of development are quite different for other stages. Other critical activities such as spawning and passage can also be affected. The principal changes in stream environment are alterations in water depth, stream velocity, temperature, and quality (chemical composition).

Changes in stream conditions may cause the loss of certain fish species even though the condition may not reach lethal levels. As both juvenile and adult fish are mobile, they may leave the altered zone or stream condition before the condition becomes lethal. They may move to different zones in the same watercourse or to different streams in a connected river system.

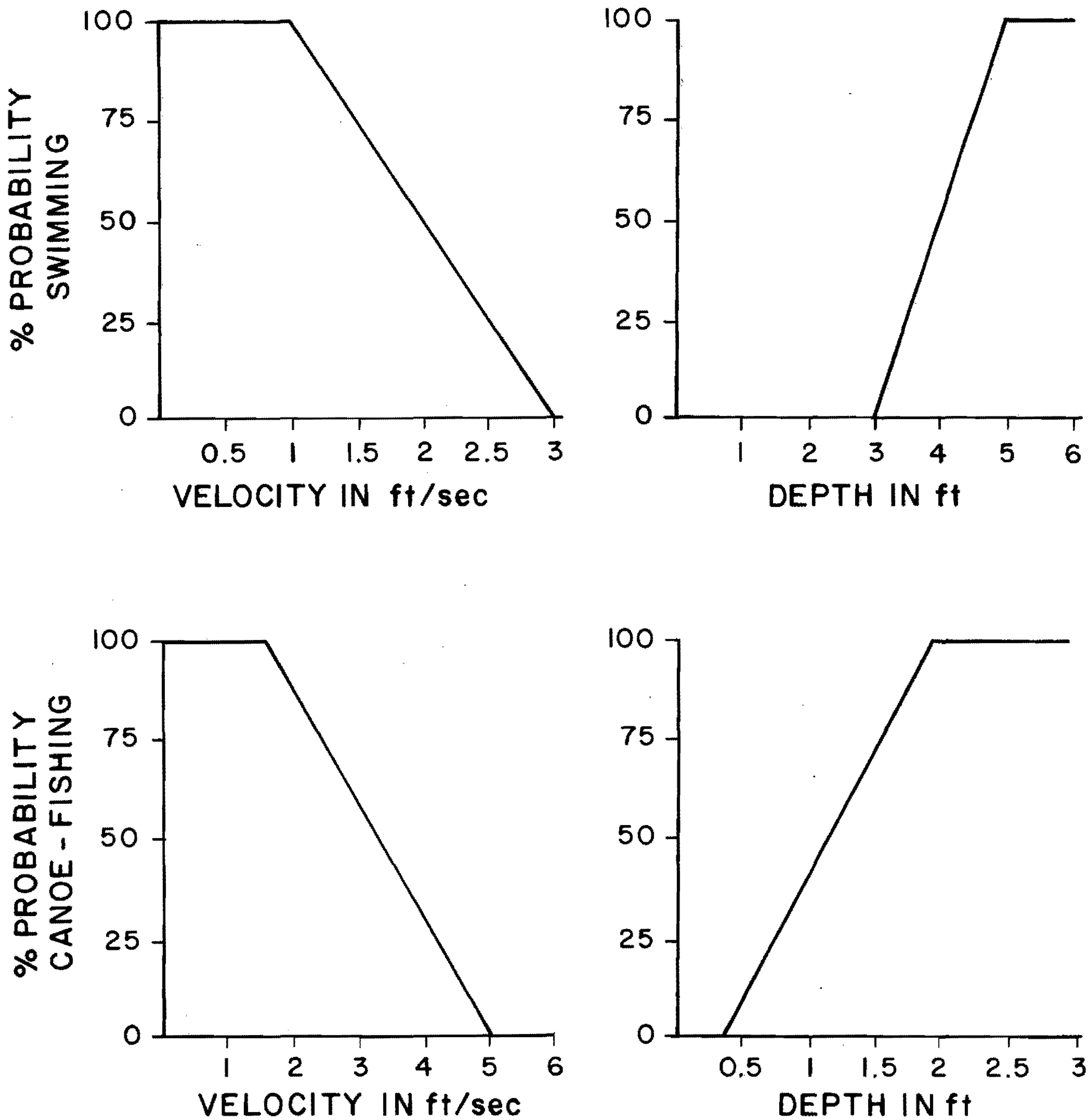

Figure 14. Probability of recreationists using flowing water for two types of recreation: swimming and canoe-fishing

Evaluating the effect that proposed changes in stream environment will have on fishing or on other related recreational activities has been expedited by a methodology developed by the Cooperative Instream Flow Service Group, Fort Collins, Colorado, supported by the U.S. Fish and Wildlife Service, U.S. Department of the Interior. The method is too complex to describe in this publication, but is available through consultants and the state division of fisheries. The methodology uses a computerized river flow simulation model into which specific river measurements are inputed, and through the use of probability curves the model predicts the before and after development conditions.

Existing fisheries are classified on the basis of minimum stream flows as a percentage of the average flow. These classifications are shown in Table 32.

Domestic Requirements at Developed Recreational Areas

Developed recreational sites require an adequate supply of water suitable for drinking and cooking and for sanitary disposal systems. The recreation area may be designed to accommodate day use only, such as picnickers and sightseers, or to provide overnight campgrounds, recreational vehicle campgrounds, marinas, resort condominiums, or clusters of seasonal or mountain cabins.

For campgrounds and day use sites, suggested use rates are given in Table 33. For sites developed with permanent buildings, Lam and Hughes (1980) measured flows at various types of recreation sites in Utah to determine if municipal design standards were adequate for recreational design. The results indicate that mountain cabins which are only seasonally used and only occupied part time have use rates less than the municipal (Utah Department of Health) standard. In contrast, condominiums which have high occupancy rates because of time sharing or "hotel" renting have higher use rates than municipal standards. Recreation vehicle parks also had higher actual use than existing standards require. The Utah standards for design of recreation areas are given in Table 34 with the suggested changes evidenced by the Lam and Hughes study.

Table 32. Minimum stream flow requirement by fisheries.

Fishery Classification	Description	Flow % of Avg.	
		Oct.-Mar.	Apr.-Sept.
I	Outstanding	40	60
II	Excellent	30	50
III	Good	20	40
IV	Fair	10	30
	Poor	10	10

Table 33. Guidelines for water requirements of recreational campgrounds in Utah.

Type of Establishment	gal/day/person
Resident Occupant:	
Season use	75
Year round	100
Camper:	
No flush toilets or showers provided	10
Flush toilets, but no showers provided	40
Flush toilets and showers provided	45
Picnicker:	
No flush toilets provided	5
Flush toilets provided	10
Swimmer:	
No bathhouse, flush toilets or showers provided	2
Flush toilets in bathhouse, but no showers	5
Flush toilets and showers provided	10
Picnic and Swim Area Participant:	
No bathhouse, flush toilets, or showers provided	5
Flush toilets in bathhouse, but no showers	10
Flush toilets and showers provided	15
Boat Launch Area Participants:	
No flush toilets provided	5
Flush toilets provided	10

Source: U.S. Forest Service, Region 2 (Flack 1976)

Table 34. Design standards for recreational development in the State of Utah.

