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The consumptive water use of six cities in the Willamette Basin of northwestern Oregon was evaluated for the period 1960-66. Consumptive use ratios were obtained by analyzing data from monthly water supply and sewage flow records. The average annual consumptive use for the six cities was found to be 26 percent, and the average monthly ratios varied from essentially zero in the winter months to as high as 53 percent in July and August.

The principal factors affecting consumptive use were found to be weather conditions, lawn watering, water system losses, cost of water, airconditioning, and proportion of water used for industrial purposes. While not affecting consumptive use, *per se*, sewer infiltration, storm runoff, and incomplete water or sewer systems can affect the calculated consumptive use ratios.

The extent to which a water right is consumptive is inferred by the use to which the water is put. On the basis of existing water law and past court decisions, it is concluded that a city has the legal right to consume the full amount of its municipal water right providing the water is used strictly in accordance with the conditions of its permit.

Consumptive Use of Surface Water by Willamette Basin Municipalities

by

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CONSUMPTIVE USE OF SURFACE WATER BY WILLAMETTE BASIN MUNICIPALITIES

I. INTRODUCTION

Much of the streamflow diverted for municipal use eventually returns to the surface waters, either directly (through sewers) or indirectly (through the ground water system). However, a substantial portion does not return; instead, it is "consumed".

The term "consumptive use"[1] refers to the quantity of water which is (a) lost to the atmosphere through evaporation, (b) given off to the atmosphere in the process of plant and animal growth, (c) incorporated in plant and animal growth, and (d) lost through or incorporated in the products of industrial processes (5).

A knowledge of the percentage of water which is lost, or conversely the amount which is returned, is important to engineers for a number of reasons. Return flow quantities are required for the design of sewer systems and sewage treatment plants. Bunch and Ettinger state that "the reuse of sewage effluents in the future will not be primarily a question of economics, but one of necessity" (8). Thus planners and designers must know what percentage of the water supplied to the city will be returned and available for this reuse.

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[1] Called "consumptive loss" by some writers.

Water resource planners must know what percentage of the municipal diversions will be lost, in their evaluations of the ability of streams to meet future water demands. Consumptive use information would also be of value to water right administrators in that it would indicate the amount of return flow which could reasonably be expected from municipal right holders.

Important as it is, there is very little substantiated information on consumptive use in the literature. Unsubstantiated data, however, can be found in many sources. Water supply and sanitary engineering textbooks almost uniformly suggest a return flow ratio of 60 to 70 percent. Although there are no references indicated in the current texts, it is strongly suspected that these figures are based on a single example cited in several books published around 1920.

The intent of this study is to develop some usable consumptive use information based on current water use patterns. Although the study is limited to a comparatively small geographical area, the Willamette Basin, the results should be applicable to much of western Oregon and Washington as well as the western portion of northern California. The procedures used for deriving the data could be used for developing similar information elsewhere.

II. PURPOSE AND SCOPE

The purpose of this study is to define quantitatively the consumptive use of municipal water in the Willamette Basin. In order to completely define consumptive use, the seasonal pattern must be established as well as the annual and peak monthly ratios. The factors which affect consumptive use will also be investigated and the legal implications of municipal consumptive use reviewed. Finally, the applicability of the consumptive use ratios developed in this report will be discussed.

The study is limited to the Willamette Basin of northwestern Oregon. The basin contains enough cities to permit the acquisition of flow information from a selection of cities of various sizes and yet is small enough to facilitate the collection of field data.

The investigation is further limited to the study of municipal consumptive use. Municipal water, in the sense in which it is used in this study, is the water supplied to a city through a municipal water system. This includes a certain amount of industrial water as well as water supplied for residential and commercial purposes. In some cases, however, large industrial water users have developed independent sources of supply, even though they are located within the city limits. The water consumption of these industries is not considered.

The basis of this study is a comparison of the volume of water supplied to a city system to the volume reaching that city's sewage treatment plant. Data for evaluation were obtained from six selected cities: Corvallis, Eugene, Forest Grove, McMinnville, Salem, and Sweet Home.

Although sewage and water flows are evaluated for the entire year, the most important part of this study is that describing the consumptive use during the dry season (May 1st through September 30th). This is the season of minimum streamflow and the time of year when the greatest demand is placed on the surface water resources of the basin.

This study investigates only the short term consumptive use (or "loss"). Over a long period of time, some of the losses which are considered in this study as consumptive are not actually losses at all. Water main and sewer leakage, for example, may eventually find its way back to the surface waters through the ground water system. However, during the dry season the ground water levels generally decline and base flow to streams diminishes, so water lost in this manner may temporarily recharge the ground water basin and only reach the streams during the following wet season. Even when conditions are favorable, ground water moves very slowly compared to surface runoff. Thus, to develop usable dry season consumptive use factors, these long term returns must be considered as a part of the consumptive use.

A monthly time period was adopted for this study. Monthly data adequately reflect the seasonal variations in flow and are much easier to collect and process than daily data. Furthermore, monthly data are more readily available in the files of the city utility departments.

In order to compensate for the annual fluctuations in water use caused by variations in weather, several years of flow data are included in the study. As will be described later, the period selected for study was 1960-1966, inclusive.

To summarize, this study is an attempt to determine the consumptive use of municipal water in the Willamette Basin by comparing monthly water supply and sewage inflow data from six cities for the period 1960-1966.

III. REVIEW OF LITERATURE

Consumptive Use Factors

A survey of literature revealed a wide range of estimates of the consumptive use of municipal water--from less than 10 percent to 40 percent. Unfortunately, very little quantitative data were presented to support these estimates, and there was nothing on the seasonal variation of consumptive use.

Probably the most widely used references on consumptive use are the sanitary engineering and water supply textbooks. However, the authors of the textbooks were least careful about qualifying their estimates. Fair and Geyer state that "Ordinarily 60 to 70 percent of the total water supplied becomes wastewater" (27, p. 29). Two other current textbooks (Clark and Viessman, and Hardenbergh and Rodie) quote exactly the same figures (10, p. 41; 35, p. 50). According to Payrow, approximately 60 percent reaches the sewers (63, p. 293). However, no reference is made in these texts to the source of these very similar figures.

Perhaps the key to the source is found in a 1958 edition of an old text by Babbitt and Baumann (4, pp. 31-32). It states that a study by the city of Cincinnati showed that 62 percent of the total water supplied reached the sewers. The losses were categorized as follows (based on 125-150 gpcd total water use):

6- 7	gpcd	steam railroads
6- 7	gpcd	street sprinklers
6- 7	gpcd	manufacturing and mechanical
3- 3-1/2	gpcd	lawn sprinklers
9-10-1/2	gpcd	consumers not sewered
18-21	gpcd	leakage

It can readily be seen that some of these values are questionable by present day standards. For example, there are very few steam locomotives still in operation. Recent studies by Linaweaver, Geyer, and Wolff show that the average annual demand for lawn sprinkling is between 20 and 50 gpcd instead of 3 to 3-1/2 gpcd (43, pp. 7, A-6). The 1932 edition of Babbitt and Baumann quotes the same series of values as the 1958 edition, and it is probable that they were also contained in the first edition (1922). This would date the Cincinnati study as 1920 or earlier. It is interesting to note that Metcalf and Eddy refer to virtually the same figures but state that the estimates were made in 1911 by the Milwaukee Sewage Disposal Commission (47, pp. 43-44).

In a Canadian text, Kuiper states that the consumptive use is on the order of 10 to 20 percent (a return flow of 80 to 90 percent) (42, p. 387). A 1953 engineering study for the Vancouver (BC) and Districts Joint Sewage and Drainage Board revealed that about 70 percent of the city's municipal water returned as sanitary sewage.

(This figure was obtained by comparing metered sewage treatment plant inflows with water demand.) The same report refers to a study done for the East Bay cities of California, where 65 percent domestic and 95 percent industrial return flows were obtained (76, pp. 98-99). Britton, in a U.S. Public Health Service study, found that at least one-third of the municipal water supplied to Sweet Home, Oregon, was used for non-sewered purposes (73, p. 7). All of the estimates mentioned thus far refer to the amount of return flow collected by the sewers, and would thus be classified as short-term estimates. It is assumed that the ranges quoted are intended to cover most of the normal municipal situations that would occur in the United States. Kuiper and the remaining references refer to the consumptive use, which, generally speaking, is the complement of return flow.

Other sources of information are the surveys of national water use made by the U.S. Geological Survey. MacKichan in the 1955 survey used the following consumptive use factors:

Public supplies	10%	Irrigation	60%
Rural - home use	10%	Industrial	2%
Rural - stock	100%		

Although these factors were applied uniformly to all of the state water use estimates, MacKichan mentions that the actual local consumptive use rate depends on the climate, season, and total use (45). With respect to the 10% estimate for public supplies (municipal use), he refers to an article by Jordan which states that "the use of water in municipalities is largely nonconsumptive--not more than 10 percent of it fails to return to the water courses below cities." Here again, no reference is made to the information from which this estimate was developed (39, p. 651).

In the 1960 survey, MacKichan and Kammerer developed individual consumptive use information for each state (46). Some examples are listed below.[2]

Public supplies	Oregon	9.2%
Public supplies	Washington	10.0%
Public supplies	Pacific Northwest	12.5%
Industrial use	Oregon	2.8%
Industrial use	United States	2.3%
Irrigation	United States	61.8%
Rural-domestic	United States	60.0%
Rural-livestock	United States	93.8%
Water power	United States	22.6%

Kammerer stated that the consumptive use values for public supplies in the individual states were calculated by comparing average daily water treatment plant outputs and sewage treatment plant inflows as reported by the U.S. Public Health Service. Although the

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[2] These percentages were computed by the writer from the total volumes tabulated in the report.

latter were based on 1953 and 1954 flow data, it was assumed that consumptive use ratios calculated from this data would be valid for 1960 flows also (71, 72). These average daily sewage flows include wet season infiltration and, in the case of combined sewer systems, storm runoff. Storm runoff and infiltration do make up a part of the sewage flows returning to the streams and should be taken into consideration when studying stream depletion on an annual basis. However, they should not be included when computing municipal consumptive use ratios as they are not actually a part of the municipal water return flows. Including storm runoff and infiltration would tend to make the consumptive use percentages lower than they should be.

Wollman, in a study for the Senate Select Committee on National Water Resources, used consumptive use estimates of 10 percent for the eastern U.S. and 20 percent for the western U.S. in his projections of future municipal water use. He defined consumptive loss (or "use") as evaporation or transpiration--disappearance of water from the region. It was noted that municipal loss varies with

1. temperature and humidity
2. amount of lawn watering
3. type and amount of airconditioning
4. extent of industrial use relative to residential use (65,

p. 17).

It should also be mentioned that his data are quoted quite frequently in the literature.

Most of the other references reported water resource studies conducted for or by individual states. Green and Gladwell used a municipal consumptive use factor of 20 percent for eastern Washington in estimating the future water demands of the state. This was a composite of estimates made by Washington State University staff engineers, estimates which ranged from 15 to 30 percent. Along with the normal water supply system losses, lawn sprinkling was given special consideration in making this estimate due to the high evapotranspiration rate characteristic of eastern Washington. For western Washington, it was assumed that most of the municipal return flow would be discharged into Puget Sound or the lower Columbia River, and that only a very minor part would be recoverable. Therefore a 100 percent consumptive use was assumed for that part of the state (77, p. IV-3; 29).

Bookman used a somewhat different approach in estimating water requirements for the coastal portion of Los Angeles County, California. Estimates were made of the quantities of water delivered to and consumed by various classes of water users in terms of feet (depth) of water delivered per unit of property area. To obtain the consumptive loss for an entire city system, the areas in each of the different types of land use would have to be totalled and the appropriate delivery and consumption rates applied (6).

Land Use	Depth of Water Per Unit Area-ft. Delivered	Consumed
Residential-single	2.6	1.3 (50%)
" -multiple	4.5	0.3 (7%)
" -estate	2.0	1.5 (75%)
" -rural	1.8	0.8 (44%)
Commercial-outlying	3.4	0.4 (12%)
" -downtown	10.2	1.1 (11%)
Industrial	9.2	1.4 (15%)
School	0.9	0.4 (44%)
Irrigated crops	1.7	1.5 (88%)

According to Wells and Gloyna, 60 percent of the 3.2 million acre-feet of freshwater withdrawn annually in Texas for municipal and industrial use is returned directly to surface waters. They further state that the ratio of return to use (a) varies widely from year to year for individual municipalities, (b) increases with increased annual precipitation, and (c) decreases with the size of the city. The return flow ratios were developed using all available municipal water supply and sewage flow records, some dating back as far as 1930. The return ratios for individual years were adjusted to correct for deviations from the mean annual precipitation. The return ratios for the different sub-areas ranged from 31 percent in the arid high plateau of west Texas to 86 percent along the eastern Gulf Coast of the state. Since these ratios are based on sewage return flows, they must be considered as short-term values (30, 78, 79).

As a part of the Johns Hopkins Residential Water Use Research Project, Geyer et al. compared residential water demands with sewage flows. They found that the dry season residential sewage flows were within five percent of the domestic water demand (total water demand minus lawn watering demand). They concluded that, for design purposes, sewage flow can be considered equal to domestic water demand and that residential consumptive use is a negligible factor where lawn sprinkling does not occur (28).

Although not directly applicable to this study, a considerable amount of information is available in the literature on the consumptive use of irrigation water.

The various municipal consumptive use ratios encountered in the literature are summarized in Table 1. It is interesting to see that the values larger than 20 percent are all short-term estimates. The annual (long-term) consumptive use ratios range from 10 to 20 percent. The short term estimates, which include water distribution system losses and that part of lawn irrigation water which seeps back into surface water systems, range from 10 to 40 percent, averaging just over 30 percent.

Table 1. Summary of Municipal Consumptive Use Factors as Cited in the Literature.

References	Consumptive Use	Geographical Area
MacKichan and Kammerer (46)	9.2%*	Oregon
" " " "	10.0%	Washington
Jordan (39)	≦10%	U. S.
Senate Select Committee (65)	10%	Eastern U.S.
Kuiper (42)	10.20%*	U.S.(?)
MacKichan and Kammerer (46)	12.5%*	Pacific Northwest
" " " "	16.8%*	U. S.
Green and Gladwell (77)	20%	Eastern Washington
Senate Select Committee (65)	20%	Western U.S.
Fair and Geyer (27)	30-40%*	U. S.
Clark and Viessman (10)	30-40%*	U. S.
Hardenbergh and Rodie (35)	30-40%*	U. S.
U. S. Public Health Service (73)	33%	Sweet Home, Oreg.
Babbitt and Baumann (4)	38%*	Cincinnati, Ohio
Metcalf and Eddy (47)	38%*	Milwaukee, Wis.
Payrow (63)	40%*	U. S.
Wells and Gloyna (78)	40%*	Texas

*definitely identifiable as short-term estimates.

A few of the consumptive use values cited above were supported by a description of how they were derived. But in most of the references, the consumptive use factors were presented without qualification. It is suspected that some of the estimates which were quoted with little or no qualification are rules of thumb that have been used by practicing sanitary and water supply engineers for years. While it is possible that these figures were originally supported by good quantitative data, the sources of the figures are by now obscure. This suspicion is supported by the example of the obsolete 1920 values still being quoted in current textbooks.

On the other hand, for several of the consumptive use values cited, it was stated that they were obtained by comparing sewage flows to water demand. Annual flow data were apparently used in these computations. However, an overall annual consumptive use value does not tell the whole story. The summer consumptive use is quite different from the winter use. Furthermore, the storm water and infiltration which show up in the total annual sewage flows must be accounted for in deriving true consumptive use ratios.

While most of the ratios cited in the literature can be appropriately applied in certain situations, it is felt that in many cases insufficient qualifying information is provided to point out their limitations. In an attempt to overcome this and some of the other shortcomings noted with respect to the values cited in the literature, this report will present both annual and seasonal consumptive use data, based on current flow information and adjusted to compensate for storm water flows and other extraneous factors. All of the necessary qualifying information will be presented also to facilitate the use of the data.

Sociological and Economic Factors Affecting Water Use

A number of sociological and economic factors affect municipal water demand (and hence consumptive use) in addition to the physical factors already noted. Task Force 440M of the American Water Works Association found that water consumption increases with income and is generally greater in the western United States than in the East (3). Dunn and Larson, in a study of water use in Kankakee, Illinois, confirmed the relationship of income to consumption and also found that water consumption increases with assessed valuation of residential property, educational level of wage earner, and size of family, but decreases with increasing age of youngest child (22). In a study of the Embarrass River Basin of Illinois, Csallany concluded that per capita consumption increases with city size and that the percent of total population served increases with the age of the utility (21). Linaweaver, Geyer, and Wolff, in a study of residential water use in 31 areas located throughout the United States, developed a quantitative relationship between market value of dwelling and water use rate (43, pp. 29-33). They also found that customers on an unmetered flat-rate system use considerably more water than those on a metered system (43, p. 48-49). Several of the cited relationships have an influence on certain factors affecting consumptive use, notably lawn watering.

Water Law

In the United States two distinct systems have been developed for apportioning surface waters among individuals for beneficial use, the riparian and the appropriative systems. The riparian system is based on the concept that each owner of land adjacent to a stream is entitled to divert and use a reasonable amount of water for beneficial purposes. When flow is insufficient to meet all needs, the available flow is shared by the riparian right-holders. In contrast, the appropriative doctrine is based on the concept of "first in time, first in right". During water shortages, the holder of the oldest right has the first claim on the available flow, followed in turn by subsequent right-holders. Another feature of the appropriative system is that water use is not limited to owners of land adjacent to the watercourse (44, pp. 119-122).

Like the other sixteen western states, Oregon has built its water law around the appropriative system. Certain aspects of the riparian system were recognized in this state at one time, but they have for all practical purposes been set aside by subsequent judicial and legislative action (9, pp. 18-20).

According to Oregon water law "all water within the state from all sources of supply belongs to the public" and "may be appropriated for beneficial use" (58). In order to obtain the right to use, store, or divert a portion of this water, a potential water user must secure a permit through the State Engineer.

The six factors which completely define an appropriative water right are:

1. the priority date of the appropriation
2. the quantity of water appropriated
3. the point on the stream at which the diversion is to be made
4. the place where this water is to be used
5. the nature of the use
6. the period or season when the right to use exists (38, p. 298; 59).

The appropriator has the option to change the point of diversion, the place of use, the nature of the use, and the period or season of use without losing the priority of his right. However, it must first be determined that no other appropriators are injured thereby. Any changes must be approved by the State Engineer (61).