Type of Development	Source Capacity (Dept. of Health)	Source Capacity (Lam and Hughes)	Storage Capacity (Dept. of Health)
Summer Home (Mountain Cabin)	800 gpd/unit	600 gpd/unit	400 gal/unit
Condominium	500 gpd/unit	800 gpd/unit	250 gpd/unit
Recreation Vehicle Campground	100 gpd/vehicle space	150 gpd/vehicle space	50 gal/vehicle space

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APPENDIX

CURVES OF CROP GROWTH STAGE COEFFICIENTS

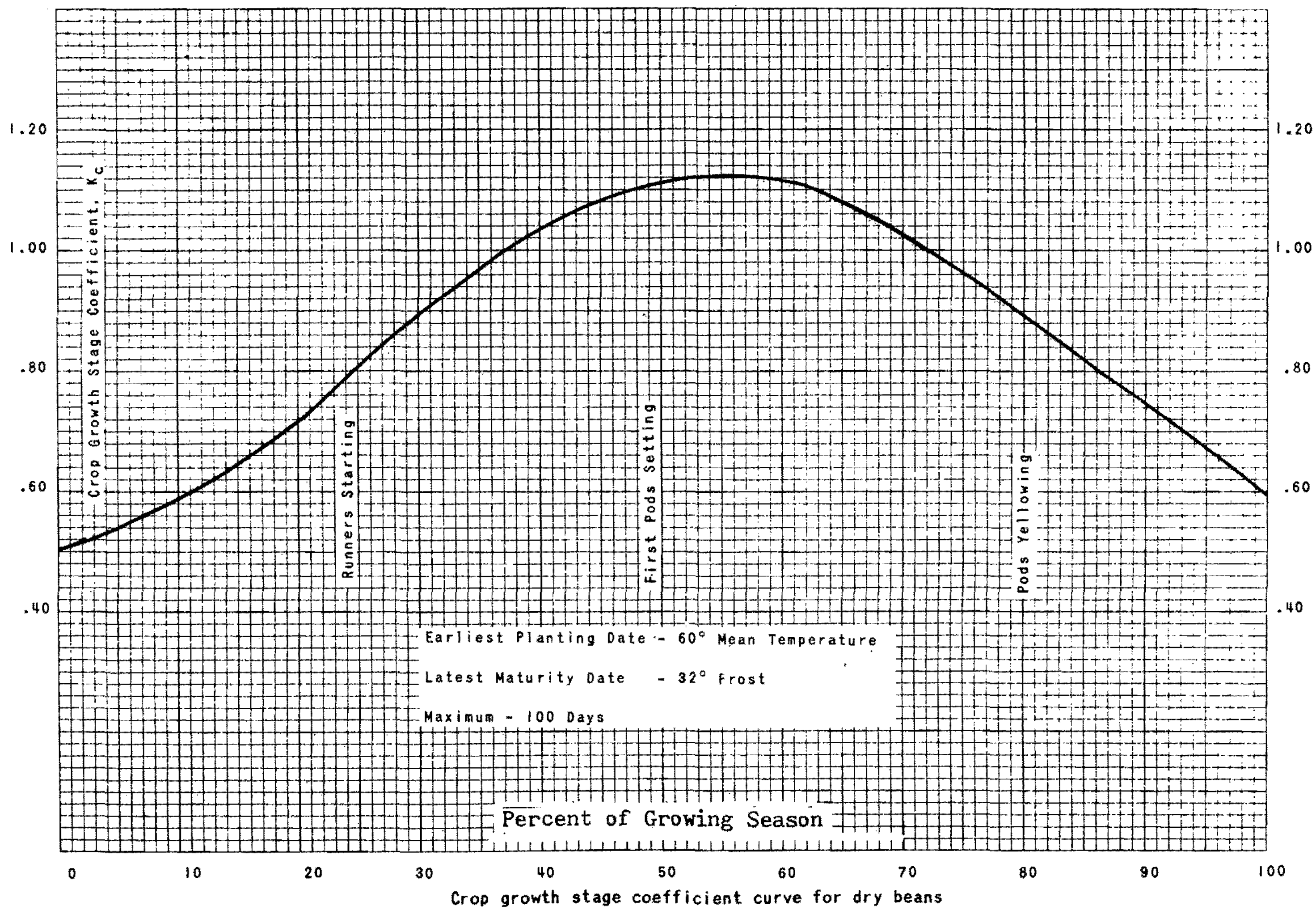


Figure A-1. Crop growth stage coefficient curve for dry beans.

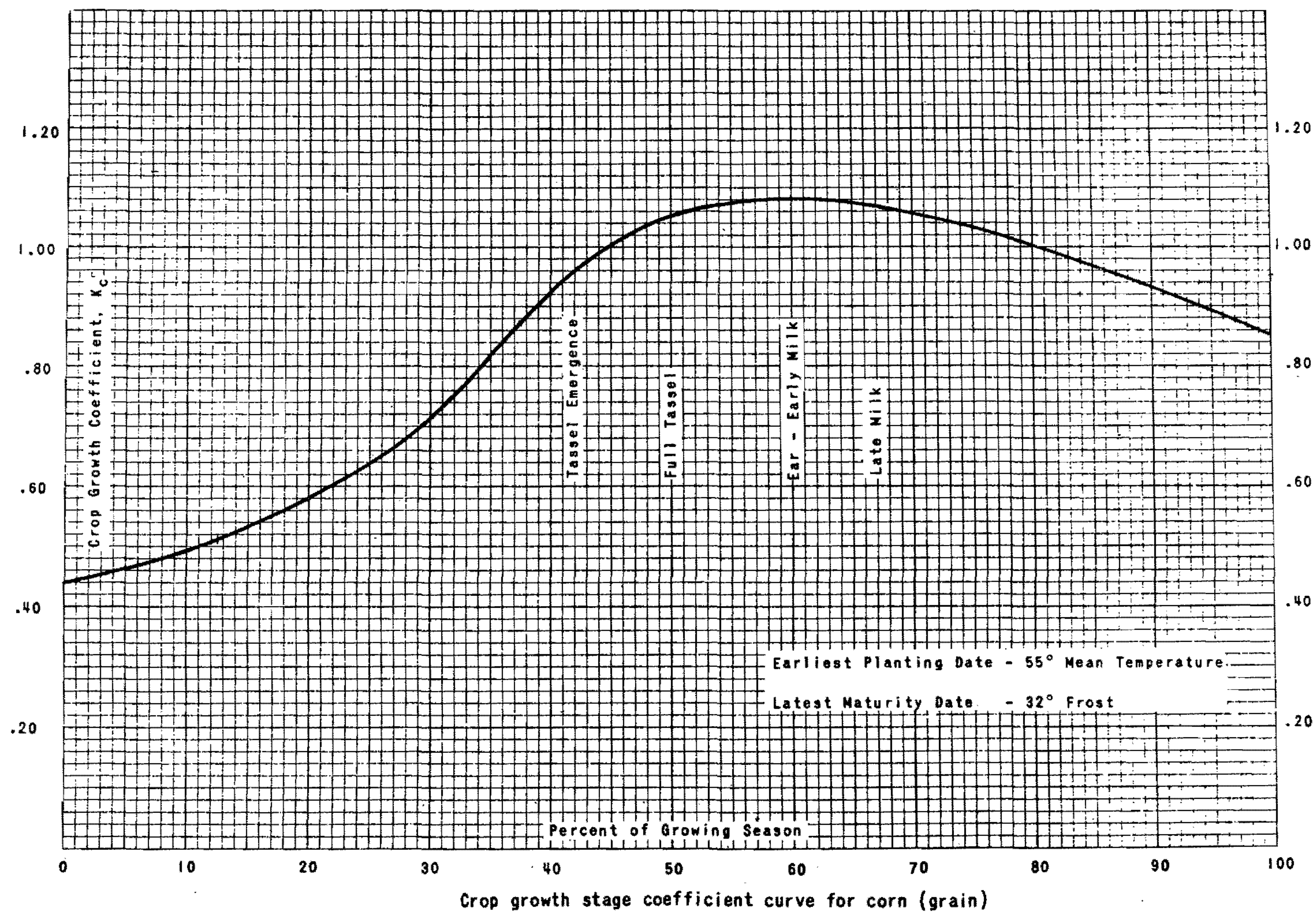


Figure A-2. Crop growth stage coefficient curve for corn (grain).

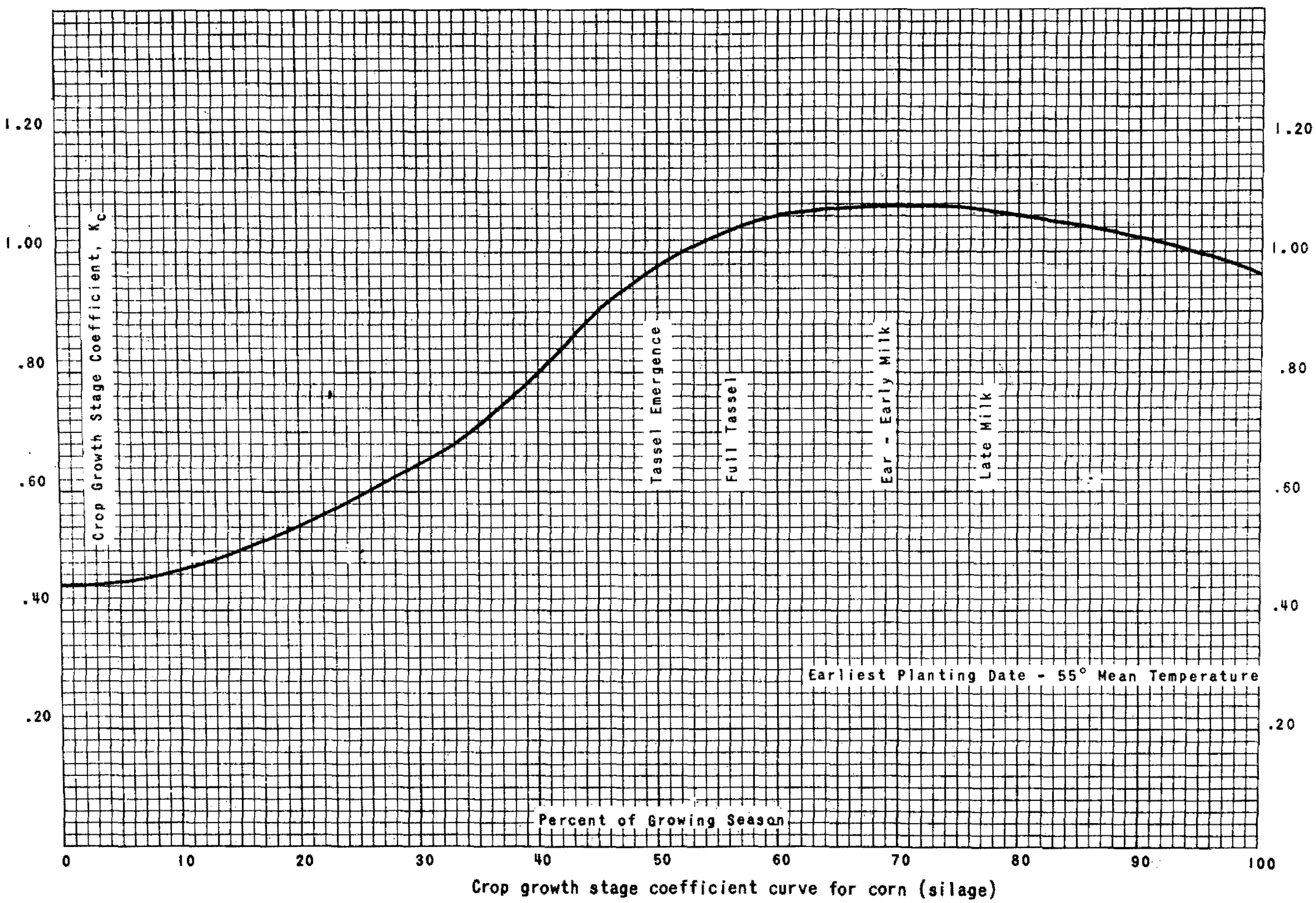
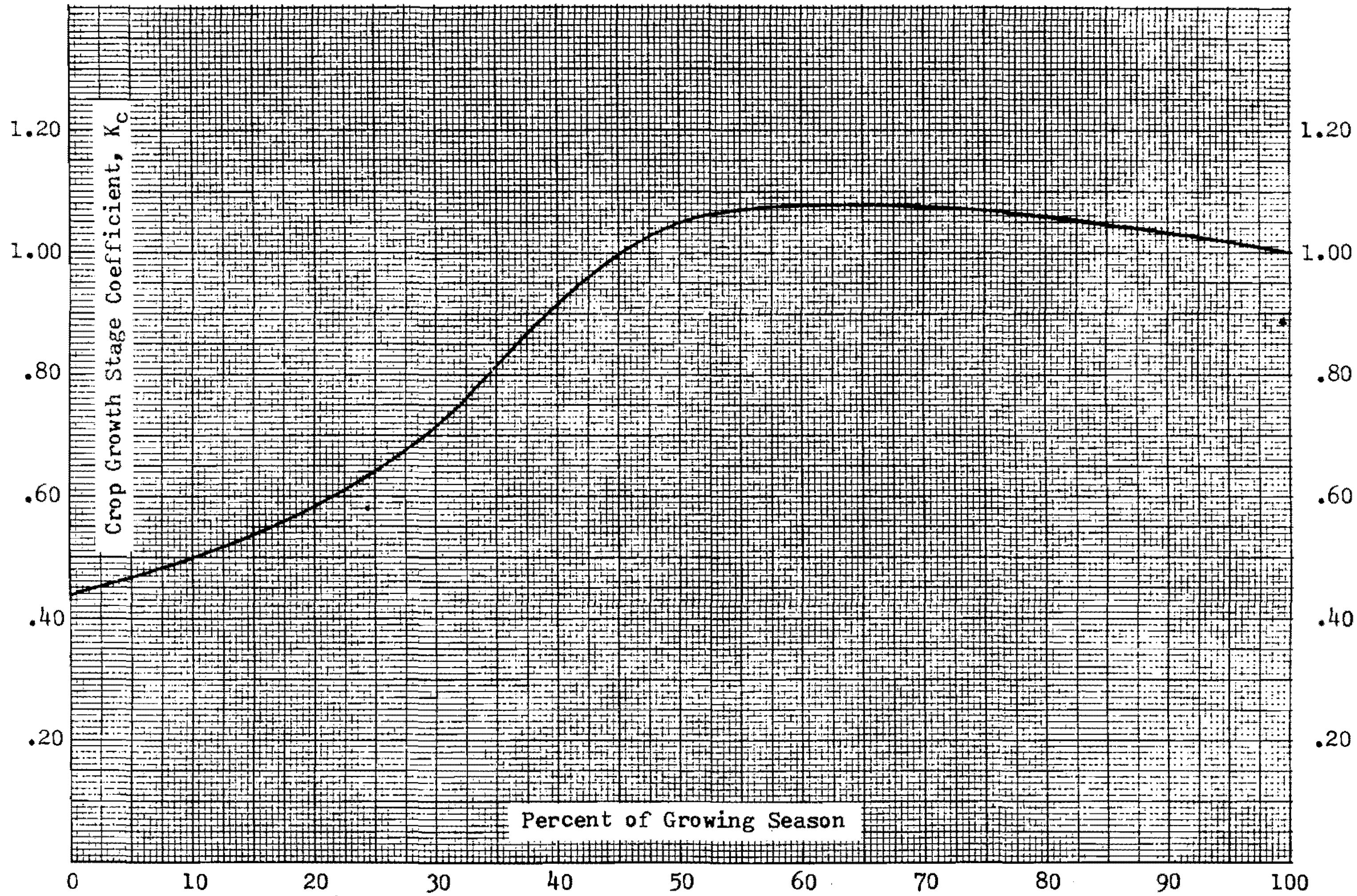
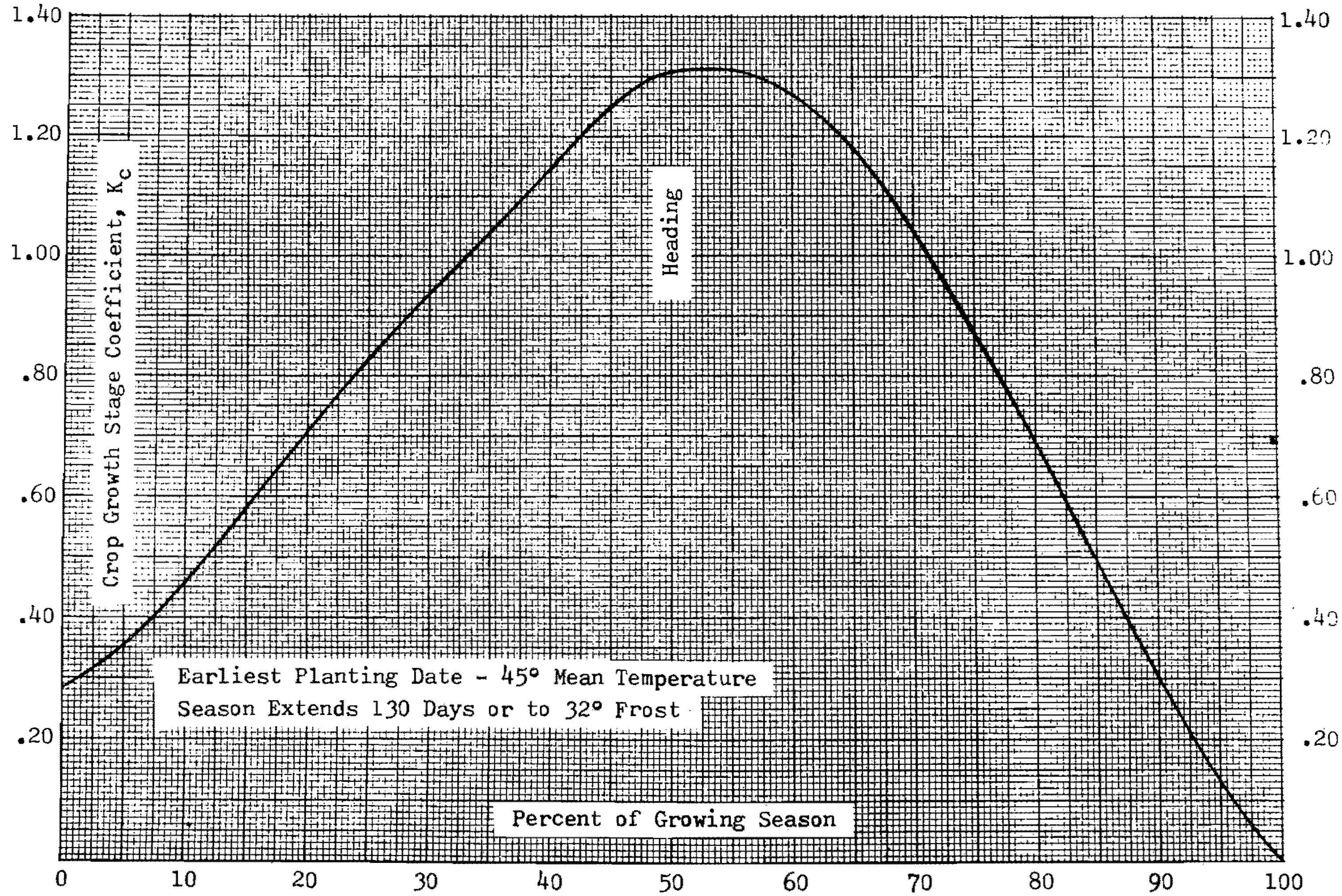