Municipal water right holders are given several advantages, the most important of which is the period allowed to develop the right. Normally, an appropriator is required to fully develop his right within five years of the issuance of his permit. Cities, however, may reserve rights indefinitely for anticipated future demands (54). Municipalities also have the power to obtain water rights through condemnation of existing rights (32, 62).

The water use determines the extent to which a water right is consumptive. A water right for development of hydroelectric power would be nonconsumptive, while a right to divert water for irrigation would be predominantly consumptive (5, p. 383). Municipal water rights, however, are more difficult to classify, in that a certain portion of the water supplied to a city is usually returned to a watercourse in the form of sewage treatment plant effluent. In this respect municipal rights appear to be only partially consumptive. Furthermore, other water users can appropriate these return flows, providing they are diverted before they return to the stream of origin (38, p. 362).

In time, cities may be forced to consider return flows as a possible source of supplementing their water supplies, thus converting their rights to fully consumptive water rights. Water users who have appropriated and come to depend on these return flows could cause difficulties for cities attempting to reuse their return flows. However, court decisions generally hold that the senior appropriator has no obligation to maintain his return or "waste" flows for the benefit of the downstream appropriators (38, pp. 362-368; 70, pp. 24-25). Furthermore, by diverting its return flows for reuse, a city is, in effect, reducing waste, and the latter is generally encouraged by water law.

Nevertheless, certain questions could be raised, depending upon the use to which the return flow is put by a city. Basically, the returned water must be used in accordance with the terms of the municipal right. For example, it has been ruled that cities cannot sell their return flows for irrigation purposes (70, p. 32). The same reasoning could probably be applied to reusing the water for industrial purposes. Conceivably, the right of a city to use these return flows to supply recently annexed properties could even be put in question, as the water would be applied to land other than that described in its permit (no relevant court decisions have been made which would support the latter assumption, however). In any case, questions would be raised only if a water user had appropriated the city's return flows and felt he was injured through the cutting off of the return flows.

In conclusion, it should be mentioned that a city wasting a sizeable volume of return flow to surface waters should take precautions to guard its right to recapture these return flows. Its permit could easily be amended to provide for the city's eventually consuming the full amount, for industrial as well as domestic and commercial purposes. The right should also clearly provide for the application of the water to additional portions of land as they are annexed.

IV. THE CITIES AND THEIR SYSTEMS

To provide a background for understanding the water use and sewage flow patterns of the cities being studied, the first part of this chapter is devoted to a short description of the Willamette River Basin, its climate,and its hydrology. The remainder of the chapter is devoted to the selection of the cities to be studied and to the description of their water supply and sewage disposal systems.

The Willamette River Basin

Geography

The Willamette River Basin is located in northwestern Oregon and contains approximately 11,500 square miles. The basin is bounded by the Columbia River on the north, the Cascade Mountains on the east, the Calapooya Mountains on the south, and the Coast Range on the west (see Figure 1). It is nearly rectangular in outline and dish-shaped in topography. The valley floor, which is centered somewhat west of the basin's centerline, contains about one-third of the total land area. The remainder of the basin is in hills and mountains, which slope up from the valley floor to the east, south, and west. The principal watersheds of the basin lie in these peripheral mountain ranges. About three-fourths of the basin is covered by forest; most of the remainder of the land is under cultivation.

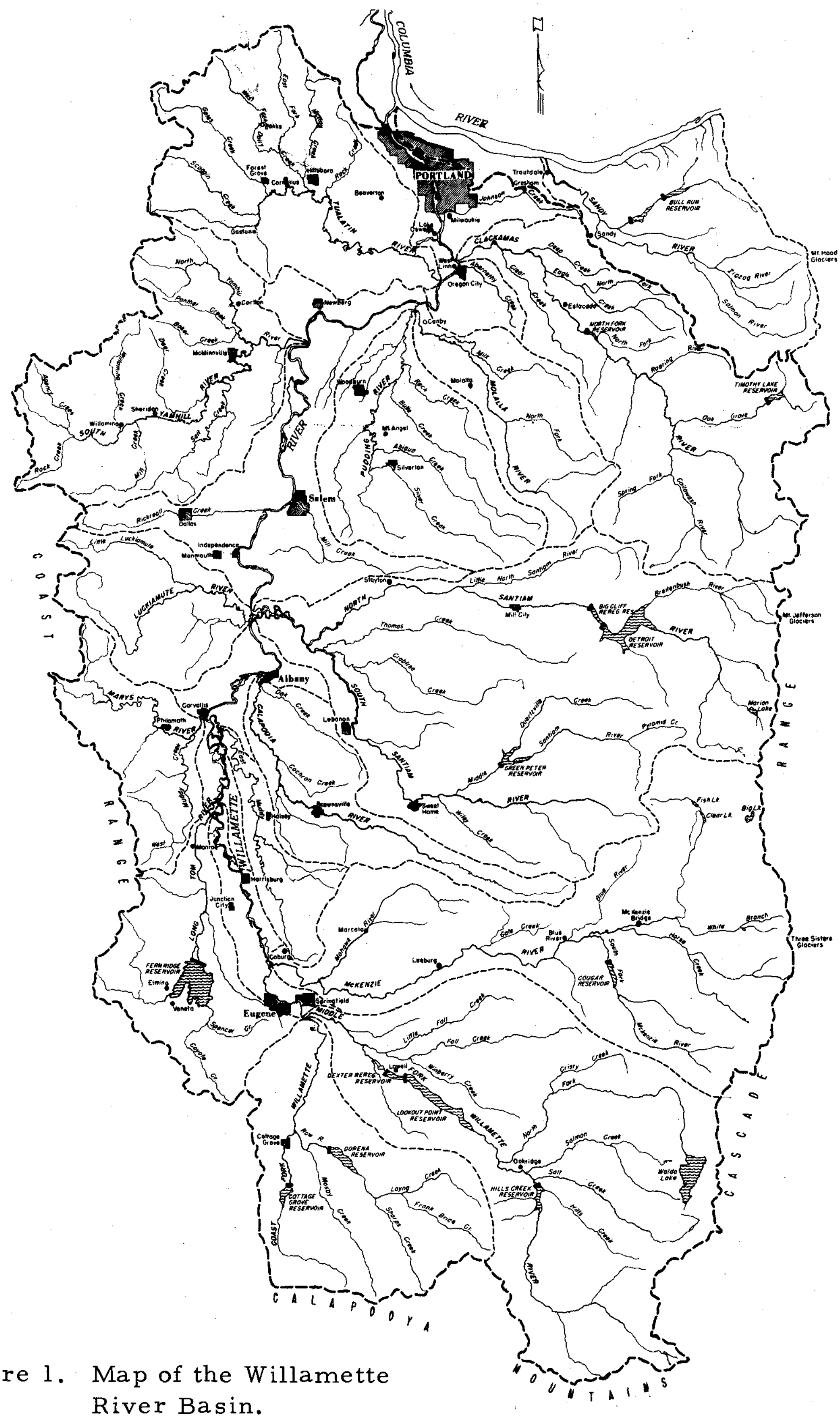

Figure 1. Map of the Willamette River Basin.

In 1960 about 1,020,600 people, nearly 60% of the population of the state of Oregon, lived in the Willamette Basin (about 12% of the area of the state). Most of the population of the basin is centered in four urban areas: Eugene-Springfield in the upper basin, Salem and Albany-Corvallis in the middle basin, and Portland in the lower basin.

The two primary industries of the basin are agriculture and forest products. Agriculture is centered in the valley floor, with food processing plants located in most of the major cities of the basin. The commercial forest lands are located in the surrounding mountains, with major forest products manufacturing centers being located at Cottage Grove, Dallas, Eugene-Springfield, Lebanon-Sweet Home, and Oregon City-West Linn. Portland supports a diversified manufacturing industry and serves as the major wholesale and retail trade center for Oregon and southeast Washington. In recent years recreation and tourism have been making an increasingly important contribution to the basin's economy (53; 54; 57; 66, p. 227).

Climate

The Willamette Basin has a modified marine climate characterized by warm, dry summers and mild, wet winters. The nearby Pacific Ocean dominates the weather pattern, but the Coast Range modifies the incoming marine air masses by precipitating much of the moisture from the air before it reaches the basin proper. The Columbia River Gorge and the Cascade Mountains also have a modifying influence on the climate of the basin, although to a lesser degree.

Rainfall varies from 40 inches annually over most of the valley floor to well over 100 inches in portions of the Coast and Cascade Ranges. Of the total annual precipitation, approximately 70 percent falls in the five month period from November through March, whereas only about 5 percent falls in the three month period June through August. Temperatures on the valley floor range from a monthly mean of about 40^{o} in January to nearly 70^{o} in July. Figure 2 shows average monthly rainfall and temperature at Salem, a typical valley-floor city (75; 80; pp. I-5, C-1 through C-4, C-31).

Hydrology

Runoff and streamflow closely follow the annual precipitation pattern of the basin. Streamflows peak in the wet winter months of December, January, and February and reach minimum flows in the summer months, when the water demands are greatest. The pattern of average monthly streamflow for the Willamette River at Salem is included in Figure 2 (68, 69).

Runoff is greatest from the large, high yield producing

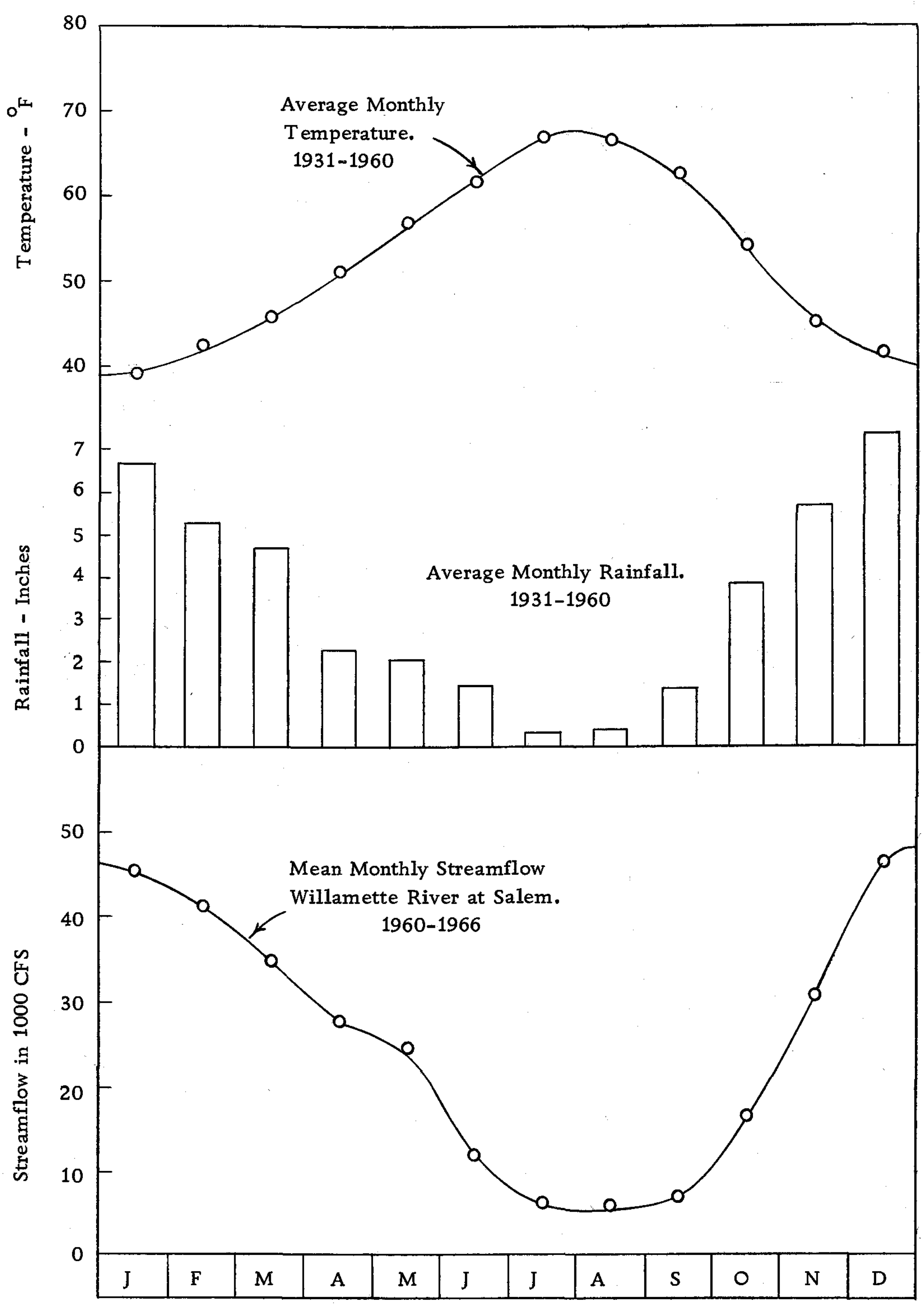

Figure 2. Climatologic and Hydrologic Characteristics, Salem, Oregon.

sub-basins of the east side of the valley (such as the Santiam and McKenzie). Runoff from the west side streams is generally lower because of the smaller drainage areas and the lower average rainfalls. Table 2 illustrates the relative contribution of major tributaries to the flow of the Willamette River (53, p. 29; 54, p. 31; 57, p. 18).

Table 2. Runoff from major tributaries of the Willamette River.

River	Area sq. miles	Mean Annual Runoff Acre-feet	Acre feet/sq. mile
Santiam	1782	5,760,000	3230
McKenzie	1342	3,847,000	2860
Middle Fork Willamette	1354	2,783,000	2060
Clackamas	1019	2,419,000	2370
Yamhill	700	1,689,000*	2420
Coast Fork Willamette	665	1,166,000	1750
Tualatin	721	1,083,000	1500
Pudding	530	930,000	1750
Molalla	348	850,000	2440
Long Tom	526	828,000	1570
Luckiamute	310	744,000	2400
Calapooia	371	614,000	1650
Marys	299	546,000	1830

*includes only runoff above confluence of the North Yamhill and South Yamhill Rivers.

To help overcome the unfavorable seasonal runoff distribution, a number of reservoirs have been constructed. At the present time, a high percentage of the late summer flow in the Willamette is made up of releases from multiple-purpose reservoirs on the

Santiam, McKenzie, Middle Fork, Coast Fork, and Long Tom Rivers. Single-purpose municipal water storage reservoirs have been constructed on Rickreall Creek and tributaries of the Yamhill and Marys rivers. Construction is planned for a large conservation storage reservoir on Scoggins Creek. However, further storage will be required to meet future municipal, industrial and agricultural needs of the basin and to maintain adequate water quality in its streams (56, p. 35; 67).

Selection of Cities

Only cities having a population of 4,000 or more were considered as smaller cities are less likely to have adequate sewage and water flow records. The basin cities having a 1966 population of 4,000 or more are listed in Table 3 (51).

Of the twenty-three cities listed, six were eliminated because they draw their municipal water supplies from wells (73). Portland, besides having a somewhat complex sewage collection system, discharges the majority of its effluent outside of the basin. Beaverton, Gladstone, Gresham, Oregon City, and West Linn are located close enough to Portland to be considered "bedroom communities", not having the balanced residential, commercial, and industrial water use pattern characteristic of self-contained cities (73, p. 14). The water demands of these cities would more logically be combined

Table 3. Willamette Basin Cities with Population of 4000 or More.

City	Population (1966 Estimate)	Source of Municipal Water
Albany	16,500	South Santiam River
Beaverton	12,300	Bull Run River
Corvallis	29,500	Rock Creek & Willamette River
Cottage Grove	5,100	Coast Fork Willamette River
Dallas	5,600	Rickreall Creek
Eugene	75,300	McKenzie River
Forest Grove	6,630	Gales Creek
Gladstone	5,120	Clackamas River
Gresham	5,940	Bull Run River
Hillsboro	11,300	Seine Creek & Tualatin River
Lake Oswego	12,600	Bull Run River & Wells
Lebanon	6,300	South Santiam River
McMinnville	8,900	Haskins Creek
Milwaukie	15,423	Wells
Newburg	4,630	Wells
Oregon City	8,430	Clackamas River
Portland	384,000	Bull Run River
Salem	66,200	North Santiam River
Silverton	4,030	Silver Creek and Wells
Springfield	24,000	Wells
Sweet Home	4,100	South Santiam River
West Linn	4,776	Clackamas River
Woodburn	5,809	Wells

with those of Portland, the parent city.

This left eleven cities: Albany, Corvallis, Cottage Grove, Dallas, Eugene, Forest Grove, Hillsboro, Lebanon, McMinnville, Salem, and Sweet Home. Contacts were made with the public works and water departments of each of these cities, and the available water supply and sewage treatment plant inflow records were examined. Several of these cities were eliminated, for the following reasons:

Albany. A recent study of the city's sewage treatment plant by the consulting firm of Cornell, Howland, Hayes, and Merryfield revealed that the plant's flowmeter was unreliable (11, p. 13). This conclusion was confirmed by the fact that the available flow data was quite erratic from month to month. This was unfortunate since good flow records are maintained by the water utility, Pacific Power and Light Company.

Cottage Grove. The city's sewage treatment plant did not have a flowmeter until 1967, when the plant was modified to include secondary and tertiary treatment. Although excellent records are now being kept on net water sold, total flow to the city from the reservoirs is not metered. However, plans call for the installation of a master meter in the near future.

Dallas. Fairly complete records were available for both sewage treatment plant inflow and water supplied to the city.

However, it was found by Cornell, Howland, Hayes, and Merryfield, in a study of the city's water distribution system, that an inordinately small percentage (50% or less) of the water supplied to the city could be accounted for (18, p. 3). Therefore, it was felt that these figures could not be compared meaningfully with those of the other systems, where 75% or more of the water is accounted for (see Table 7).

Hillsboro. Complete records on the sewage treatment plant inflow were not available. Only the newer of Hillsboro's two plants has a meter for measuring sewage inflow. Furthermore, equipment has not been provided for measuring the water entering the city's distribution system.

Lebanon. Daily water supply records for Lebanon's system are kept by Pacific Power and Light Company. However, the meter was frequently out of order during the 1960-1966 period, often for weeks at a time. At other times, the flow values appear to be erratic. Therefore, it was felt that these records were not reliable. On the other hand, fairly complete sewage inflow records are maintained at the Lebanon treatment plant. While the per capita sewage inflow rates are somewhat high (seldom less than 250 gpcd even in late summer), the records do appear to be consistent.

The water and sewage inflow records for the remaining six cities were complete for the years 1960 through 1966 and were considered to be fairly reliable. The records for these cities--Corvallis, Eugene, Forest Grove, McMinnville, Salem, and Sweet Home--serve as the basis for the remainder of this study.

Description of City Systems

This section contains brief descriptions of the six cities and their water supply and sewage disposal systems. Also included for each city is a brief discussion of some of the special problems which must be considered in evaluating their respective water and sewage flow data.

Most of the information on the water supply and sewage disposal systems was obtained by interviewing the respective operating personnel. This was supplemented by reports prepared by consulting engineers, the U.S. Public Health Service, and the Oregon State Sanitary Authority.

Corvallis

Located on the Willamette River in the middle portion of the basin, Corvallis has a population of 29,500 (1966 estimate) and ranks as one of the five largest cities of the state. The economy of the city is centered around Oregon State University and its related research and development organizations. In addition, Corvallis is the site of several food processing plants and, together with Salem and Albany, serves as the trade center for the agricultural middle Willamette valley (7, p. 305; 36).

Water Supply. The city of Corvallis has for many years drawn water from a municipally owned watershed on Marys Peak drained by Rock Creek, a tributary of Marys River (see Figure 3). A 4.5 mgd filtration plant has been constructed for treating this water. While runoff from the watershed exceeds the treatment plant capacity in the winter, summer runoff has been insufficient to meet the city's expanding needs for a number of years. To make up the summer deficits, a second treatment plant was constructed in 1949 to draw water from the Willamette River just above Corvallis. The plant originally had a capacity of 4.0 mgd but has since been expanded to 8.0 mgd. This plant is so designed that it can be expanded to handle 16.0 mgd, the full amount of the Willamette River water right held by the city (13, pp. 28-36; 73, p. 48).

While the Rock Creek watershed continues to serve as the city's primary source of supply, the Willamette River source is becoming increasingly important. For example, in 1960 the Willamette plant furnished less than 14% of the annual demand; in 1966 it supplied 33.2%, including 60.2% of the August demand. It is expected that additional future needs will primarily be met by using Willamette River water (54, p. 50).

Sewage Treatment. The Corvallis sewage treatment plant

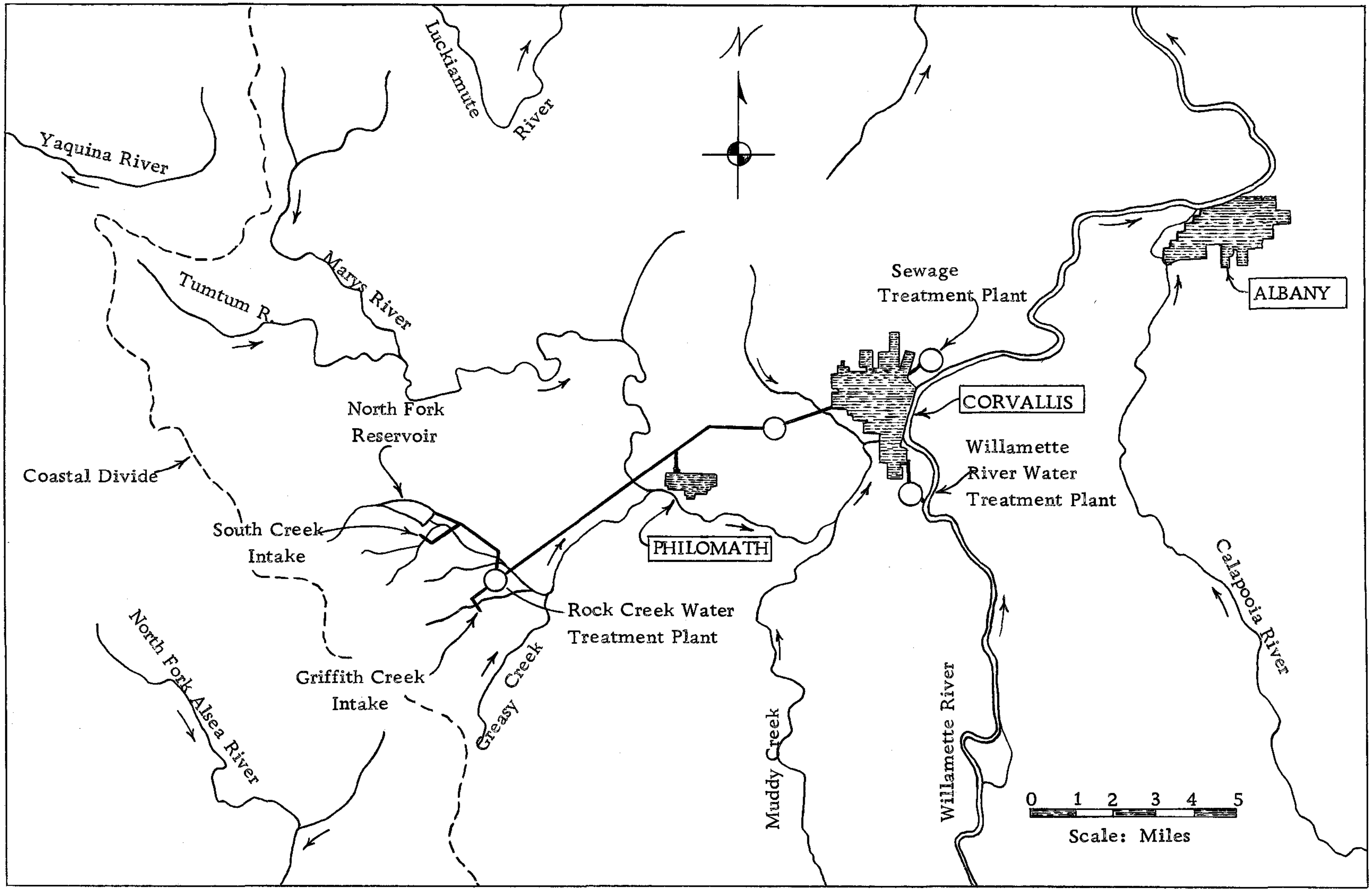

Figure 3. Corvallis Water Supply System and Sewage Treatment Plant.

was originally completed in 1954 as a primary treatment plant. In 1966 the plant was enlarged and expanded to incorporate secondary treatment by trickling filters. The plant was designed to handle 7.26 mgd and a total population equivalent (domestic plus industrial) of 147,740. For the period June-October, 1966, the plant was handling a population equivalent of more than 50,000 (52, pp. 40, 45).

The plant is located just north of the city and discharges its effluent into the Willamette River. A small, recently annexed development north of the city, Village Green, is served by an oxidation lagoon. However, plans are underway to connect this area to the main sewer system in the future.

Special Considerations. As is the case with most of the cities studied, certain portions of Corvallis are not yet completely connected to the sewer system. South Corvallis, for example, was annexed in 1962 for health and sanitation reasons. However, by the end of 1966, even though the sewer mains were all in place, about 50% of the residents of the annexed area had not yet connected to the system.

On the other hand, city water service is much more desirable and easy to install. As a result, new water connections generally keep up with annexations and new construction. In fact, city water service is so desirable that in the past service has been extended to certain areas outside of the city. However, the current policy is to make new connections only within the city limits.

The city of Philomath has been served by the Corvallis water system for many years. In 1960, realizing that it was becoming increasingly difficult to obtain sufficient water for its own customers, the city of Corvallis set a limit of 1.0 million cubic feet of water per month as the maximum quantity of water which it could guarantee to the Philomath system. Additional water could be supplied if available, but at a premium rate.

Part of Corvallis is served by combined storm and sanitary sewers. This accounts for the high winter-time sewage treatment plant inflows. Work is underway to separate these combined sewers wherever practicable.

Another factor which must be considered when analyzing annual water consumption and sewage inflow patterns is the seasonal nature of the industrial water demand. The principal industrial customer, the Blue Lake Cannery, operates only between July and November. While their demand does not have a great effect on the city water demand, their August peak load is reflected on the sewage treatment plant inflow curve (Figure 9).

Oregon State University is the city's largest water consumer. Although the student population of the campus is comparatively small during the summer, the water demand is maintained at a high level through the extensive lawn-watering requirements.

Eugene

Eugene, with a population of 75,300 (1966 estimate), is the second largest city in the state and is located on the Willamette River in the upper part of the basin. It is the county seat of Lane County and serves as the trade center for a large part of central Western Oregon. It is the home of a large forest products industry as well as the Eugene Fruit Growers' Association, one of the largest canneries in the West. Another important part of the city's economy is the University of Oregon and its more than 10,000 students (7, p. 307).

Water Supply. Eugene's municipal water system is operated by the Eugene Water and Electric Board (EWEB), an elective board operated independently of other municipal government functions. Water is withdrawn from the McKenzie River at Hayden Bridge, about 6-1/2 miles east of Eugene (see Figure 4). The 80 mgd Hayden Bridge filtration plant processes the water before it is sent to the city through 30-inch and 45-inch mains. EWEB holds McKenzie River water rights to 194 mgd, a quantity adequate to meet the city's needs in the foreseeable future (26; 73, p. 44).

Sewage Treatment. The Eugene sewage treatment plant was originally constructed in 1954 as a primary treatment plant. It was expanded in 1961 to include secondary treatment and further enlarged

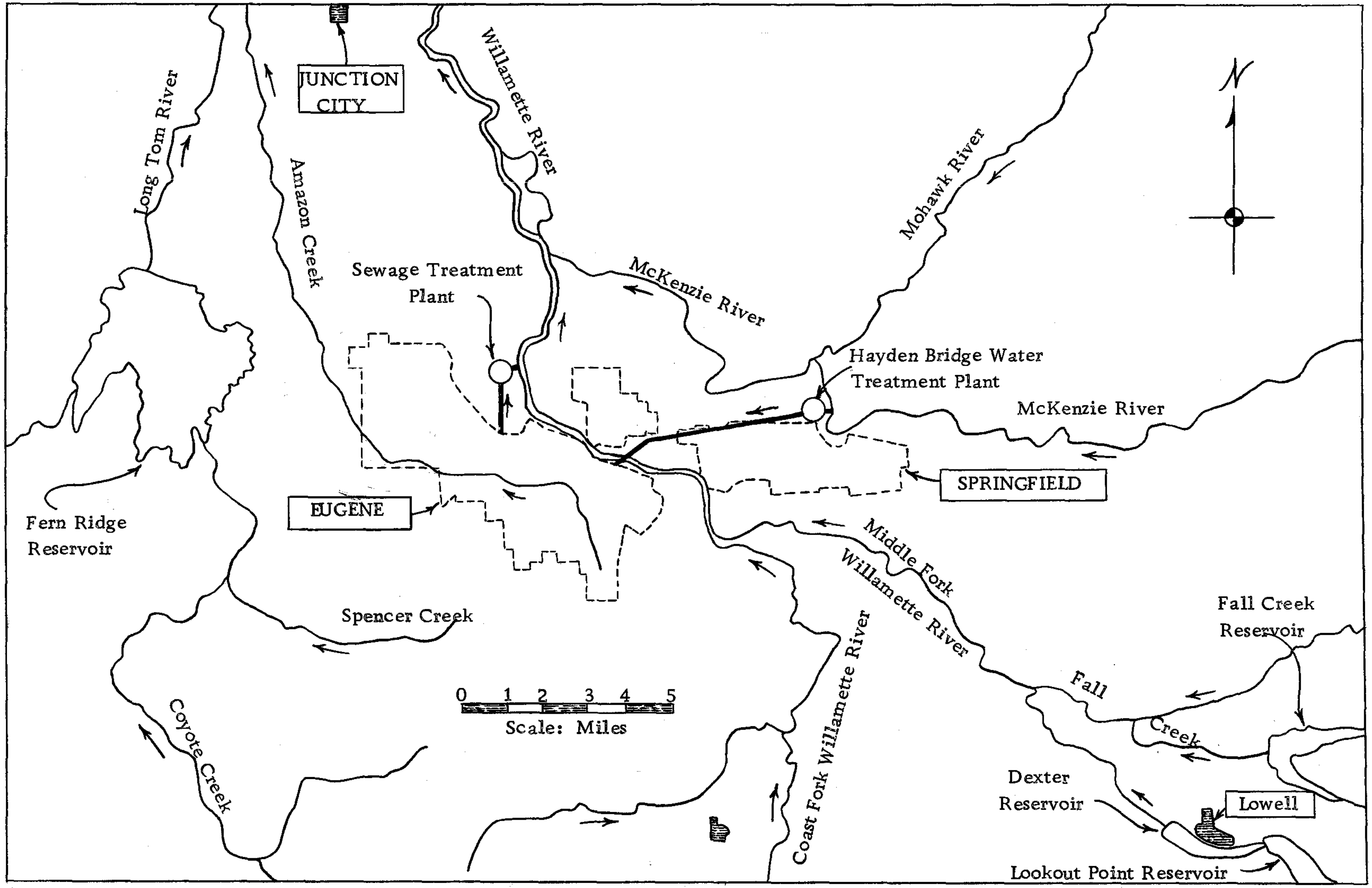

Figure 4. Eugene Water Supply System and Sewage Treatment Plant.

in 1966. The plant is of the high rate trickling filter type and was designed to handle a total population equivalent (municipal plus industrial) of 328,500. During the last half of 1966, the plant was handling an average population equivalent of 154,000 (52, pp. 40,45).

The plant is located north of town (see Figure 4) and discharges into the Willamette River. Most of the city is served by separate sanitary and storm sewers (20, p. 113).

Special Considerations. Although an active sewer construction program is underway, the city has expanded so rapidly in the past few years that it has been impossible for sewer construction to keep pace with annexation. In 1966, it was estimated that 63,000 of the city's population of 72,600 was served by the sewer system (52, p. 40).

The Eugene Water and Electric Board serves a number of suburban water districts as well as the city of Eugene. The following table lists the number of metered services in the city and each of the water districts for 1966.

City of Eugene	20,548
College Crest Water District	230
Glenwood Water District	300
Oakway Water District	870
River Road Water District	3,000
Santa Clara Water District	1,853

For the period 1960-1966, between 15.3 and 21.1 percent of the Hayden Bridge Plant's output was supplied to the water districts. In recent years the water districts' share has decreased as several districts have been annexed to the city (25).

Eugene has three very large water consumers: the University of Oregon, the Southern Pacific Railroad, and the Eugene Fruit Growers' Association. As can be seen from the following canning schedule (for 1962), the Eugene Fruit Growers plant reaches its peak of operation in late summer and early fall. This peak shows up as a late summer rise in the Eugene sewage treatment plant inflow curve (Figure 10).

Rhubarb	April 30	to	July 13
Strawberries	June 7	to	July 5
Sweet Cherries	July 6	to	August 5
Sour Cherries	July 14	to	August 15
Beets	July 10	to	September 20
Beans	July 28	to	August 31
Peaches	August 14	to	August 31
Corn	August 31	to	September 9
Pears	September 1	to	September 13
Carrots	September 28	to	December 31

This schedule is representative of the operating schedules of the numerous other fruit and vegetable packers operating in the

Willamette Basin.

Most of the other industrial water-users, including the Southern Pacific Railroad, the creameries, and the wood products manufacturers, have a relatively constant year-around demand.

Forest Grove

Forest Grove is located in the foothills of the Coast Range, about 20 miles west of Portland. The city has a population of 6,630 (1966 estimate) and is located in an extensive fruit growing area. Two major canneries (Hudson House and Gray and Company) and a lumber mill rank among the major industries of the town. Forest Grove is also the home of Pacific University, one of Oregon's major private schools.

Water Supply. Forest Grove draws its municipal water from Gales Creek, a tributary of the Tualatin River. Intakes are located on Gales Creek and two tributaries, Iller and Clear Creeks (see Figure 5). Treatment is provided by a 4.0 mgd filtration plant located just northwest of town. Although a 6.53 mgd water right is held on these creeks, stream runoff from the watershed may drop to 1.5 mdg during dry periods. An additional source of water is required to meet dry season deficits and to provide for future growth. Several alternatives have been proposed including storage on Gales Creek, single-purpose reservoirs on the Wilson and Trask Rivers

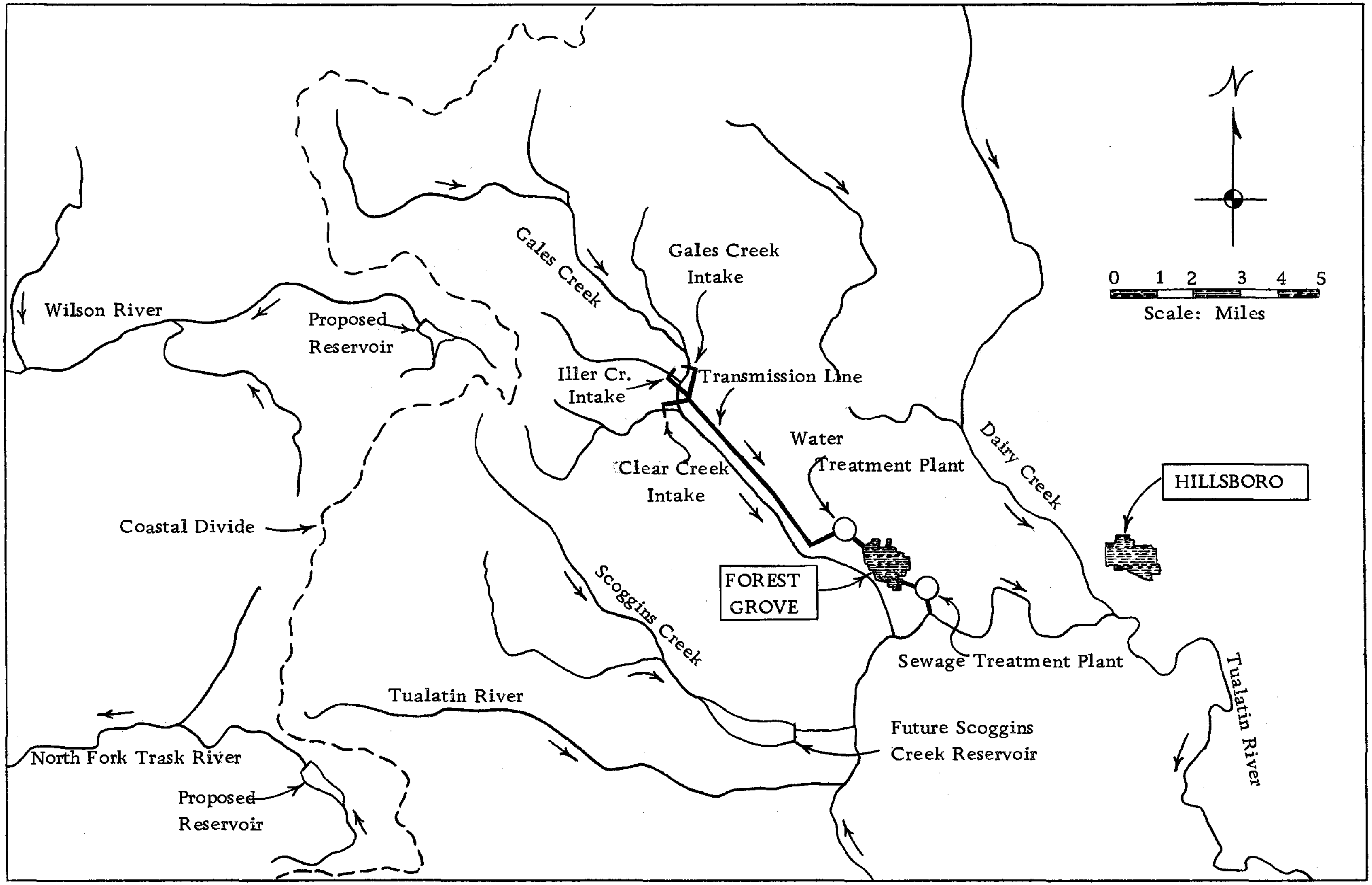

Figure 5. Forest Grove Water Supply System and Sewage Treatment Plant.