Figure A-3. Crop growth stage coefficient curve for corn (silage).



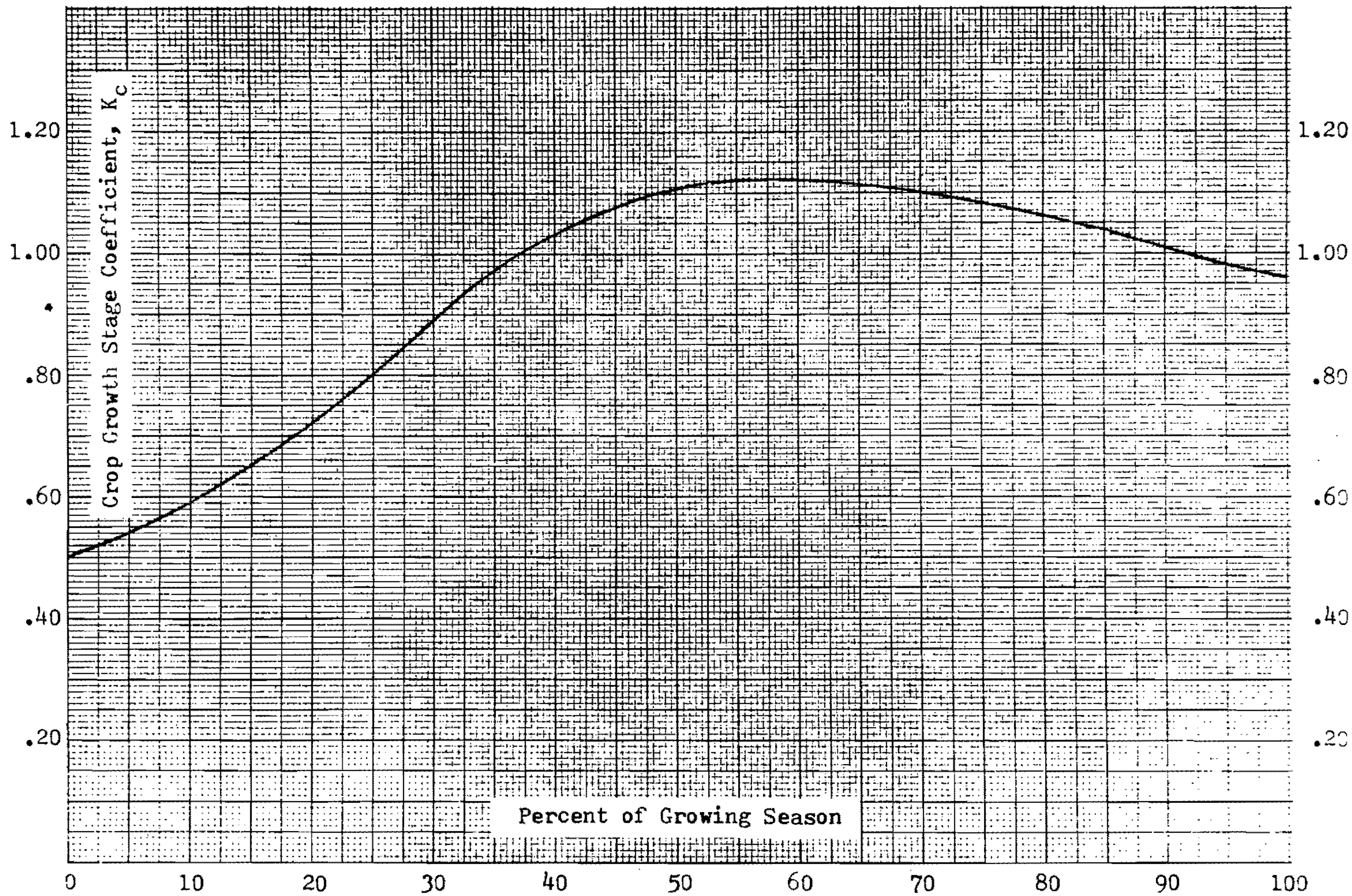
Crop growth stage coefficicnt curve for sweet corn

Figure A-4. Crop growth stage coefficient curve for sweet corn.



Crop growth stage coefficient curve for spring grain

Figure A-5. Crop growth stage coefficient curve for spring grain.



Crop growth stage coefficient curve for peas

Figure A-6. Crop growth stage coefficient curve for peas.

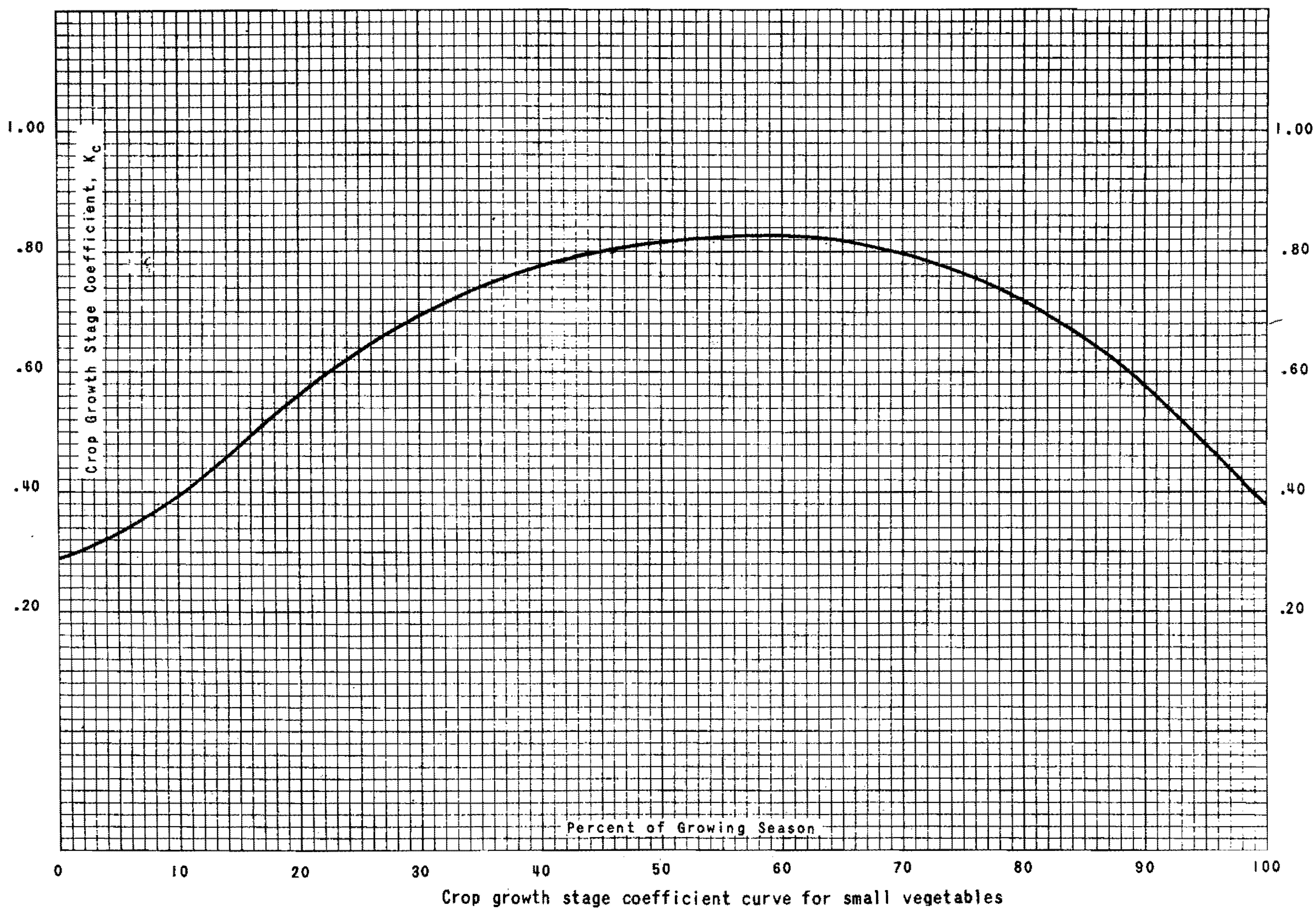


Figure A-7. Crop growth stage coefficient curve for small vegetables.

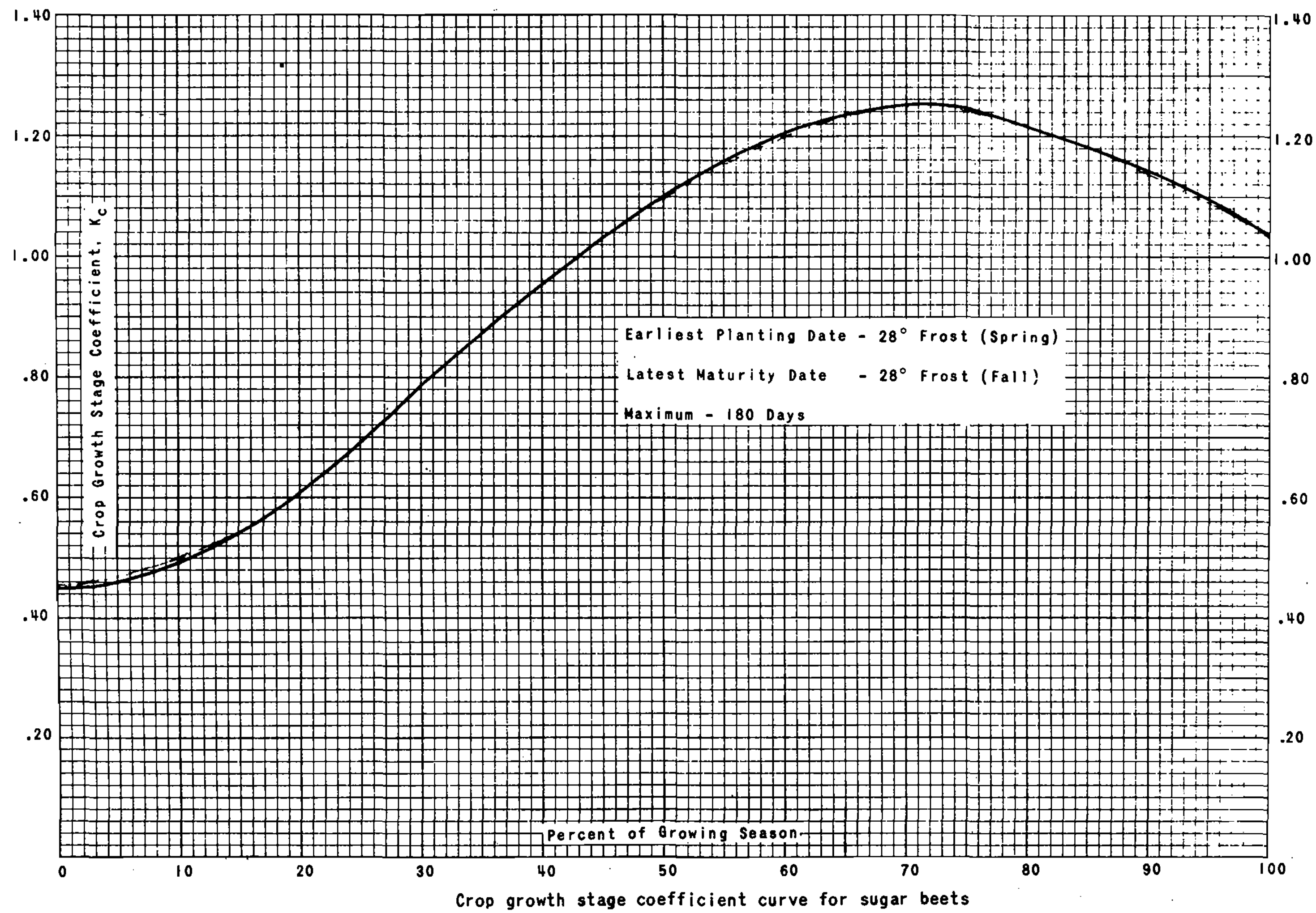


Figure A-8. Crop growth stage coefficient curve for sugar beets.