(coastal streams), and storage in the recently authorized U.S. Bureau of Reclamation Scoggins Creek Reservoir (53, pp. 59-60; 55, p. 69; 56, p. 35; 73, p. 60).

Sewage Treatment. The city's sewage treatment plant was originally constructed in 1952 to provide primary treatment and was expanded to include secondary treatment by trickling filters in 1965. Although the plant normally serves a population of about 6,630, the late summer load imposed by the canneries increases the influent BOD to a population equivalent in excess of 40,000 (52, p. 40). While this load is large, it occurs over a comparatively short period of time. It would have been impractical to provide additional trickling filter capacity which would be required only a few weeks each year. The problem was solved by installing oxidation lagoons to handle the BOD that cannot be removed by the trickling filters when operating under heavy loads. This high cannery load occurs during the late summer and early fall when rainfall is low and evaporation high. As a result, very little outflow from the lagoons occurs until the late fall, after the cannery load has been reduced by the ponds. The plant, including the lagoons, is capable of handling a population equivalent of 90,500. Effluent is discharged into the Tualatin River below the Fern Hill Road bridge (see Figure 5) (15; 52, p. 45).

Special Considerations. In Forest Grove sewer installation has not kept up with construction and annexation. Table 4 illustrates this problem (it is assumed that 100% of the population has municipal water service).

Table 4. Water and sewer accounts, Forest Grove, 1960-66.

Year	Water Accounts	Sewer Accounts	Percent Sewered
1960	1985	1446	72.8%
1961	2032	1475	72.7%
1962	2110	1498	71.0%
1963	2134	1540	70.3%
1964	2155	1556	72.3%
1965	2169	1582	72.9%
1966	2210	1633	74.0%

No sewer or water service is provided outside of the city limits.

The sewers are, for the most part, combined storm and sanitary sewers. This accounts for the high per capita daily sewage treatment plant inflows during the winter (see Figure 11). During periods of high storm runoff, a portion of the inflow must be bypassed directly to the river.

The waste from the canneries has a pronounced effect on the quantity as well as the BOD load of the dry season sewage treatment plant inflow. The August inflow is almost twice as large as it would be if the dry season sewage inflow followed the pattern of

Sweet Home, a city of similar size but without the seasonal cannery load (see Figure 14).

McMinnville

McMinnville, with a population of 8,900 (1966 estimate), serves as the trade center for much of the Yamhill sub-basin and is the seat of Yamhill county. It is located in the center of a rich, diversified agricultural area where some of the most important crops grown are strawberries, caneberries, cherries, prunes, green beans, sweet corn, hops, walnuts, and filberts. Dairy products, poultry, and beef; forest products; and manufacturing are also important. McMinnville is also the home of Linfield College, another of Oregon's better known private schools (7, pp. 135-136; 49, p. 258).

Water Supply. McMinnville currently obtains its water supply from the watershed of Haskins Creek, a tributary of the North Yamhill River (see Figure 6). Winter runoff is stored in a 250 mg reservoir to supplement the natural streamflow of Haskins Creek. Treatment at present is limited to chlorination and taste and odor control. While the city holds rights to 13.0 mgd on Haskins Creek, a flow which should be adequate to meet McMinnville's needs for many years to come, it is felt that the watershed has already been developed to its economic limit. Future needs will be met with diversions from a coastal stream, the Nestucca River. The city

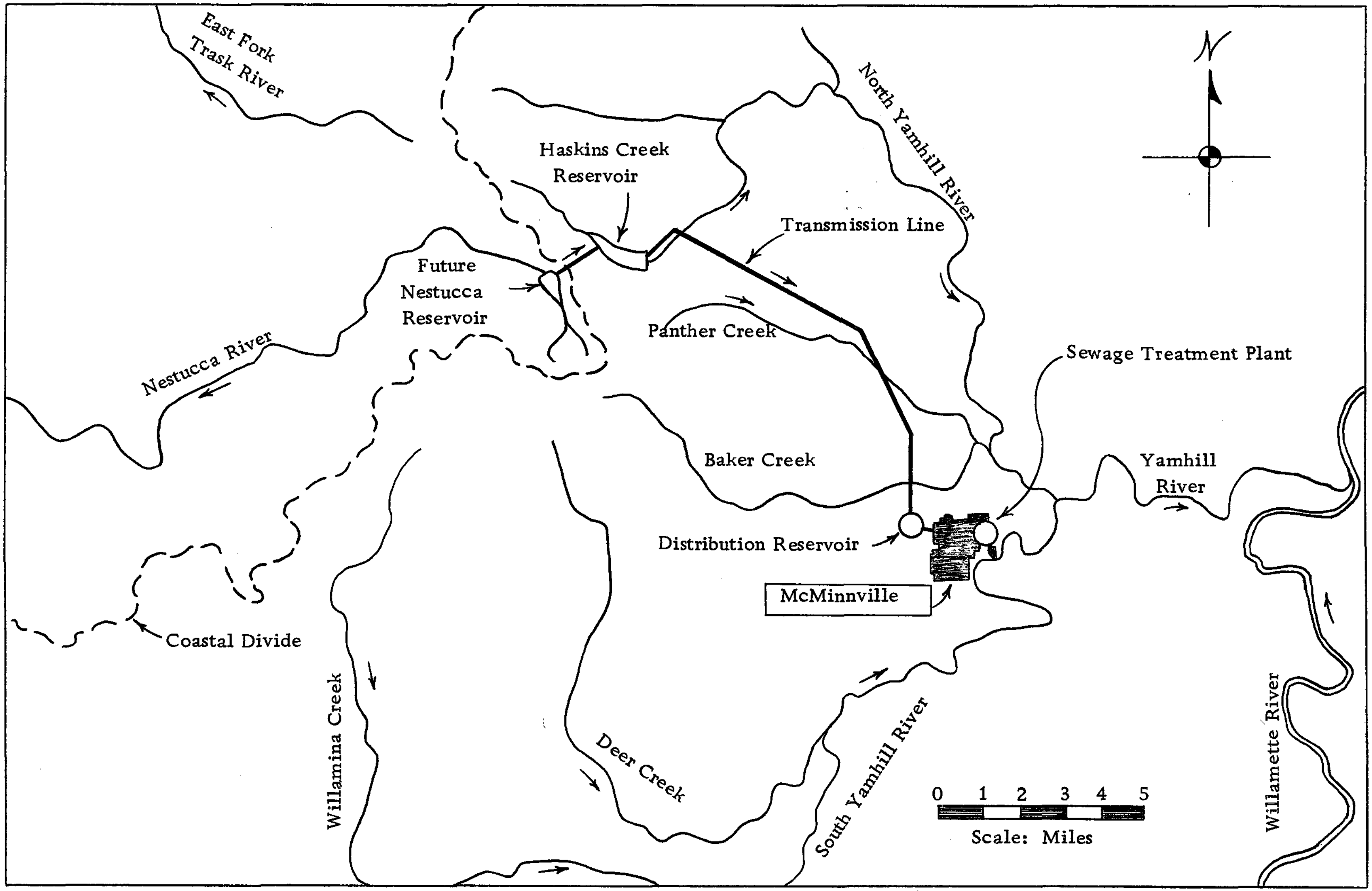

Figure 6. McMinnville Water Supply System and Sewage Treatment Plant.

holds water rights on the Nestucca, and plans to begin construction of a reservoir on this stream in 1968. (17, p. 7; 54, pp. 49-51; 73, p. 55).

Sewage Treatment. Secondary treatment of the city's sewage is provided by a trickling filter installation. Designed for a sewage inflow of 1.51 mgd and a total design population equivalent of 11,800, at times the plant is required to handle an influent with a population equivalent of over 15,000. However, plans are currently being made for expansion of the facility. The plant is located on the eastern edge of the city and discharges into the South Yamhill River (52, pp. 41, 45, 47).

Special Considerations. McMinnville is comparatively free of many of the factors which complicate the comparison of per capita water use and sewage flows. Virtually all water users of the city are connected to the municipal water system, and an unusually high percentage (93.7% in 1960) are connected to the sewers (64). No water or sewer connections are made to customers outside of the city.

The industrial water demand, while fairly high at 35% of the total annual demand (1963), does not fluctuate seasonally as greatly as that of cities where canneries account for a large part of the industrial demand. For example, the requirements of the Farmers Cooperative Creamery (which accounts for 19% of the city's annual demand), do not fluctuate greatly over the course of the year (12). As a result it is fairly easy to identify the dry season base sewage flow, as the sewage inflow curve reaches a definite low point in September.

On the other hand, McMinnville's system of combined storm and sanitary sewers makes any comparison of wet season water and sewage flows difficult. Also, the city's low water rates have encouraged unusually high per capita water use (on the order of 250 gpcd) which makes direct comparison with most other city systems somewhat difficult (12).

Salem

Salem, the capital of Oregon and the seat of Marion County, is located on the Willamette River, about 45 air miles (70 river miles) south of Portland. With a 1966 population of 66,200 (estimated) it is the third largest city in Oregon. In addition to its status as a center of government, Salem is the site of numerous industries, ranging from forest products and textile mills to carnival ride fabricators. The city is also one of the largest fruit and vegetable processing centers in the United States, handling about one-fourth of the fruits and vegetables processed in the Pacific Northwest. Salem serves as the trade center for much of the middle Willamette Basin (7, pp. 317-318).

Water Supply. Salem's municipal water is drawn from the North Santiam River through infiltration galleries located on Stayton Island, about sixteen miles east-southeast of the city (see Figure 7). The water is of sufficiently high quality that only chlorination is required. The city holds water rights to 85.3 mgd from the North Santiam River. This supply can be supplemented by 9.2 mgd of ground water rights which were acquired when the old Salem Heights Water District was absorbed by the Salem municipal system in 1962. The combined supply of 94.5 mgd should be adequate for the foreseeable future. Additional supplies for the more distant future could come from the present source or the Willamette River (54, pp. 49-50; 73, p. 50).

Sewage Treatment. Sewage is treated by a high rate trickling filter plant located north of the city at Willow Lake (see Figure 7). This plant was completed in 1964, replacing a primary treatment plant constructed in 1952. Although the domestic load of the city is only 66,200 people, the new plant was designed to handle a total population equivalent of 455,000. The majority of the additional capacity is required to handle industrial wastes, of which a large share comes from the food processing plants. Treated effluent is discharged into the Willamette River below Salem (16; 52, pp. 43,45).

Special Considerations. Although quite a large percentage of the water-users in the city are connected to sewers (96.8% in 1960),

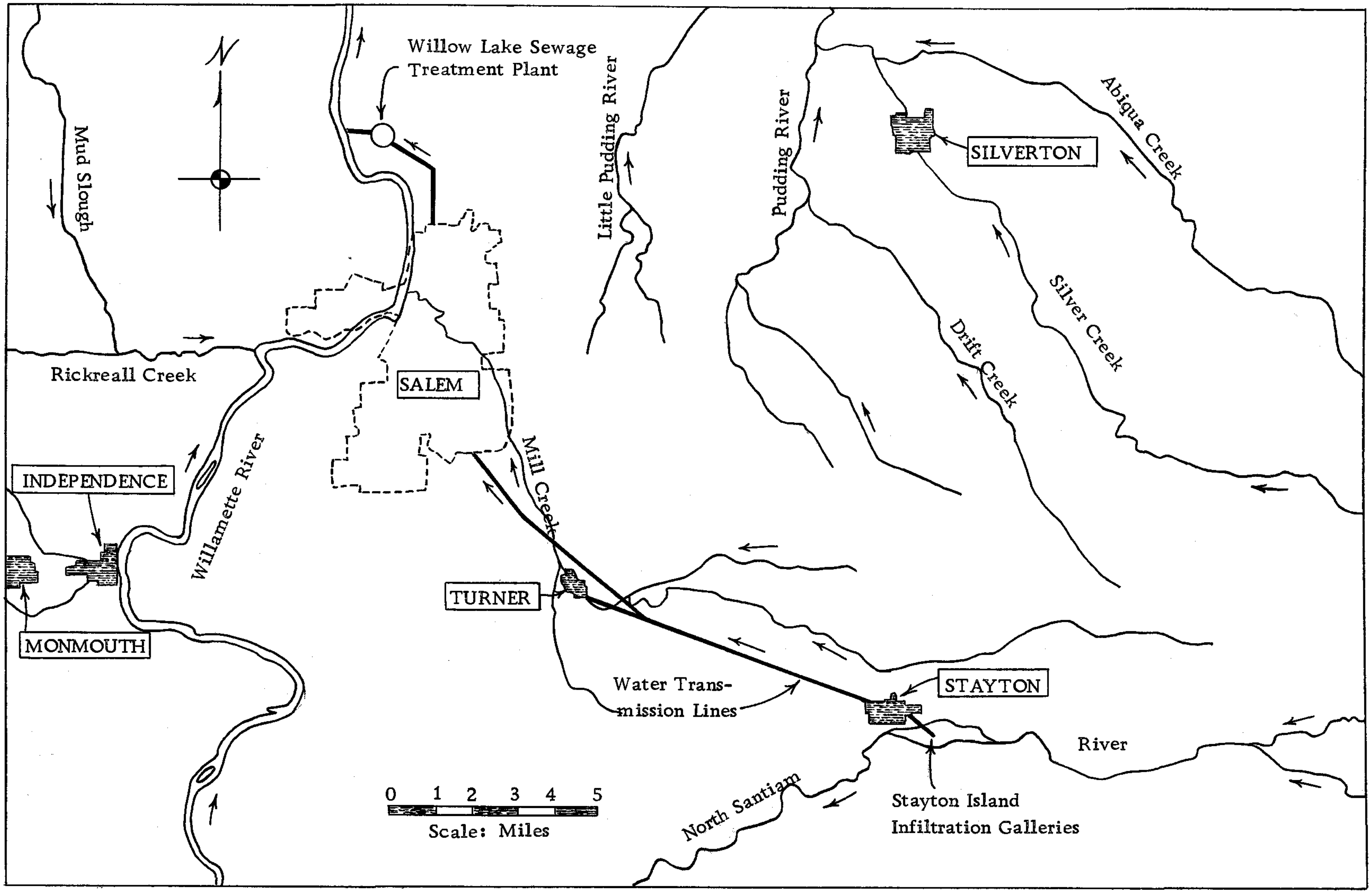

Figure 7. Salem Water Supply System and Sewage Treatment Plant.

recent annexations such as West Salem and Salem Heights have made it difficult for sewer construction to keep up with the new customers. Separate storm and sanitary sewer systems serve nearly all of the city (16, p. 12).

Salem does sell water to incorporated water users outside of the city limits. The Keizer and East Salem Water Districts and the city of Turner are the largest users of this type. It should be noted that the Keizer Water District uses Salem water mainly to supplement its own well system. Also among the water-users not discharging their waste to the Salem sewage treatment plant is the city's largest industrial water user, Boise-Cascade Corporation. The Boise-Cascade paper mill has its own facilities for treating its waste sulfite liquor and fiber.

As can be seen from the breakdown of monthly water sales by category for 1960-1966 (Figure 20), the industrial water use reaches a late summer peak of five times the winter rate. Most of this added demand can be attributed to the food processing industry. This demand is also reflected in the sewage inflow rates, both with respect to volume and to BOD. Among the largest of these processors are:

Blue Lake Packers, Inc.	Oregon Fruit Products Co.
California Packing Corp.	Sunset Packing Co. of Oregon
Dole Company	U.S. Products Corp.

Kelly-Farquhar & Co. United Flav-R-Pack Growers Inc. Pilgrim Turkey Packers and the Oregon Turkey Growers Association also have fairly large water demands and sewage loads, but their demands and loads are relatively constant throughout the year.

Sweet Home

Sweet Home is a town of 4,100 (1966 estimate) located on the South Santiam River in the foothills of the Cascade Mountains. The economy is oriented heavily toward the support of logging and the processing of forest products. However, in recent years, Sweet Home has also served as the base of operations for the construction of Foster and Green Peter Dams. A number of forest products plants are located here including the large Santiam Lumber Company and Willamette National plants.

Water Supply. Water is drawn directly from the South Santiam River as it passes through the city (see Figure 8). The municipal filtration plant was initially constructed in 1938 and enlarged to handle a total of 1.9 mgd in 1952. In 1967 the plant was converted to the MicroFloc process, which increased its capacity to 3.4 mgd. The city has water rights on the South Santiam River to 6.4 mgd, which should fill its needs for the immediate future. It is expected that future needs will be met from storage in Foster Reservoir. Intake facilities have been installed in Foster Dam with

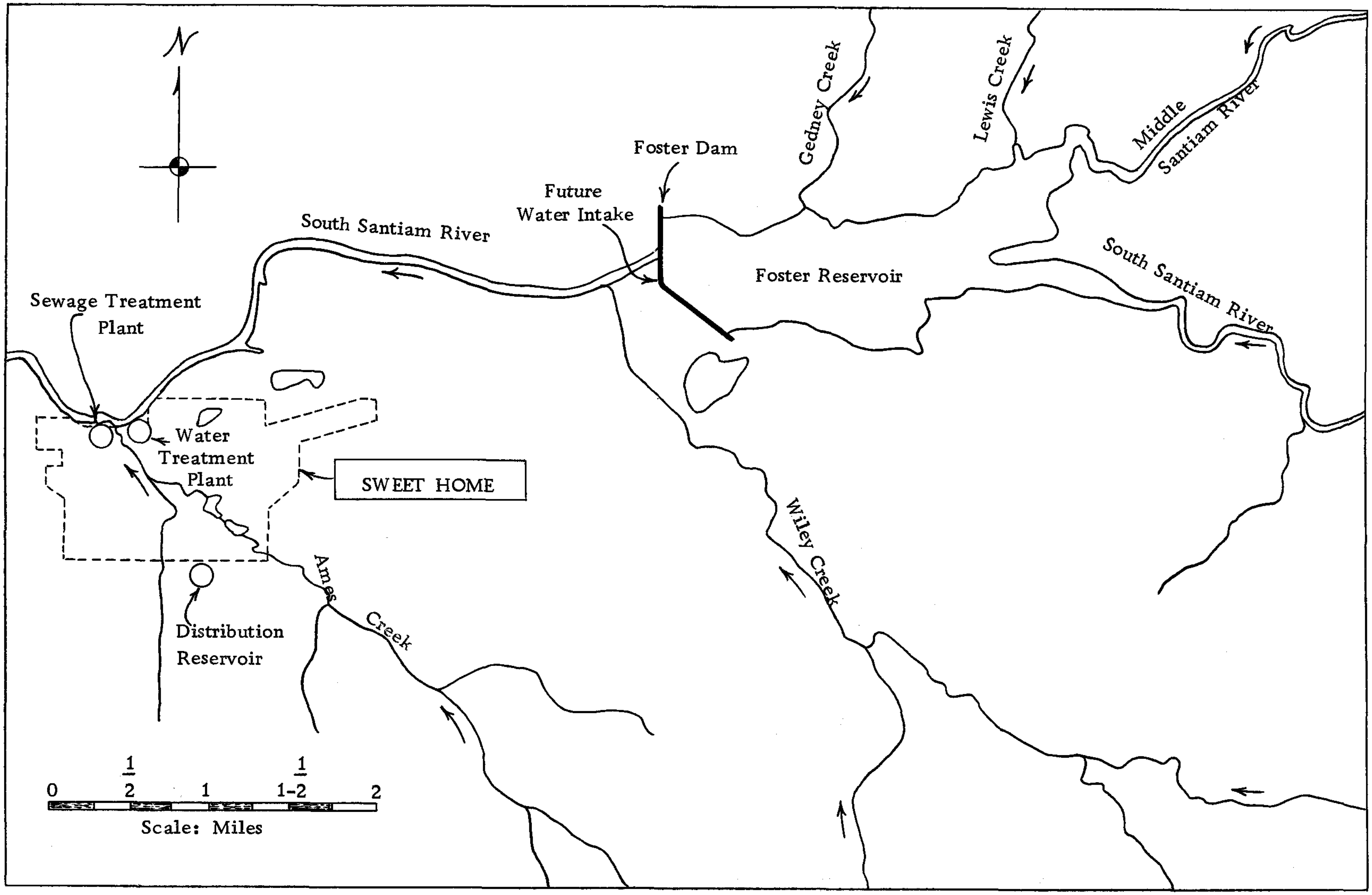

Figure 8. Sweet Home Water Supply System and Sewage Treatment Systems.

this in mind (14).

Sewage Treatment. The city's sewage treatment plant was constructed in 1948 as a secondary treatment plant and was modified in 1966 to increase its capacity. The plant was designed to handle a flow of 1.7 mgd and a population equivalent of 3,500. In the summer and fall of 1966 a BOD reduction of 89.7% was being achieved on an influent having an average population equivalent of about 2,500. Effluent is discharged into the South Santiam River about one-half mile below the water treatment plant intake (52, p. 43).

Special Considerations. As of 1960, about 17.7% of the city's dwellings were not served by sewers (64). While an active sewer construction program is underway, annexations have brought in additional customers as fast as new connections can be made. The discrepancy between the number of water customers and sewer customers is further widened by the city's policy of selling water to customers outside the city. In June, 1961, the city had water accounts with 111 customers located outside the city.

The water demand of the major industrial users, the lumber and plywood mills, does not vary greatly over the year. However, it is probable that a substantial portion of the water used by the mills ultimately finds its way to the log ponds instead of the sewers.

V. ANALYSIS OF DATA

Basic Data

Data Required

The basic data consist of the volumes of water used by the cities and the volumes of effluent discharged by the sewer systems.

In order to get a good picture of the seasonal flow variations, monthly average flows were selected as the basic data unit. Several years of data were evaluated in order to include both "dry" and "wet" years. Two factors limited the period of analysis. The first was the date of installation of the sewage treatment plants (sewage flow measurements were not made regularly prior to the construction of the plants). Of the eleven cities initially considered, the treatment plants of nine were put into operation in the period 1952-1954 (52, pp. 40-43). The second factor was the length of time that the utilities kept their flow data on hand. This was especially important in the case of the smaller cities, which often keep records on hand for only six or seven years. Therefore the seven year period 1960 through 1966 was selected as the period of analysis. This period was considered long enough to average out the flow irregularities of individual years.

Collection of Data

Sewage Treatment Plant Inflows. Sewage inflow records were usually readily available. Monthly tabulation sheets, which record sewage influent and effluent quality information as well as daily sewage inflows, are kept by the plant operators for the Oregon State Sanitary Authority. These daily sewage inflow volumes are measured by flowmeters which record the amount of flow entering the primary phase of the treatment process. The sewage inflow records are usually kept on file at the treatment plants.

Water Supply Data. The acquisition of water supply data was somewhat more complex. In most cases the data were obtained from the respective water department offices. The form in which the data were kept varied widely.

The Corvallis water department prepares monthly reports showing both water delivered and water sold. In many cases, however, the data are available only in the water departments' master record books, along with billing information. In some of these cases, detailed information on the breakdown of water sales is maintained also. The curves showing residential, commercial, and industrial water use for Salem (Figure 21) were prepared from data of this type. The Dallas water department had available only daily figures. At Forest Grove the records were kept in the log book of the water treatment plant operator. At Sweet Home the data were maintained at the treatment plant in the form of monthly chlorination reports prepared for the Oregon State Sanitary Authority. (Reports of this type are submitted by all municipal water systems which chlorinate their water.) Curves showing daily water flows for Albany and Lebanon were obtained at the engineering offices of Pacific Power and Light Company in Portland.

In all cases the water data represent the total amount of water supplied to the city, the master flowmeters being located on the supply mains carrying water from the sources of supply to the distribution systems. Normally one or more service reservoirs are included within a city's distribution system to handle peak demands in excess of the instantaneous capacity of the supply mains or treatment plant (27). Because these reservoirs tend to average out daily and other short-term fluctuations, a daily master flowmeter reading does not necessarily represent the actual amount of water used by the city on that day. However, such daily discrepancies tend to cancel each other over a monthly period.

In addition, most cities maintain monthly records of water sold. These figures are obtained by totalling the monthly customer billings. However, since the individual customer readings are not all made on the same day of the month, the monthly values of water sold cannot be directly compared with the monthly values of water supplied to the city. For this reason, the percentages of unaccounted for water (Section VI) are computed by comparing only the yearly totals (34).

Summary of Basic Data

The basic data described in the preceding section have been summarized in Appendix I. Included are the following tables:

Municipal Water Supply Inflows by Month, 1960-1966

12. Corvallis
13. Eugene
14. Forest Grove
15. McMinnville
16. Salem
17. Sweet Home

Sewage Treatment Plant Inflows by Month, 1960-1966

18. Corvallis
19. Eugene
20. Forest Grove
21. McMinnville
22. Salem
23. Sweet Home.

Reduction of Data

All of the flows tabulated in Appendix I are expressed in terms of millions of gallons (mg) except the Eugene and Forest Grove sewage treatment plant inflows, which are in millions of gallons per day (mgd). All flows were reduced to gallons-per-capita-per-day (gpcd) in order to put the data on a common base for purposes of comparison.

The first step was to convert all monthly flows to mgd flows. These were then further reduced to gallons-per-capita-per-day (gpcd) by use of population figures (Table 5) obtained from the 1960 Census and from annual population estimates by the Oregon State Center for Population Research and Census (50, 51). It was assumed that (after accounting for the demands of the Corvallis, Eugene, and Salem out-of-town water customers as described below) the number of water and sewer customers served is essentially equal to the city's estimated population. The validity of this assumption will be discussed later. The resulting gpcd water supply and sewage treatment plant inflows are tabulated for each city in Appendix II.

The Corvallis, Eugene, and Salem water systems supply water to small municipalities and water districts outside their city limits, and the demands of these municipalities and districts are included in the master flowmeter readings. It was necessary to correct for

Table 5. Populations of Willamette Basin Cities, 1960-1966[2].

City	1960	1961	1962	1963	1964	1965	1966
Corvallis	20.669	22.350	25.633	26.440	27.383	28.400	29.500
Philomath	1.359	1.344[1]	1.328	1.375[1]	1.422	1.460	1.556
Eugene	50.977	52.475	55.413	58.078	70.203	72.600	75.300
Forest Grove	5.628	5.855	5.988	6.276	6.453	6.550	6.630
McMinnville	7.656	7.927	8.151	8.319	8.461	8.600	8.900
Salem	49.142	49.614	50.529	50.759	62.861	64.000	66.200
Sweet Home	3.353	3.630	3.477	3.634	3.945	4.050	4.100

[1] estimated by interpolation

[2] references 50 and 51

these outside services in order to obtain figures which could be compared directly with the sewage flows.

Data on the amount of water sold by the city of Salem to the city of Turner and other water districts (Appendix III, Table 39) were obtained along with the total water production figures. Thus it was only necessary to subtract the former values from the total production to get the net flows listed in Table 16 of Appendix I. The total flow values for Corvallis (Appendix I, Table 12) were divided by the combined populations of Corvallis and Philomath to obtain the gpcd figures tabulated in Appendix II (it was assumed that Philomath residents used water at the same rate as Corvallis residents). The total Eugene water production values (Appendix I, Table 13) were adjusted by the following factors to correct for the amount of water supplied to water districts.

1960	81.1%	1964	84.1%
1961	82.3%	1965	84.5%
1962	80.2%	1966	84.7%
1963	78.9%		

These factors represent the percentage of water actually supplied to the city and were estimated from bar graphs in the Eugene Water and Electric Board annual reports (24, 25, 26).

In a few cases some daily sewage flow values were missing due to power outages or meter malfunctions. The resulting partial monthly figures were adjusted to full monthly values by assuming that the average flow for the days of record was representative of the entire month.

Results

Graphical Relationship of Water Demand to Sewage Flow

The following series of curves was constructed from the data in Appendix II to show the relationship of gpcd water demand to sewage treatment plant inflow. These curves (Figures 9-14) show the average monthly flows for the seven-year period 1960-1966 for each of the six cities.

Consumptive Use Factors

Ideally,the difference between the water supply curve and the sewage treatment plant inflow curve should represent the consumptive use. However, a certain amount of storm water enters any sewer system, even where separate storm sewers have been provided. This storm water tends to mask out the actual sanitary sewage flows, which are of prime interest in making the consumptive use calculations. Therefore, it is necessary to separate storm water flows from sanitary sewage flows. This was done by assuming the late summer sewage flow to be entirely sanitary sewage, and

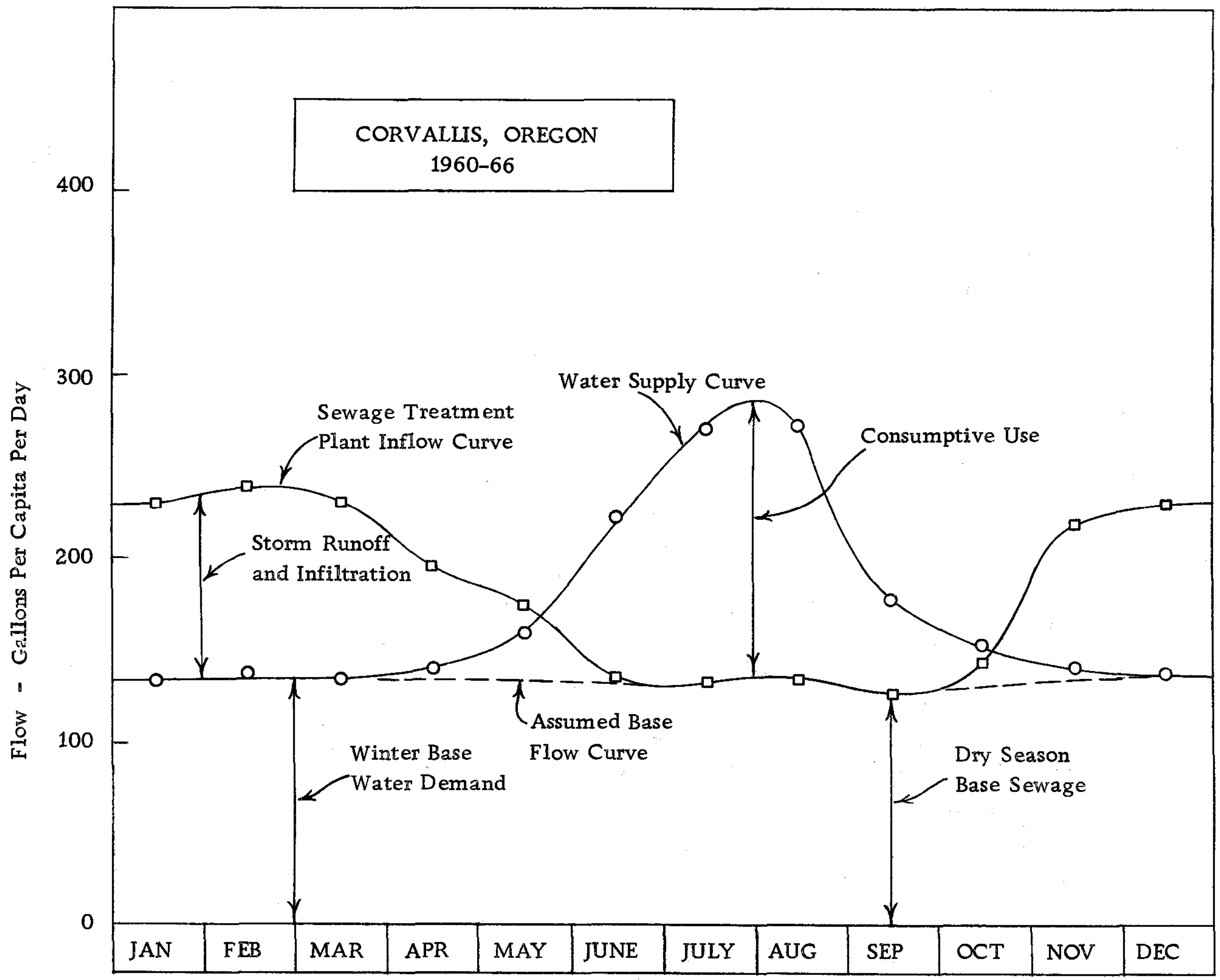

Figure 9. Annual Consumptive Use Pattern, Corvallis, 1960-66.

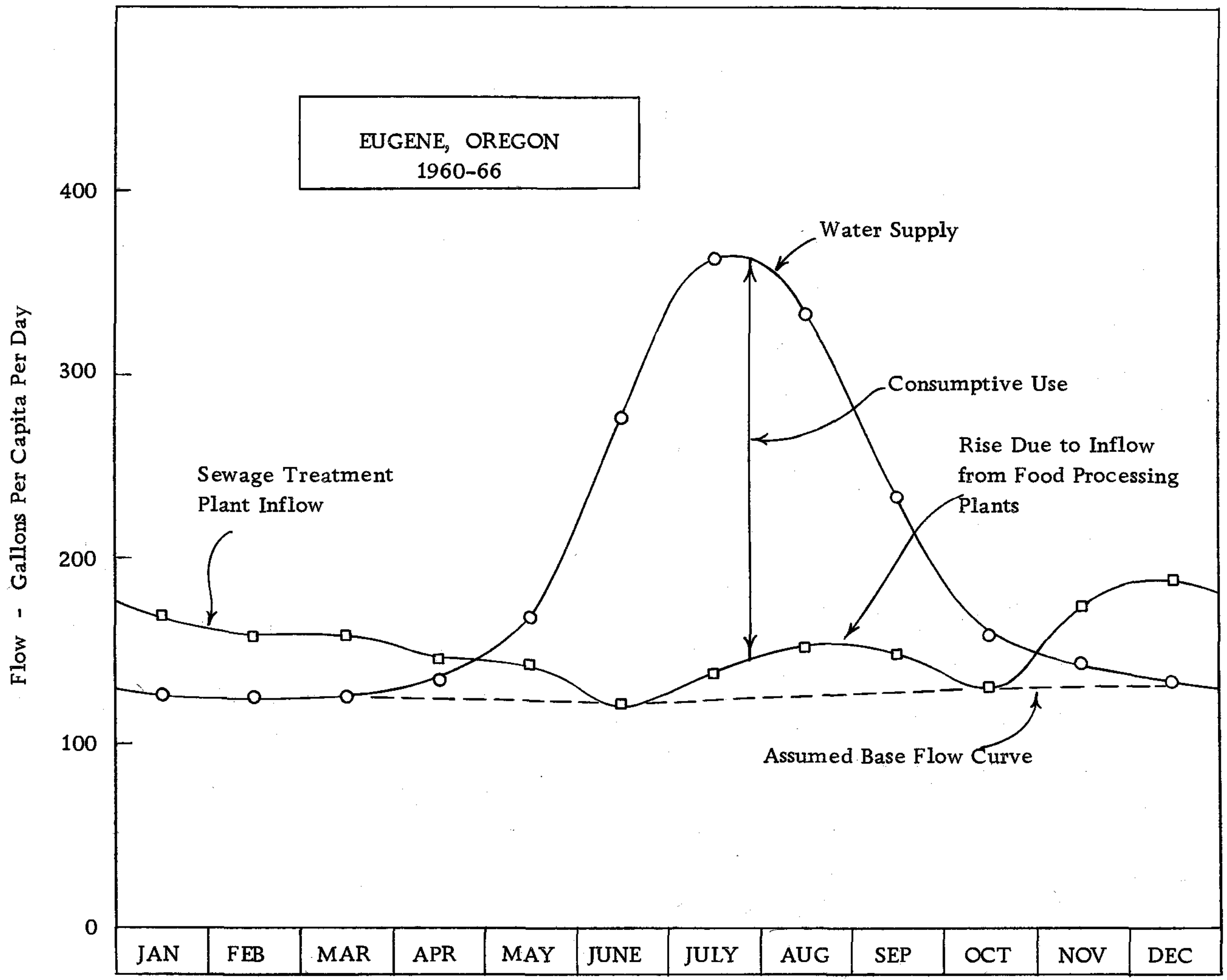

Figure 10. Annual Consumptive Use Pattern, Eugene, 1960-66.