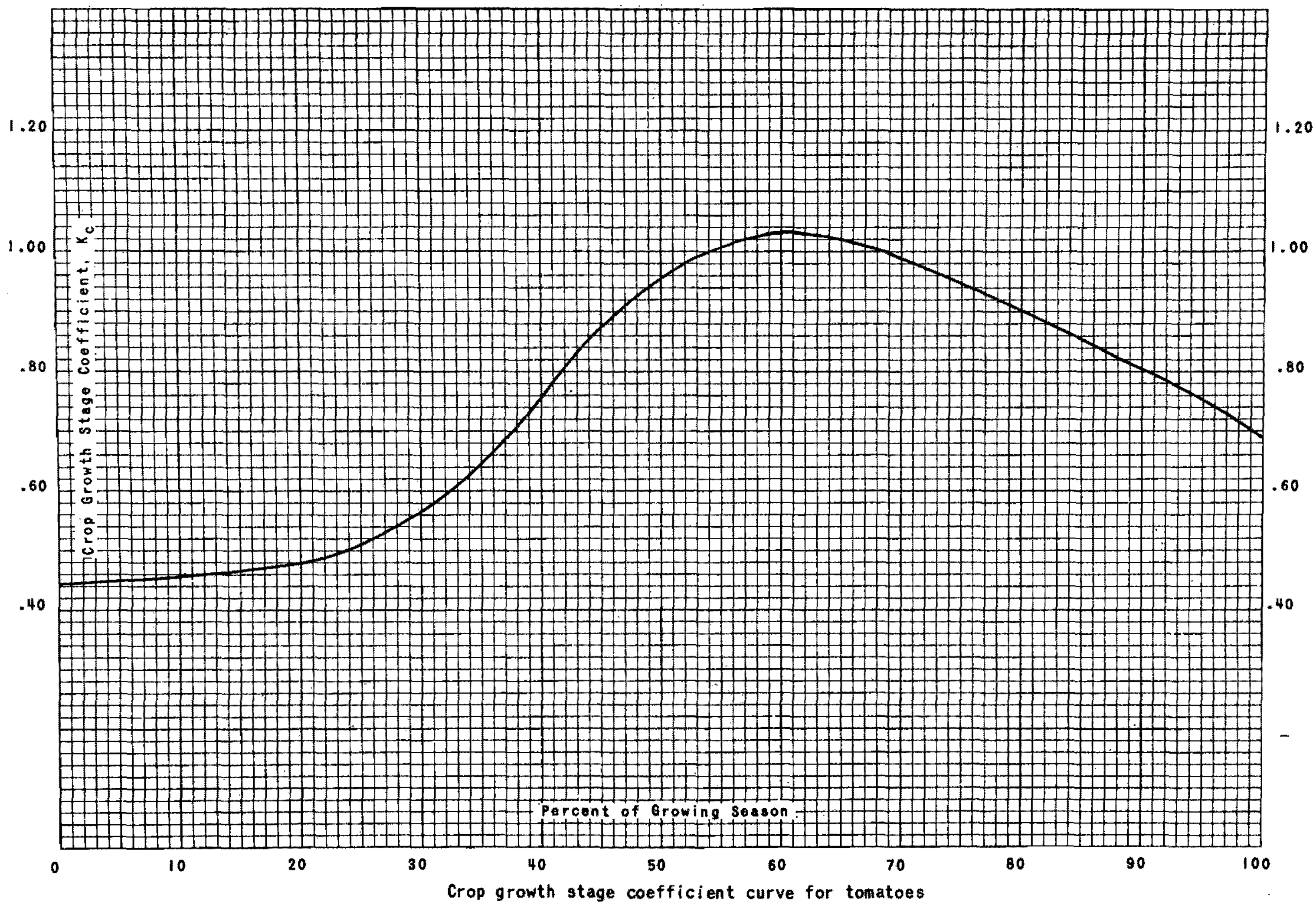


Figure A-9. Crop growth stage coefficient curve for tomatoes.

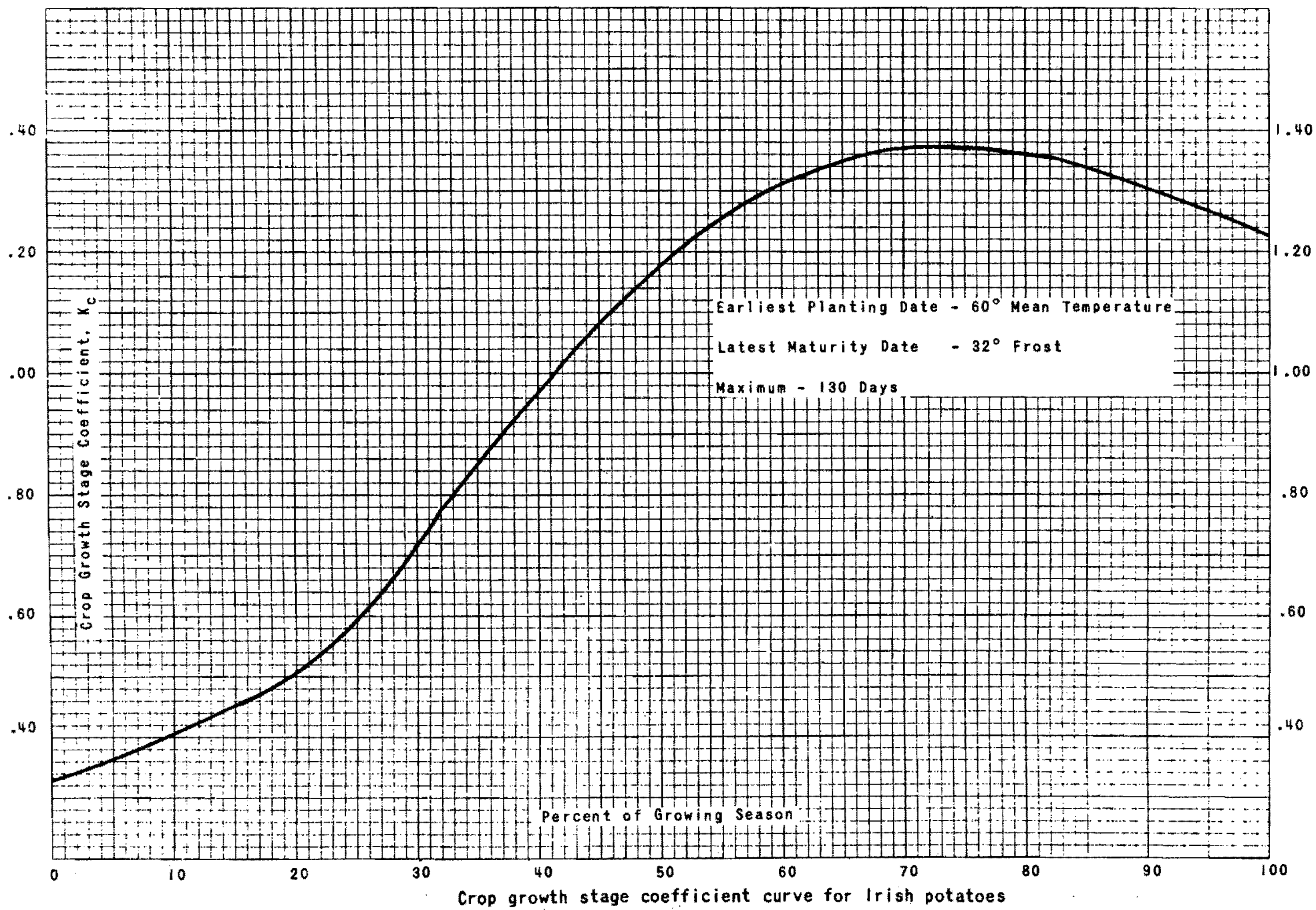
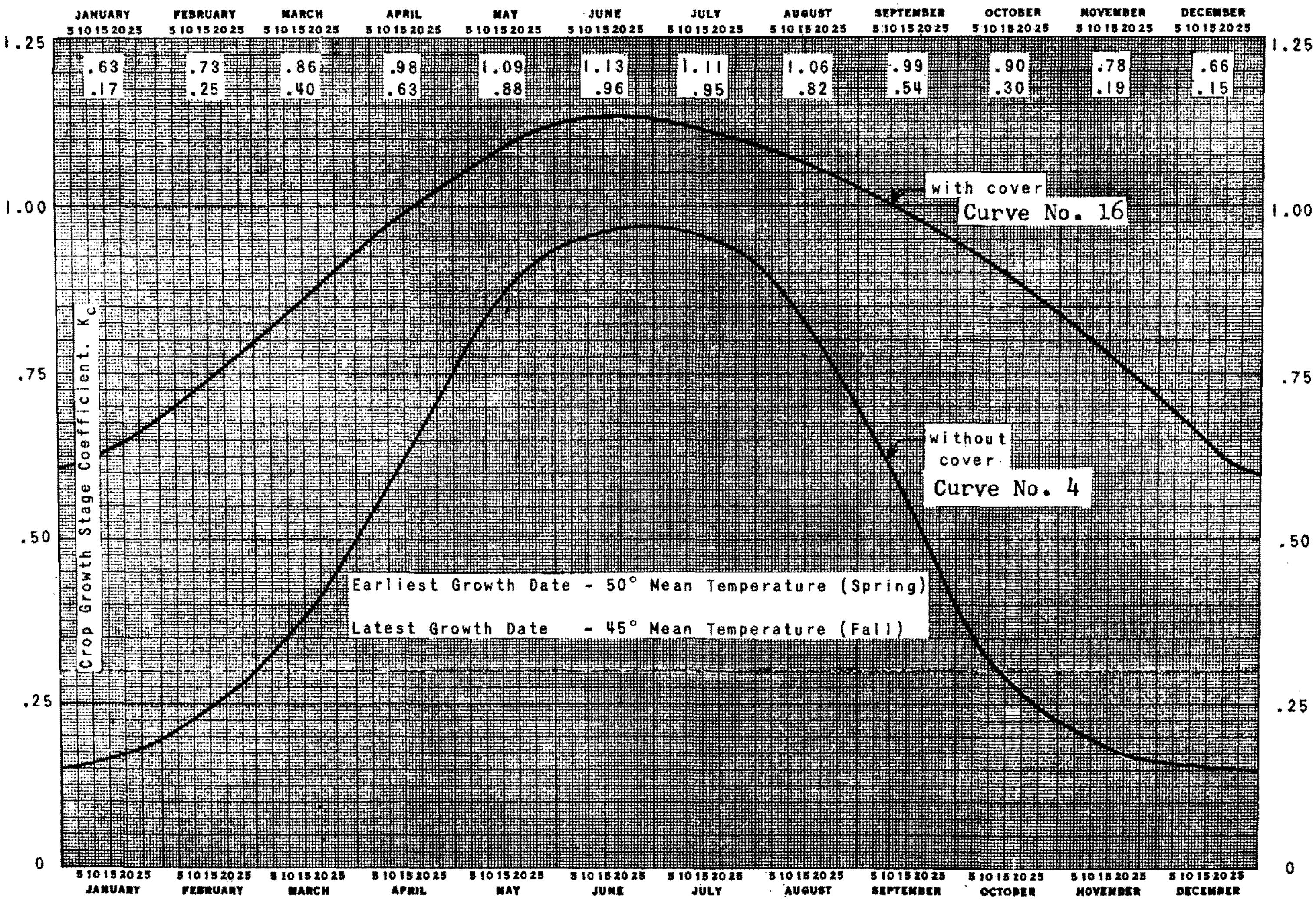


Figure A-10. Crop growth stage coefficient curve for potatoes.



Crop growth stage coefficient curve for deciduous orchards

Figure A-11. Crop growth stage coefficient curve for deciduous orchards.

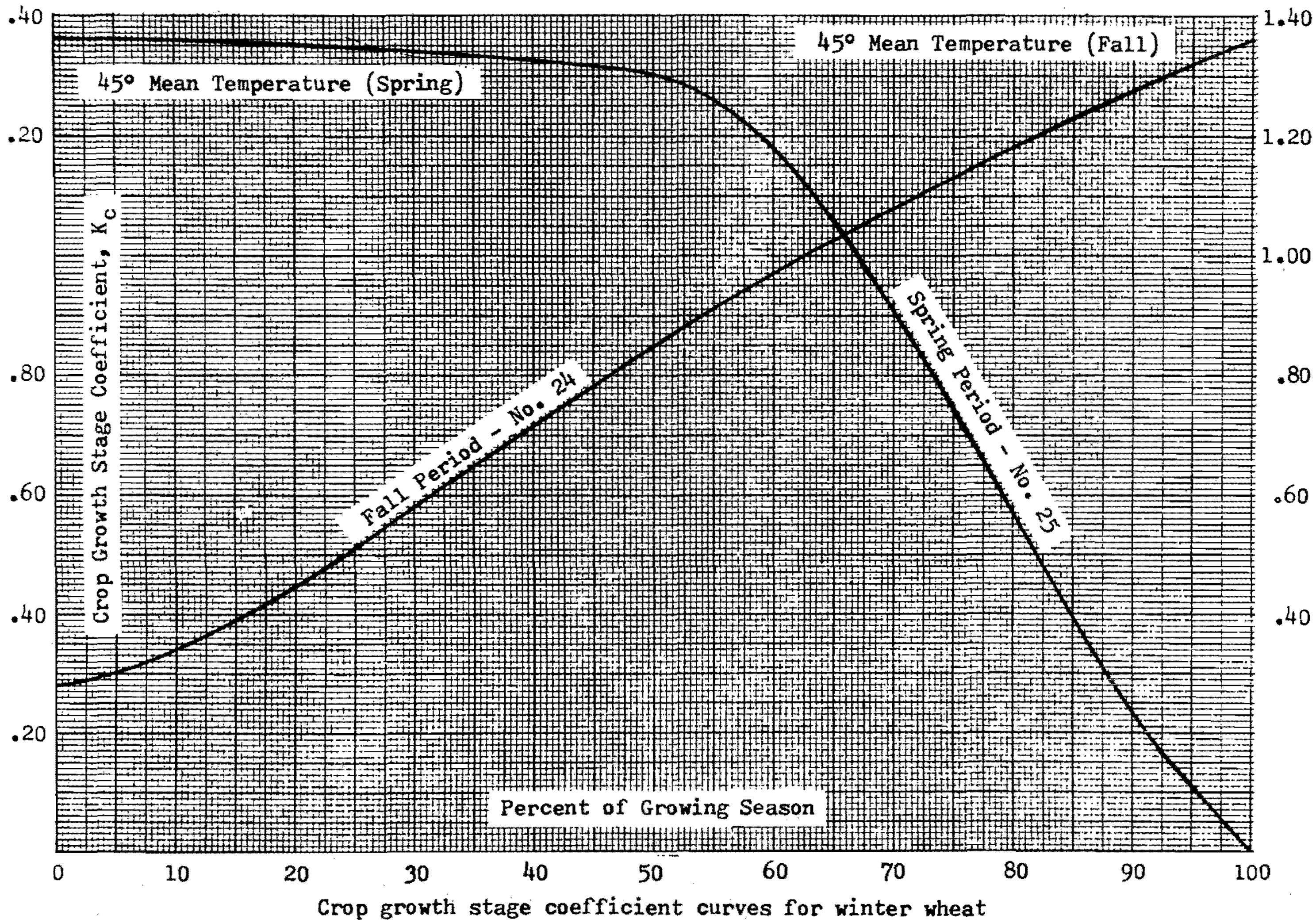
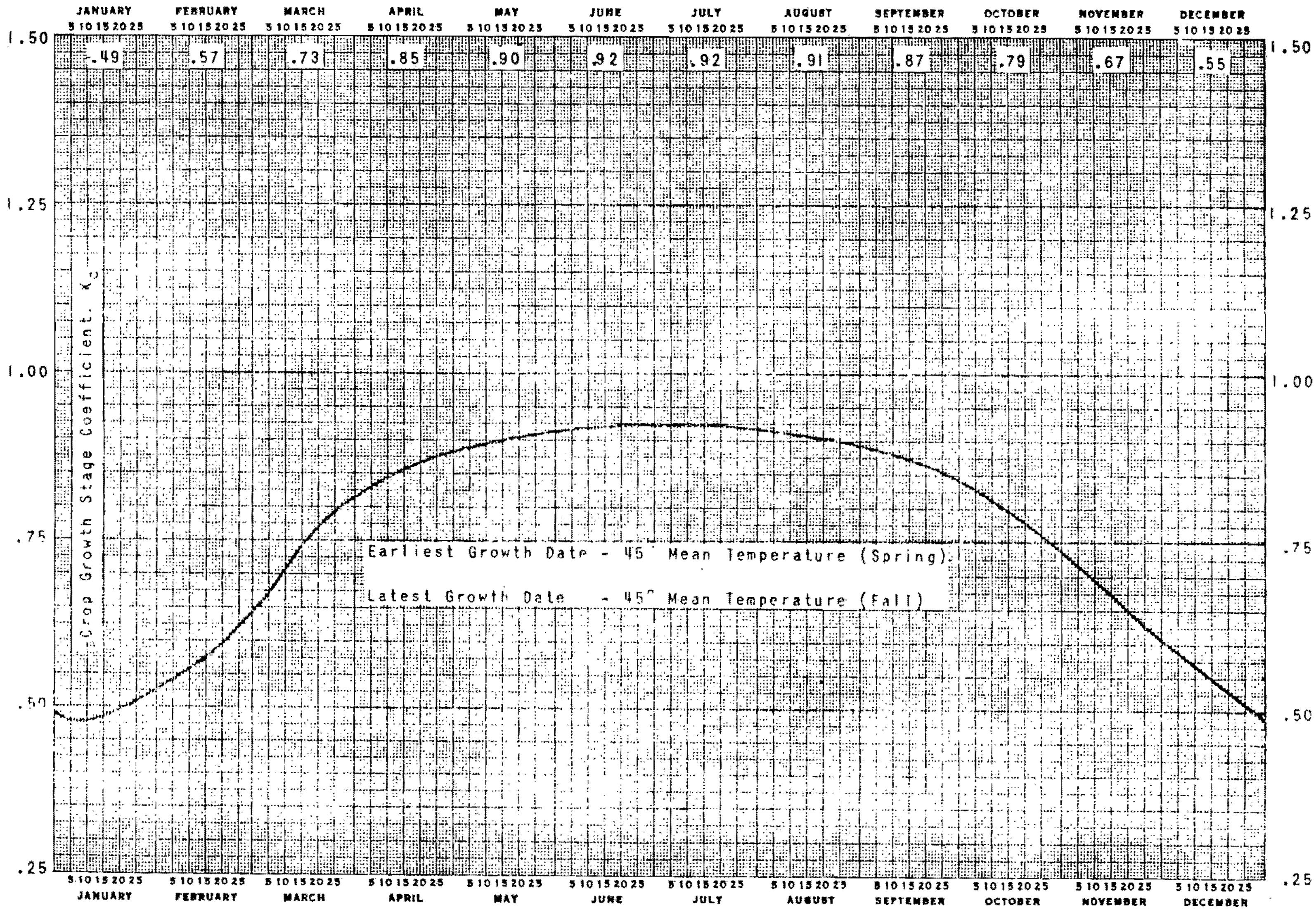
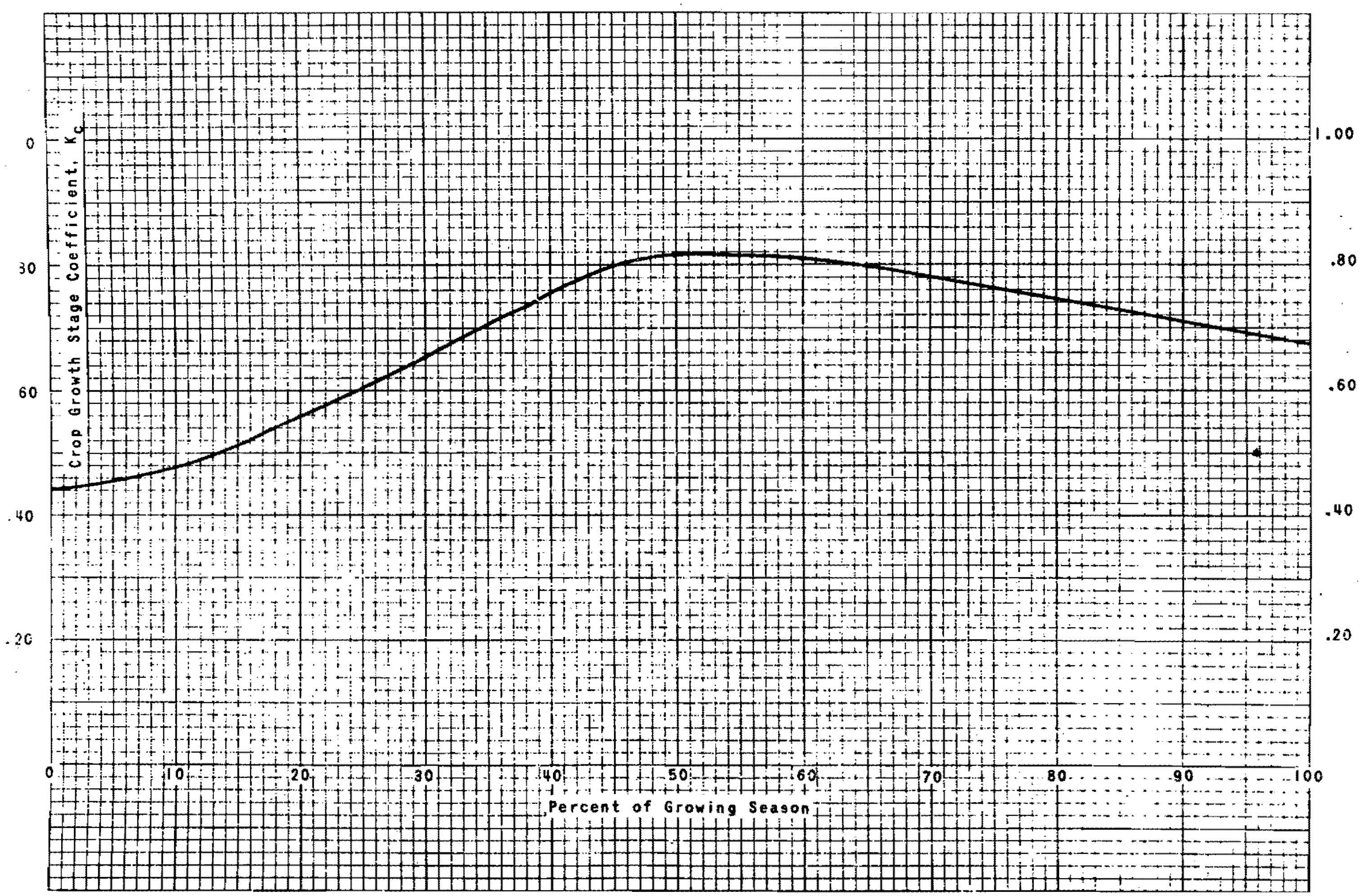