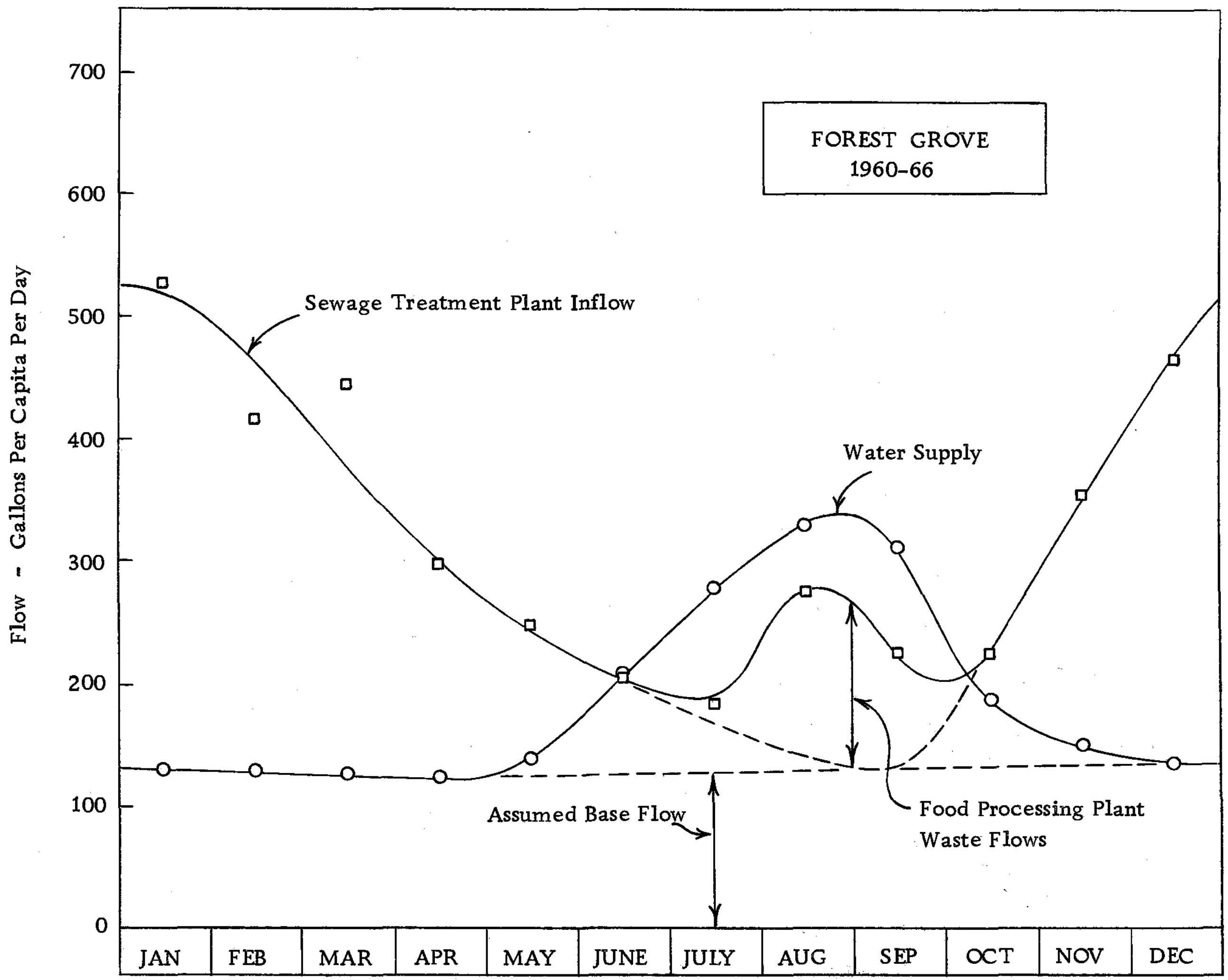

Figure 11. Annual Consumptive Use Pattern, Forest Grove, 1960-66.

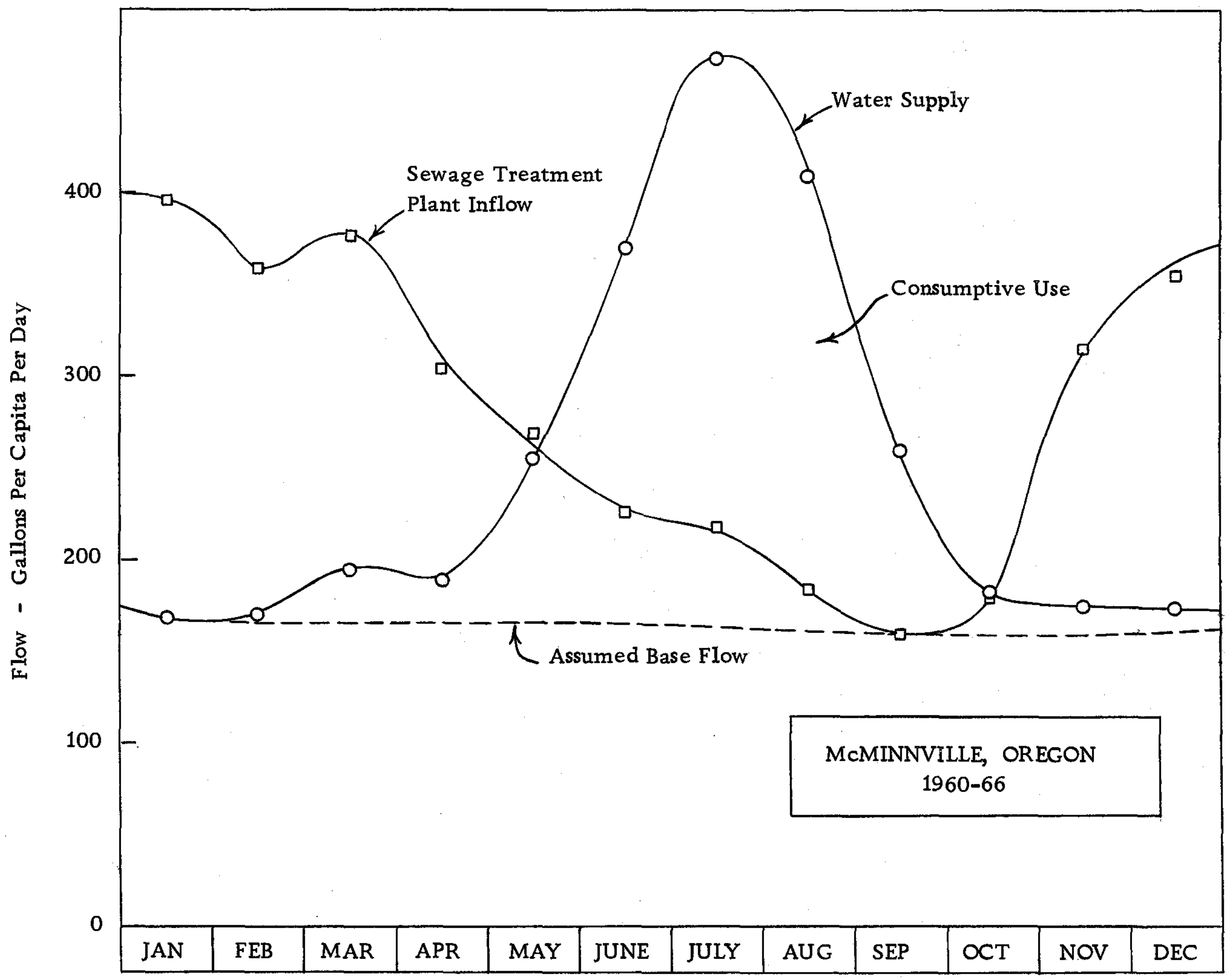

Figure 12. Annual Consumptive Use Pattern, McMinnville, 1960-66.

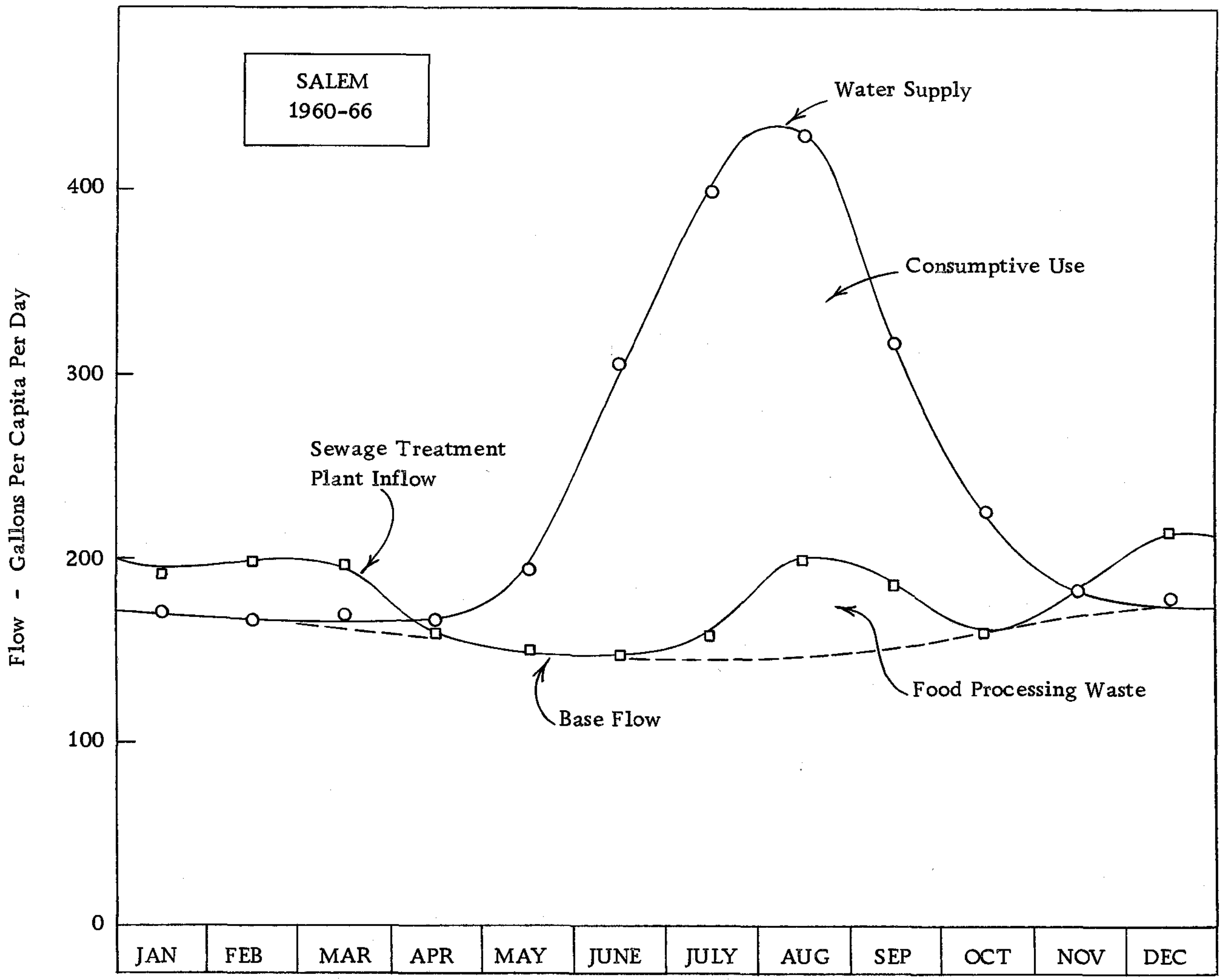

Figure 13. Annual Consumptive Use Pattern, Salem, 1960-66.

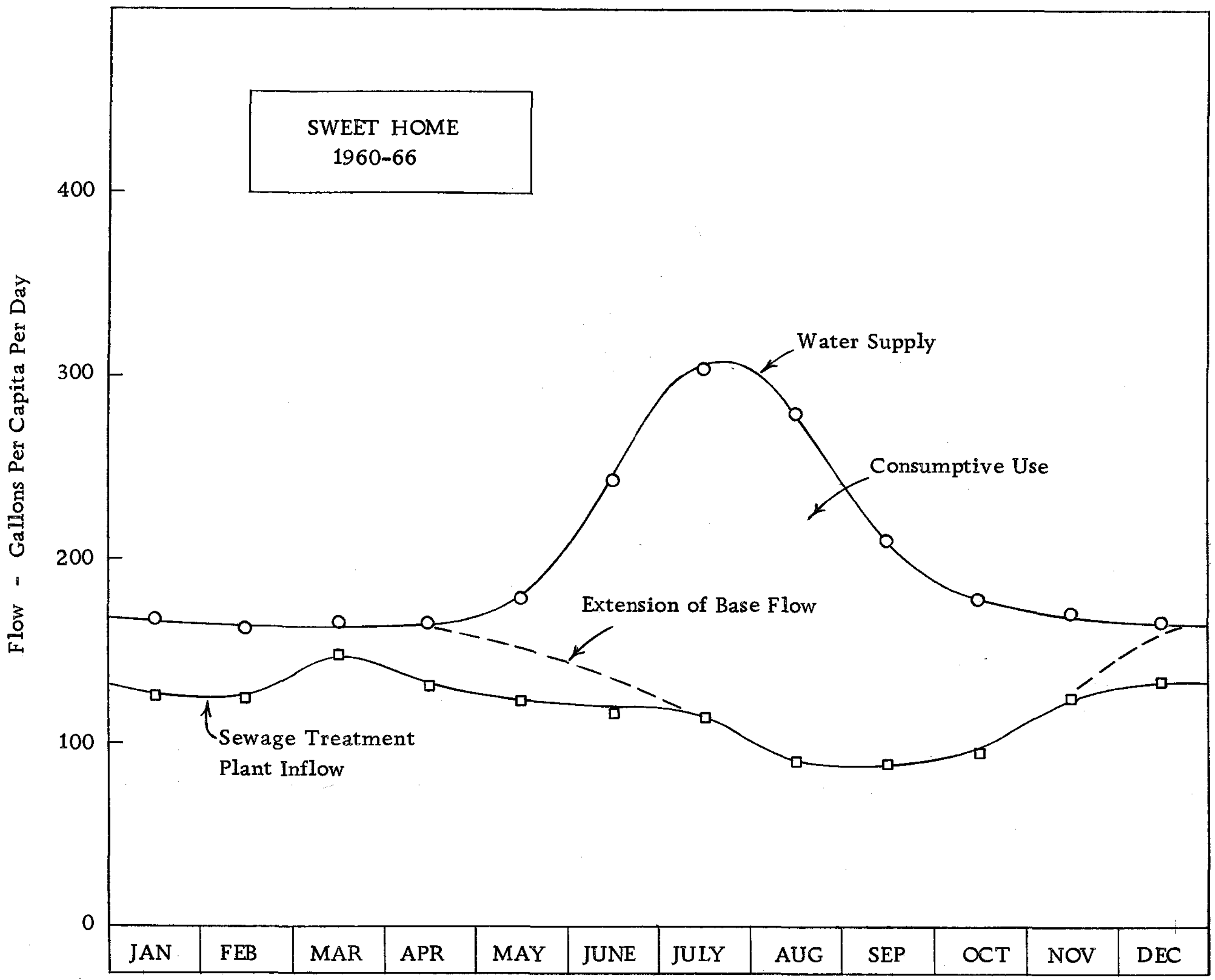

Figure 14. Annual Consumptive Use Pattern, Sweet Home, 1960-66.

hence the base flow (the effect of ground water seepage, neglected here, is considered later). To obtain the base flow for some cities, it was necessary to disregard the late summer surge caused by fruit and vegetable processing plant waste, which is a seasonal load and not a part of the year-round sanitary sewage base flow.

The assumed sanitary base flow (the late summer sewage flow) is in most cases nearly equal to the winter municipal water demand. This is to be expected since during the winter most of the water demand is used in normal residential, commercial, and industrial functions which are carried on the year around. These uses are such that nearly all of the flow finds its way into the sewer system, thus making up the sanitary base flow. Therefore the sanitary base flow lines shown on each of the preceding curves were constructed by drawing smooth curves (dashed) between the winter water demand points and the late summer sewage flows. This assumption is supported by the results of a study by Geyer _et al._ of coincident residential water and sanitary sewage flows in a Baltimore suburb (28, p. 6-8). An exception exists in the case of the Sweet Home curves (Figure 14). This will be discussed in detail later.

Three types of consumptive use factors were calculated from the curves: annual factors, five-month dry season factors, and monthly factors for each of the five dry season months (May through September). The annual factors were obtained by comparing the areas under the sanitary sewage base flow curves to the areas under the water supply curves for the entire year. The monthly factors were computed by comparing the mid-month base flows to the monthly average water supply flows. The five-month dry season flows were obtained by comparing the sum of the five monthly sewage base flows to the sum of the corresponding five monthly water supply values.[3]

In computing the consumptive use factors for Corvallis, Eugene, Forest Grove, and Salem, the late summer rise in the sewage curves was incorporated into the "base flow" curve. While these wastes are not a part of the base flow, they are a regular component of the summer waste flows returned to the streams and must be accounted for in estimating the consumptive use.

The consumptive use factors calculated for each of the situations described by the preceding curves are listed in Table 6.

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[3] The procedures listed above give the return flow percentages. The consumptive use factors were obtained by taking the complement of the return flow percentages (100% - return flow percentage = consumptive use factor).

Table 6. Consumptive Use Factors for the Period 1960-66, by City, in Percent Consumptive Use.

City	Annual Factor	5-Month Mean	Factors for the Five Dry Season Months					Reference
			May	June	July	Aug.	Sept.	
Corvallis	24	40	16	40	51	51	29	Figure 9
Eugene	33	49	27	56	62	54	36	Figure 10
Forest Grove	18	30	12	39	46	20	28	Figure 11
McMinnville	36	54	38	55	65	60	38	Figure 12
Salem	33	49	23	52	60	54	41	Figure 13
Sweet Home	34	52	16	44	62	57	58	Figure 14
Average[1]	27	44	18	44	55	49	38	Figure 15

[1] Values obtained from six-city average curve, Figure 15.

VI. EVALUATION OF RESULTS

Annual Patterns of Water and Sewage Flow Variation

Before examining in detail the various factors which affect the water demand and sewage inflows, the general shapes of the annual demand and inflow curves and their interrelationship will be considered.

Figure 15 shows the average sewage and water flows for the six cities for the period 1960-1966. It can be seen that the municipal water demand is fairly constant at about 150 gpcd from late fall until mid-spring (November through April). This demand represents the normal domestic, commercial, and industrial demand (or base demand) which would be experienced the year around. Once the growing season begins and the rainfall diminishes, the water demand curve begins to rise sharply, reaching a July-August peak of more than twice the winter base demand. This added demand represents primarily water used for irrigating lawns and home gardens and, as can be seen by comparison with the sewage inflow curve, is largely consumed. A lesser but also significant contribution to the summer peak is the water demand of food processing plants. Once the growing season is past and the fall rains commence, the demand tapers off, returning to the base flow in November.

Sewage treatment plant inflows exhibit an opposite trend and

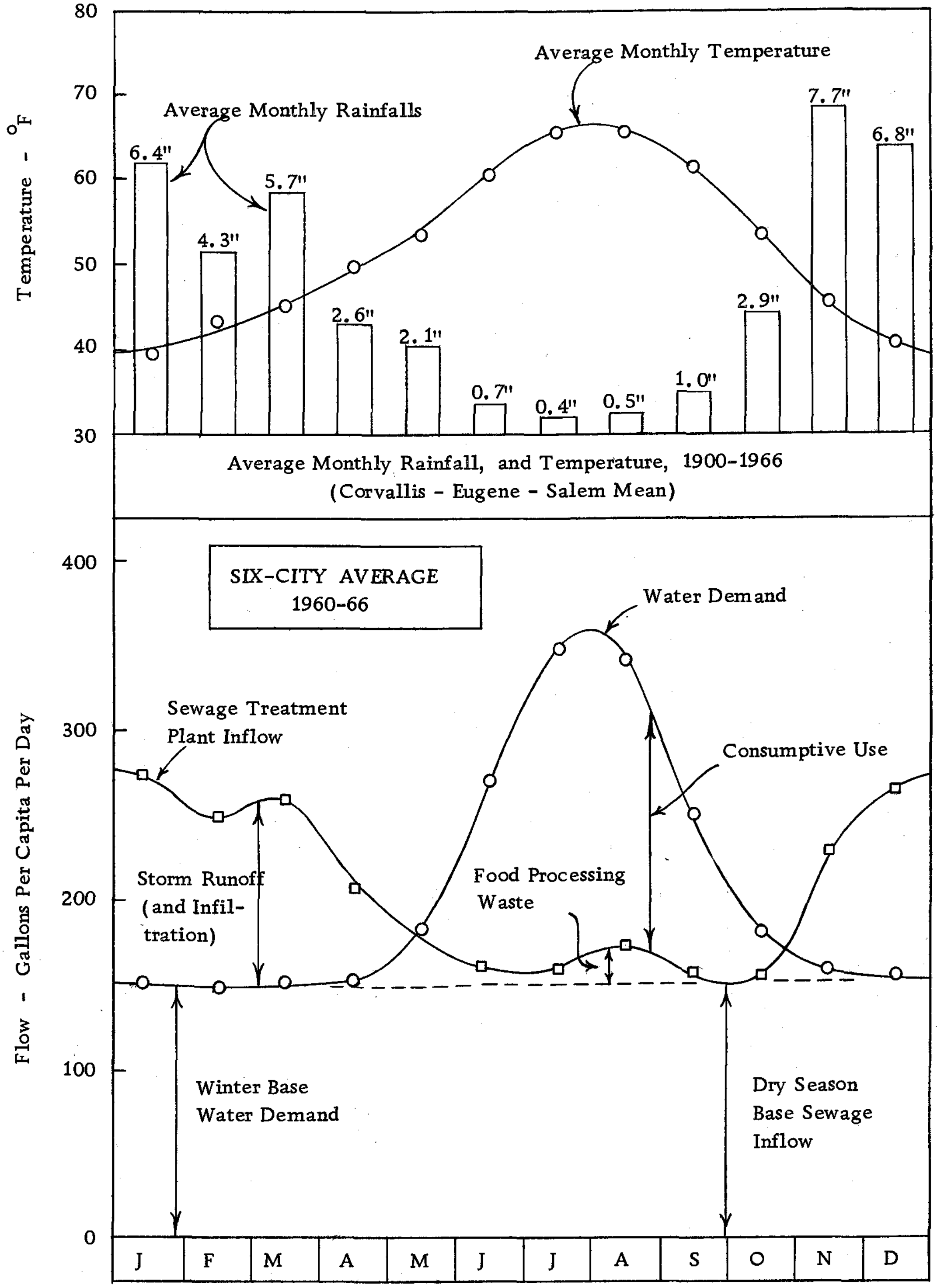


Figure 15. Six-City Average Consumptive Use Pattern and Corresponding Climatic Conditions, 1960-66.

are highest in the winter months, when they greatly exceed the water demand. This difference is mainly attributable to storm runoff and infiltration. As rainfall drops off in the spring, so does the sewage inflow curve. During the dry summer months, sewage inflow decreases to a low of about 150 gpcd. This flow corresponds very closely to the winter water demand. Both of these flows represent essentially the same volume, the city's "base flow".

The rise in the summer sewage inflow curve represents the added waste contribution of food processing plants. The late winter irregularity in the same curve is due to the fact that, over the seven year period of the study, the February average precipitation was lower than normal and the March average was higher than normal.

It can be said that, in general, the difference between the dry season water demand and sewage inflow curves represents consumptive use, and the difference between the wet season sewage inflow and water demand curves represents storm runoff.

Factors Influencing Consumptive Use

Weather

Weather is perhaps the most significant single factor influencing consumptive use as it has a direct effect on many of the other important factors. For example, storm runoff and infiltration are both dependent on rainfall; lawn watering is related to both rainfall and temperature; and temperature has a direct effect on the amount of water used for airconditioning.

Figure 16 shows the average water and sewage flows for the six cities for each of the years studied and describes the corresponding temperature and rainfall patterns. Also illustrated are the deviations of temperature and rainfall from the 1931-1960 normal for each of the five growing season months, April through September (the rainfall deviations were weighted inversely proportional to the normal monthly rainfalls to put the small summer deviations in perspective with the larger spring deviations).

While none of the years can be considered warmer than average, 1961 and 1966 were comparatively warm years and 1962, 1963, and 1964 were comparatively cool. The deviation of rainfall from normal is quite random, varying widely from month to month. Only 1963 had a significantly wet overall growing season, but 1960 and 1965 both had abundant rainfall in the early part of the season. Both 1964 and 1966 could be classified as drier than normal. It is interesting to note that, with the exception of 1964, all of the months of June were drier than normal. Generally speaking, however, the period studied did contain enough variations in weather to give a good overall picture of the climate.

As might be expected, the winter sewage inflow follows the

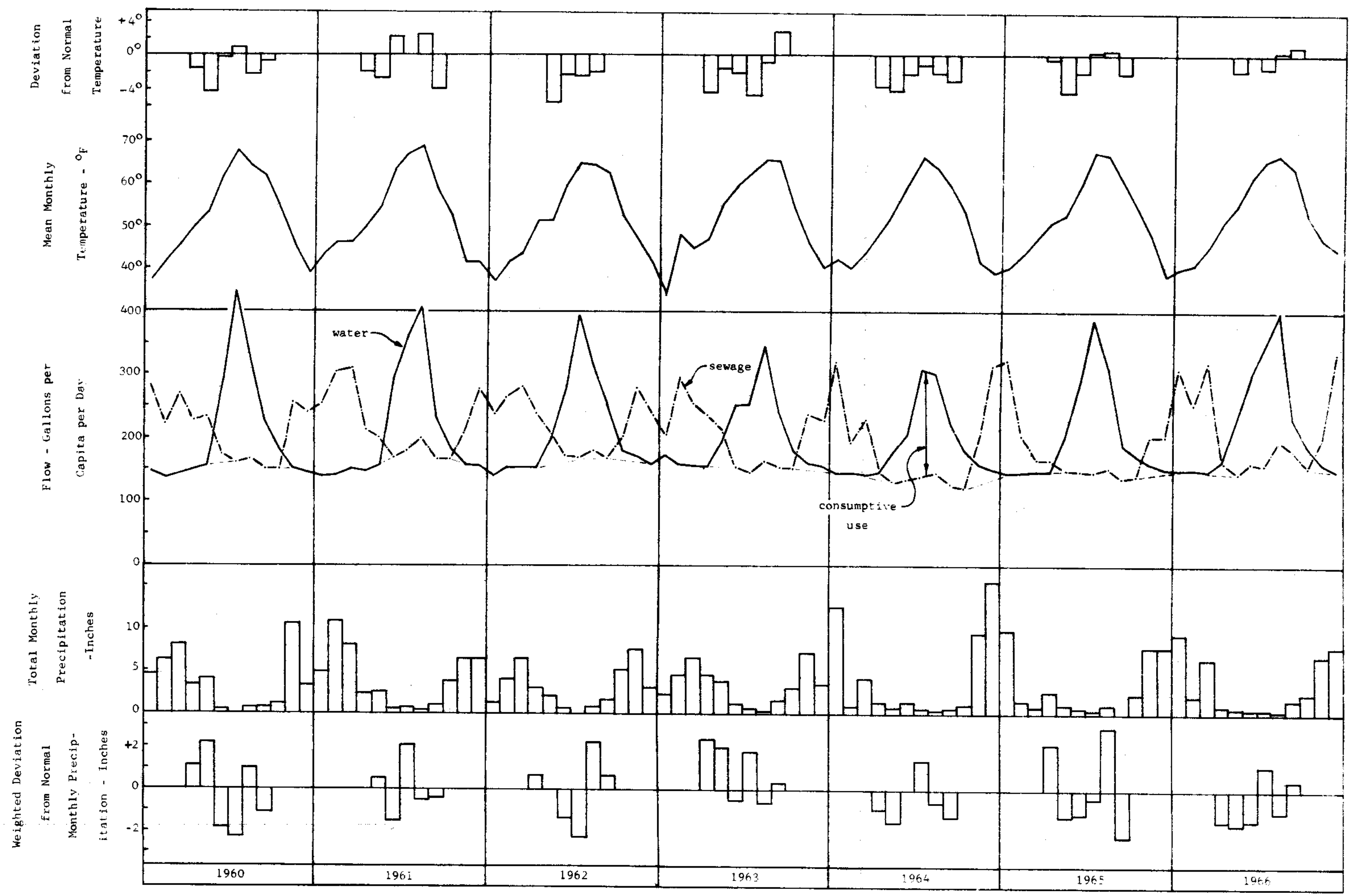


Figure 16. Effect of Weather Variation on Consumptive Use Pattern

precipitation pattern very closely, thus confirming the supposition that the difference between the winter sewage flow and the summer base flow consists mainly of storm runoff and infiltration caused by rainfall. During the summer there is not enough rainfall to cause any marked effects in the sewage inflows (it would be difficult to identify any small flow variations due to rainfall as they would be masked out by the food processing waste flows; however, summer sewage flows directly attributable to rainfall are comparatively insignificant).

Temperature has a marked effect on water use, and hence consumptive use. The shapes of the summer water demand curves generally follow the corresponding temperature plots. It can be seen that water consumption (and consumptive use) is lowest in two of the coolest years, 1963 and 1964. Interestingly enough, one of those summers was comparatively dry (1964), and the other was wet (1963). From comparing the water demand and weather characteristics of these two summers, it can be hypothesized that temperature has a greater effect on summer consumptive use than rainfall. This is reasonable since even during "wet" summers, rainfall in the Willamette Basin is not adequate to meet the water needs of growing plants (so a comparatively high summer rainfall would not have much effect on water demand). On the other hand, the warmer the weather, the greater the amount of water which is transpired by plants. Therefore it can be said that the lawn watering demand is influenced chiefly by temperature.

Although airconditioning water use is still comparatively small in the Willamette Basin, it is fairly easy to see how weather could affect this water demand. The warmer the weather, the greater the airconditioning load, hence, the greater the water demand.

The preceding discussion applies to the effect of variations in weather within a single climatic unit, the Willamette Basin. However, variations in climate would produce the same effect on the consumptive use pattern. For example, an area with hot, dry summers would have a higher average consumptive use than one with cool, wet summers.

Storm Runoff

Storm runoff makes up a large percentage of wet season sewage treatment plant inflow from combined sanitary and storm sewer systems. The McMinnville system provides a good example of this (see Figure 12). A portion of the storm runoff may not be recorded, as many plants must bypass flows in excess of their capacity during periods of heavy runoff.

While separate storm and sanitary sewer systems are supposed to relieve the sewage treatment plants of having to process storm runoff, unauthorized connections and inadequately sealed manhole covers can bring significant quantities of storm runoff into sanitary sewers. In some older areas it has been impractical to replace existing combined sewers with separate ones, and additional storm runoff is brought into the treatment plant in this way. Salem and Eugene are, for the most part, served by separate sewer systems. But as can be seen on Figures 10 and 13, a certain amount of winter sewage inflow in excess of the water demand is experienced. It is assumed that this is mainly storm runoff, along with some sewer infiltration.

In the calculation of consumptive use, storm runoff does not pose much of a problem. As described previously, an approximate estimate of the storm runoff volume (along with wet season infiltration) can be made by assuming the sanitary sewage inflow to be equal to the winter base water demand and the balance of the sewage inflow to be storm runoff. This is illustrated by Figure 17. Actually, very little storm runoff normally occurs in the Willamette Basin during the period of greatest interest, May through September.

Sewer Infiltration

Ground water finds its way into sewers through cracks in pipes and through joints and manholes that are not watertight. The amount of infiltration depends upon

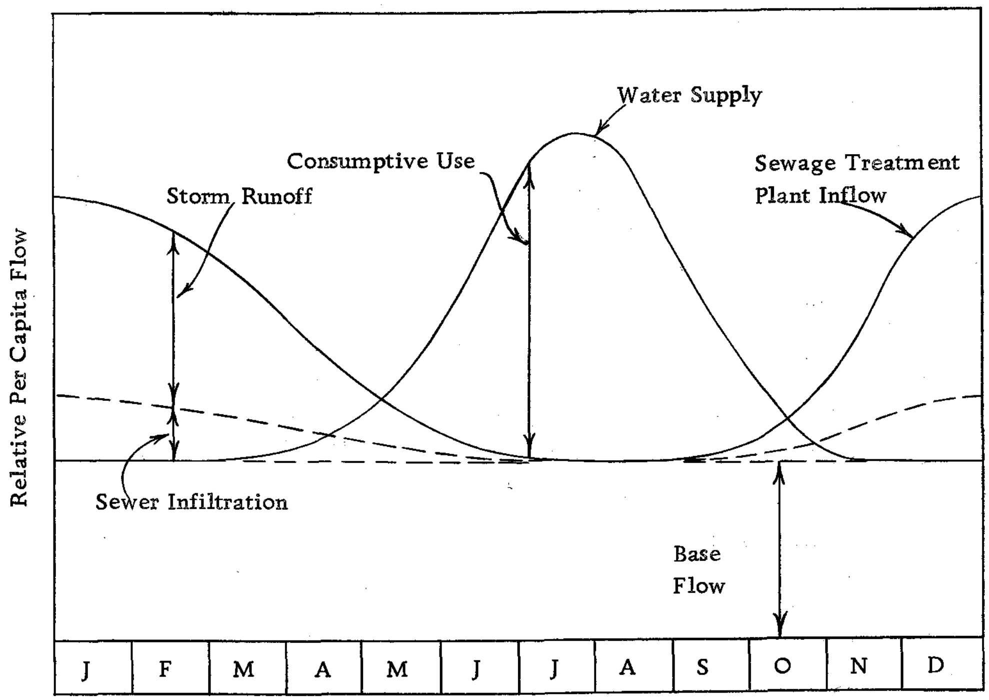


Figure 17. Separation of Storm Runoff and Sewer Infiltration from Total Sewage Inflow.

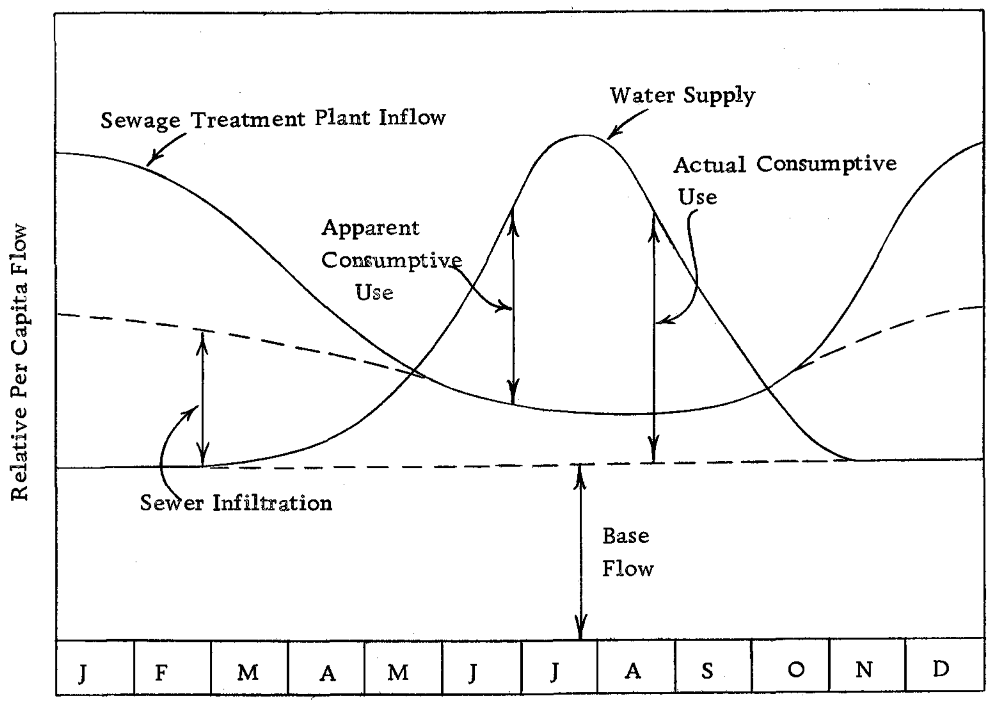


Figure 18. Effect of Large Sewer Infiltration Volumes on Consumptive Use Pattern.

a. the height of groundwater table above the sewer invert

b. the workmanship exercised in the installation of the sewers and the building connections

c. the permeability of the soil.

In some areas, infiltration allowances of up to 300 gpcd must be made in sizing sewers (27, p. 21). In the Willamette Basin, infiltration is greatest in the winter, when rainfall is heavy and the groundwater table is high. Locally, infiltration would be greatest in low areas, especially where the sewers are near streams or other water bodies. Nearby water main leaks could also contribute.