Figure A-12. Crop growth stage coefficient curves for winter wheat.



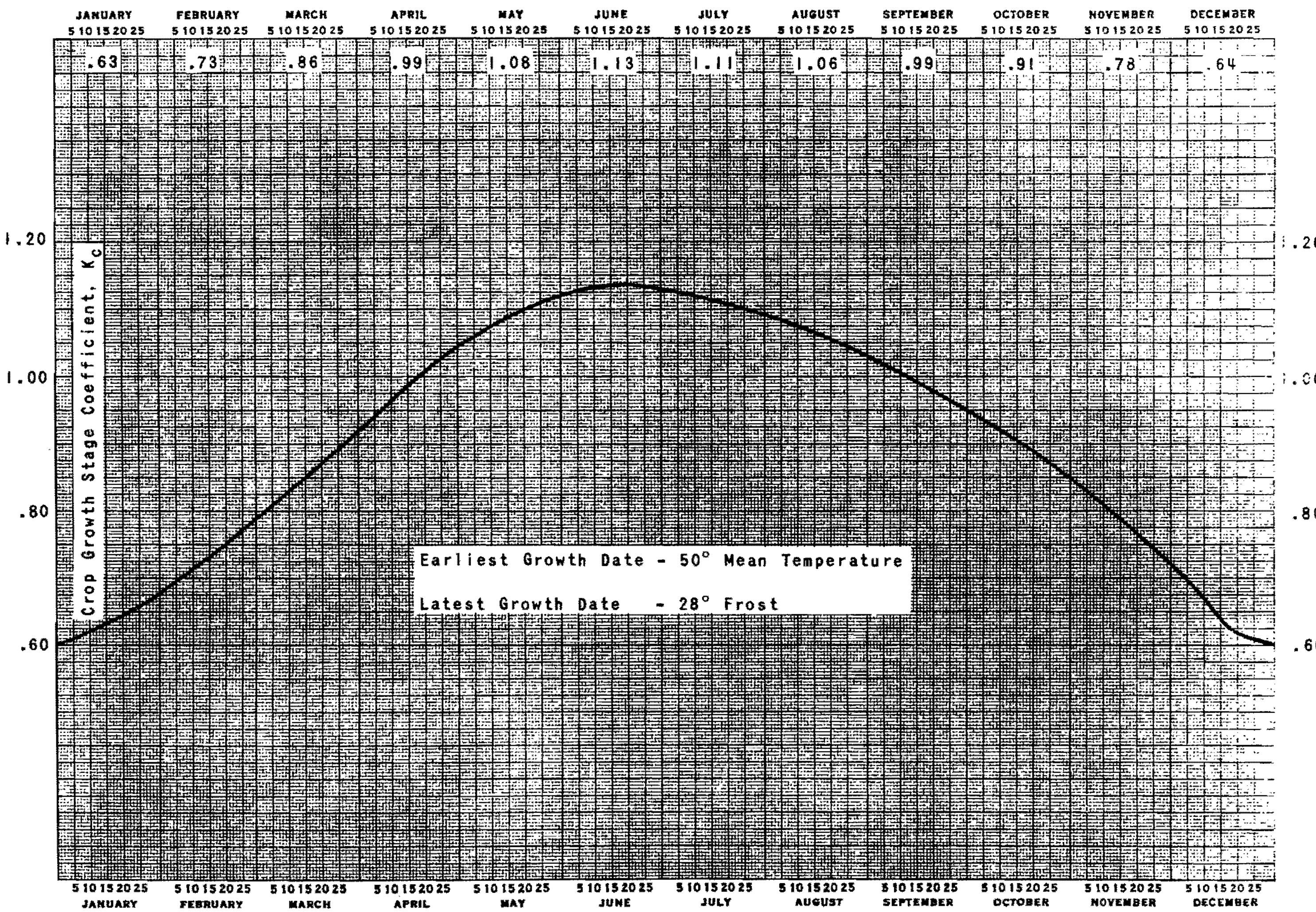
Crop growth stage coefficient curve for pasture grasses

Figure A-13. Crop growth stage coefficient curve for pasture grasses.



Crop growth stage coefficient curve for melons and cantaloupes

Figure A-14. Crop growth stage coefficient curve for melons and cantaloupes.



Crop growth stage coefficient curve for alfalfa

Figure A-15. Crop growth stage coefficient curve for alfalfa.