Since most infiltration occurs in the rainy season, it would probably show up as a portion of the storm runoff component on the curves. That portion which occurs during the summer would be included as a part of the sewage base flow. However it should be noted that during the dry season, when the water table is low, water could leak out of the sewers also. Summer infiltration is generally considered low in the Willamette Basin and can be neglected whenever the dry season sewage base flow is approximately equal to the winter base water demand. Figure 18 illustrates the effect of unusually large year-around sewer infiltration on the consumptive use pattern.

Unaccounted-For Water Losses

A discrepancy nearly always occurs between the amount of water supplied to a city system and the city's metered consumption. This discrepancy is referred to as the unaccounted-for system loss. Some of the most common contributors to the unaccounted-for loss are discussed below.

Leakage. Distribution system leakage is one of the largest unaccounted-for losses. Although to some extent unavoidable, it can be minimized through a careful inspection and maintenance program. Some factors affecting the amount of system leakage are (2):

a) age of the system

b) system operating pressure

c) per capita use per mile of main

d) quality of materials and workmanship

e) ground conditions.

Part of the leakage eventually returns to surface waters and could therefore be classified as a consumptive loss only on a short-term basis. Where sewers are located close to the water mains, leakage may reach the sewers and thus would not appear to be consumed at all.

Meter Error. A second important contributor to the discrepancy between water supplied and water sold is meter error. Meters generally have a tendency to underregister. That tendency increases with age and is most pronounced at low flows (37, 41). According to an American Water Works Association committee report (2), meter error ranges from 2 to 15 percent, but can be kept below 3 percent with periodic maintenance. Although individual customer meters are usually the main source of error, the master supply meters are also subject to error. Meter error is not a true water loss, consumptive or nonconsumptive, but it can mean a loss in revenue to the utility.

Hydrant Use. Although not normally metered, significant amounts of water can be drawn from fire hydrants for fire fighting, street washing, main testing and flushing, and hydrant testing. According to a study of Indianapolis by Niemeyer (48), these uses consume less than 1.5 percent of the total water supplied. With the possible exception of fire fighting, these would be nonconsumptive uses where sewers are available to collect the flows.

Park Irrigation. Where a city owns its water system, unmetered water is usually supplied for irrigating municipal parks (41). Water used in this manner would be considered to be used consumptively.

Theft and Unauthorized Use. Occasionally, unauthorized unmetered connections are made to city water mains. In other cases, water is used from unmetered connections for unauthorized purposes. An example of the latter was recently found in a Willamette Basin city, where a large industrial user withdrew large quantities of water from an unmetered industrial fire protection system.

Losses of this type could be either consumptive or nonconsumptive depending on the circumstances.

Operational Waste. A certain amount of water is lost in the operation of water treatment plants. Although largely nonconsumptive, these losses normally would not be counted as they usually occur above the master supply meter (48).

Unaccounted-for water loss ratios are computed by comparing the unaccounted-for loss volume (the gross volume supplied minus the volume sold) to the gross volume supplied to the city. Table 7 lists the average unaccounted-for loss ratios calculated for the cities studied (supporting data may be found in Appendix IV). It is interesting to note that Eugene, which has a self-supporting semi-independent water system, has by far the lowest loss ratio of the cities studied. Forest Grove, with an average unaccounted-for loss of 16.4 percent for the seven-year period, has gradually reduced its loss from 25.2 percent in 1960 to 3.3 percent in 1966. On the other hand, Dallas was eliminated from this study because it suffered unaccounted-for losses in excess of 50 percent (18, 19).

By way of comparison, Kuehlthau, in a study of Wisconsin municipal systems, found unaccounted-for losses ranging from 0 to 50 percent (41). The American Water Works Association states that a good performance is indicated by loss of 10-15 percent, or less where large industrial demands cause higher per capita use

Table 7. Percent Unaccounted-for Loss, by City.

City	1960	1961	1962	1963	1964	1965	1966	Mean
Corvallis	24.8	22.7	25.2	26.2	21.3	25.3	--	24.2
Eugene	3.4	--	4.1	4.0	2.7	1.8	6.7	3.8
Forest Grove	25.2	23.4	27.5	20.0	15.0	0.0	3.3	16.4
McMinnville	20.4	17.8	25.5	26.2	--	25.5	--	23.1
Salem	19.8	18.3	24.8	33.3	28.0	27.4	23.7	25.0
Sweet Home	--	28.7	--	--	--	--	--	28.7

rates (2).

The characteristics of the various unaccounted-for losses are listed in Table 8. Although the unaccounted-for losses are comparatively large for most of the cities studied, they do not affect the consumptive loss pattern very much. Meter error, the largest contributor, is not actually a loss at all, and that portion of leakage which seeps to adjacent sewers is not consumed. Park irrigation, however, could have some influence on the summer consumptive use where a city maintains sizeable parks.

Lawn Watering

Residential lawn watering (which also includes the watering of flowers, shrubs, and vegetable gardens) is the largest single source of municipal consumptive water loss. As the quantity of water required for normal domestic or household purposes within a home remains essentially constant throughout the year, most of the difference between summer and winter use in residential areas is attributable to lawn watering (43, p. 9).

In contrast to water used for normal household purposes (which is mostly returned to sewers and is hence nonconsumptive), lawn watering is almost completely a consumptive use. Part of the water applied to lawns evaporates immediately; most of the remainder seeps into the ground where it is consumed by plants in the

Table 8. Summary of Unaccounted-For Losses.

Type of Loss	Relative Size of Loss	Nature of Loss	Time of Year When Loss is Incurred
Hydrant Use			
Fire Fighting	small	mostly consumptive	year around
Street Washing	small	mostly nonconsumptive	mostly in summer
Main and Hydrant Flushing and Testing	small	mostly nonconsumptive	year around
Park Irrigation	varies	consumptive	mostly in summer
Meter Error	large	not a loss	year around, but greatest percentage-wise in winter when meter flows are low
Leakage	large	both	year around
Unauthorized Use	varies	varies	year around

process of evapotranspiration. A small amount may find its way to sewers or surface waters as surface runoff or ground water, but this quantity is comparatively small (43, pp. 14-15). The influence of lawn watering on the consumptive use pattern is illustrated by Figure 19. Figure 21 shows the summer-peak effect that lawn watering has on the residential water consumption pattern of Salem, a typical Willamette Basin city.

Linaweaver, Geyer, and Wolff found that the annual lawn sprinkling demand of 10 western residential areas averaged 186 gallons per day per dwelling unit, or approximately 50 gpcd, based on an average population density of 3.8 persons per dwelling (43, pp. 7, 21). By assuming the entire demand in excess of the winter base demand to be used for lawn watering, the average annual consumption for the six Willamette Basin cities studied was found to be about 55 gpcd. Adjustments for the summer peak demands of the food processing industry (Figure 25) and other industrial and commercial installations would tend to bring the Willamette Basin average closer to the 50 gpcd found by Linaweaver _et al_.

Figure 20 shows the cumulative net lawn watering requirement based on an average lawn watering requirement of 1.5 inches per week and cumulative normal mean annual rainfall data for Corvallis, Eugene, and Salem (33, p. 466; 73, p. 11; 75). Based on an average lawn area of 3500 ft^2 per home, a population density of three people

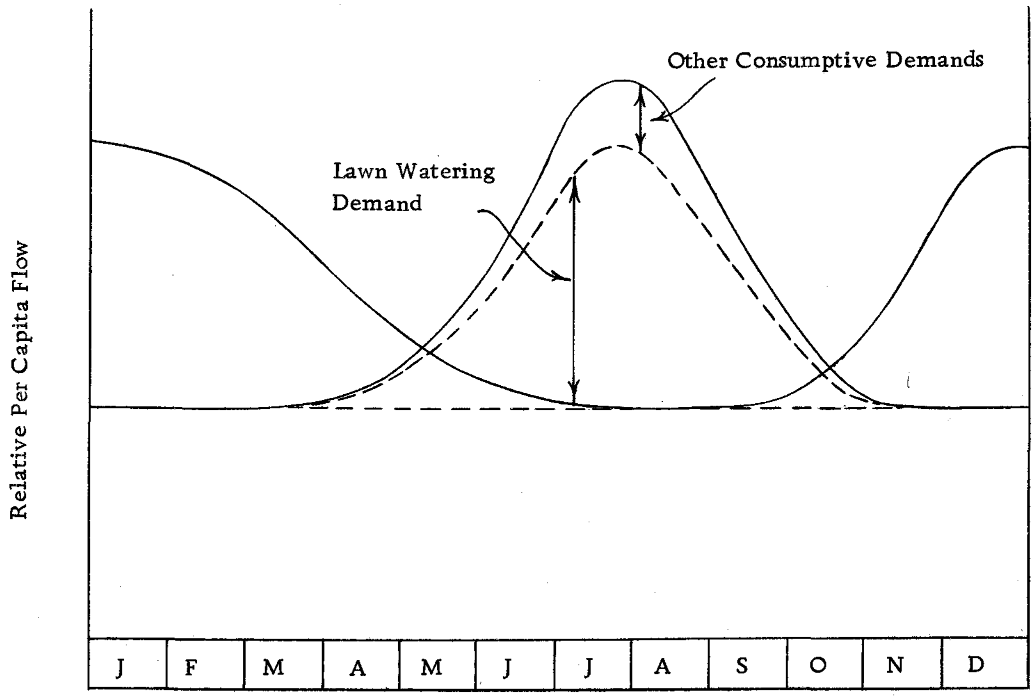


Figure 19. Effect of Lawn Watering on Consumptive Use Pattern.

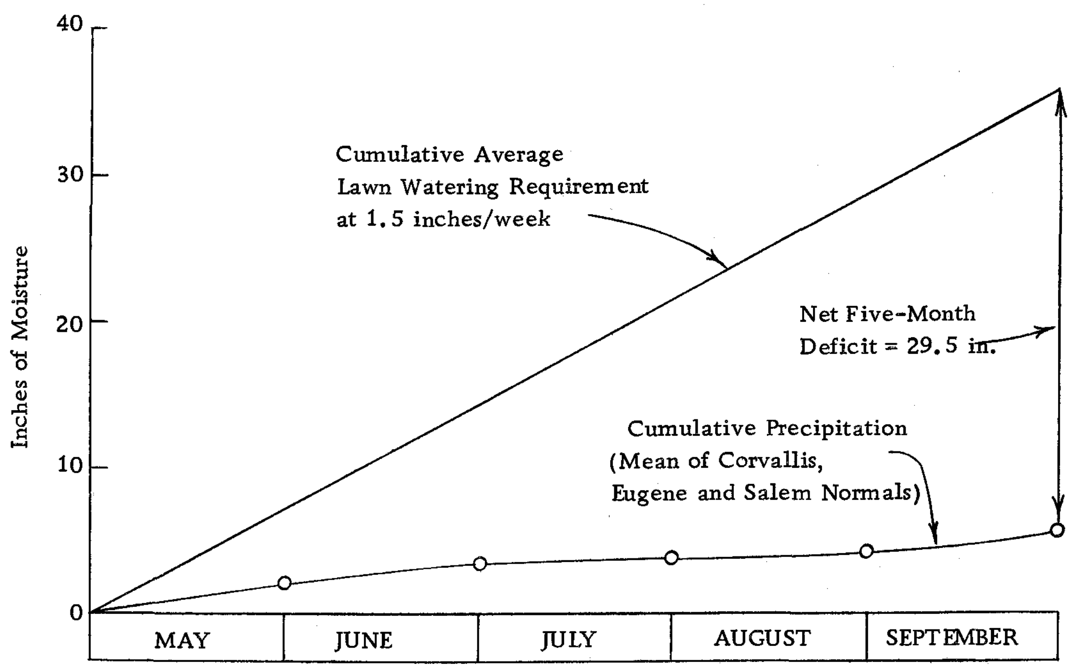


Figure 20. Cumulative Lawn Watering Requirement and Moisture Deficit.

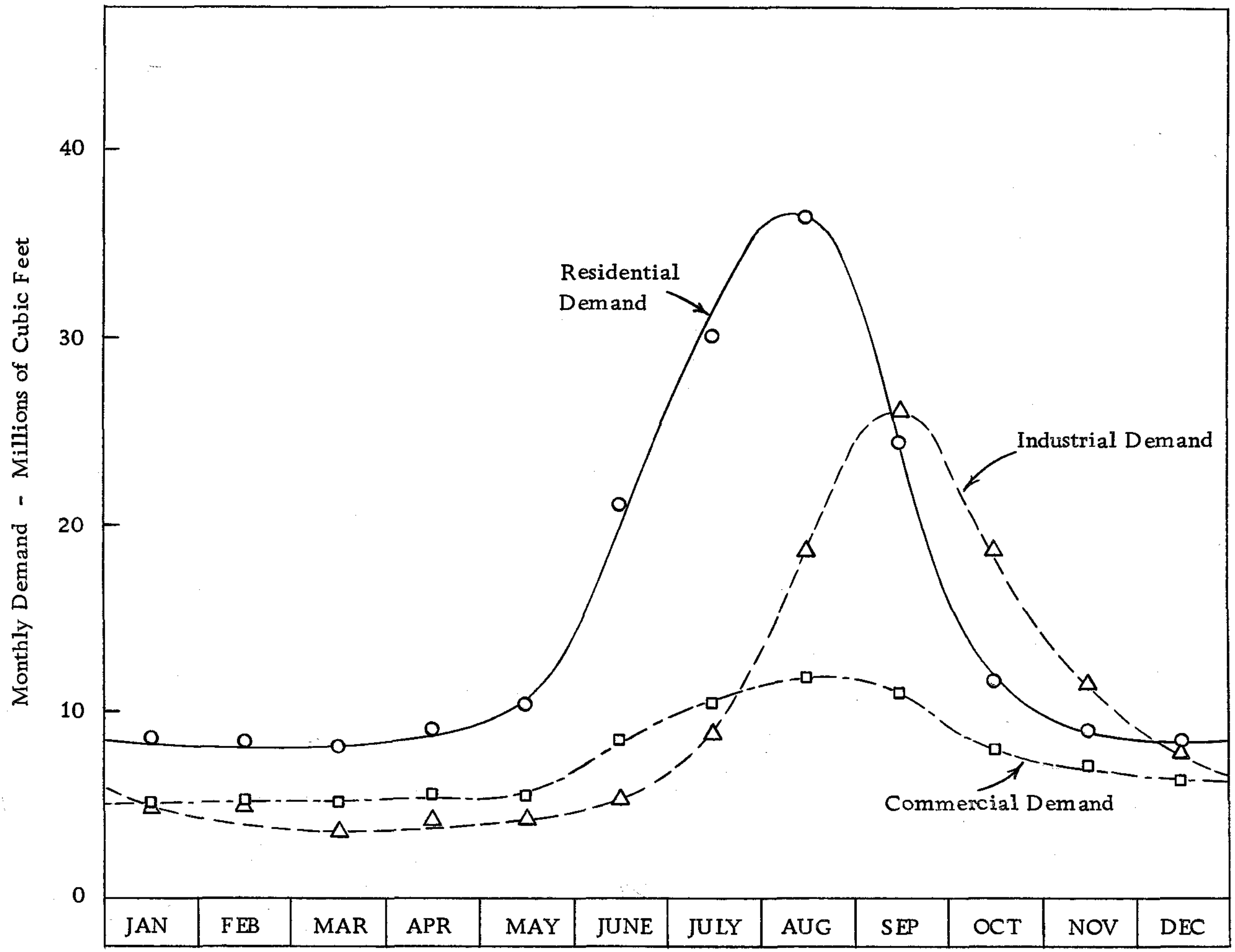


Figure 21. Average Monthly Residential, Industrial, and Commercial Demands, Salem, Oregon, 1960-66.

per household, and an April-September growing season, the average annual lawn watering requirement would be about 63 gpcd (73, p. 11). This is somewhat higher than the 55 gpcd observed, but it has been found that most people do not give lawns as much water as they could use (33, pp. 462-477; 43, pp. 32-43). This is evidenced by the fact that midsummer lawn watering always drops sharply after a rain, even when the total precipitation is insignificant with respect to a lawn's water needs. In some areas, an inadequate source of water supply may force curtailment of lawn watering. This was an important factor in Forest Grove, which has a comparatively small summertime consumptive loss (Figure 11).

Although the majority of summertime consumptive loss is due to lawn watering, smaller amounts are due to car washing, maintaining swimming and wading pools, and the use of evaporative air-conditioning equipment (43, pp. 53-54).

Airconditioning

Although airconditioning is not used as widely in the Willamette Basin as it is in many parts of the country, it is finding increased use, especially in offices and stores. In parts of the country, the widespread use of certain types of airconditioning equipment has made it difficult for city utilities to meet their daily peak water demands. Different types of water-using airconditioning systems affect the consumptive use of water in different ways.

Evaporative Cooling. This is the simplest type of airconditioning. Air is circulated over or through a wet medium and is cooled when heat is extracted from the air to evaporate the water (1, pp. 644-646). Since evaporation takes place, water supplied to this type of unit is consumptively lost. This type of cooling can be used effectively only where the relative humidity is quite low, and finds widest use in the Southwest and in the Northwest east of the Cascade Mountains. A variation of evaporative cooling, roof flooding or sprinkling, is used to some extent in the Willamette Basin.

Condenser Type. This system uses some type of evaporative medium circulated through coils to cool the air. Heat is extracted from the evaporative medium in a condenser, which may be air or water cooled (1, pp. 561-578). In many types of water cooled condenser installations, city water is passed through only once and then wasted to the sewer. While water used in this type of system is not consumed, it is often required in large volumes. If a water utility has a large number of these units operating in its system, its ability to meet other demands during hot summer days will be severely hampered. For this reason many utilities have placed rate surcharges on customers using once-through cooling to encourage the use of conservative cooling systems. A typical water-conserving cooling system would utilize a cooling tower, which enables the condenser cooling water to be recirculated. A comparatively small percentage of additional water is required to make up evaporation losses. Water used by a system of this type would of course be consumed. It is expected that both once-through and conservative systems can be found in the Willamette Basin.

Since the use of airconditioning in the basin is still limited, the quantities of water required are relatively small. Therefore airconditioning would have very little influence on the municipal consumptive use pattern. Nevertheless, attention should be given to this factor in future studies of this type. Figures 22 and 23 show how sizeable airconditioning water demands could influence the consumptive use pattern.

Industrial and Commercial Use

The percentage of a water system's demand that is supplied to industrial water users has a significant effect on the magnitude of consumptive use ratios. As was noted, industrial water use is largely nonconsumptive (6; 46; 77, p. IV-4). Figure 24 illustrates the relative effect which a large and a small constant industrial demand would have on the consumptive use ratios. Several special cases which appear to be consumptive from the standpoint of this study are discussed in the next section.

The two major industrial water-users in the Willamette Basin

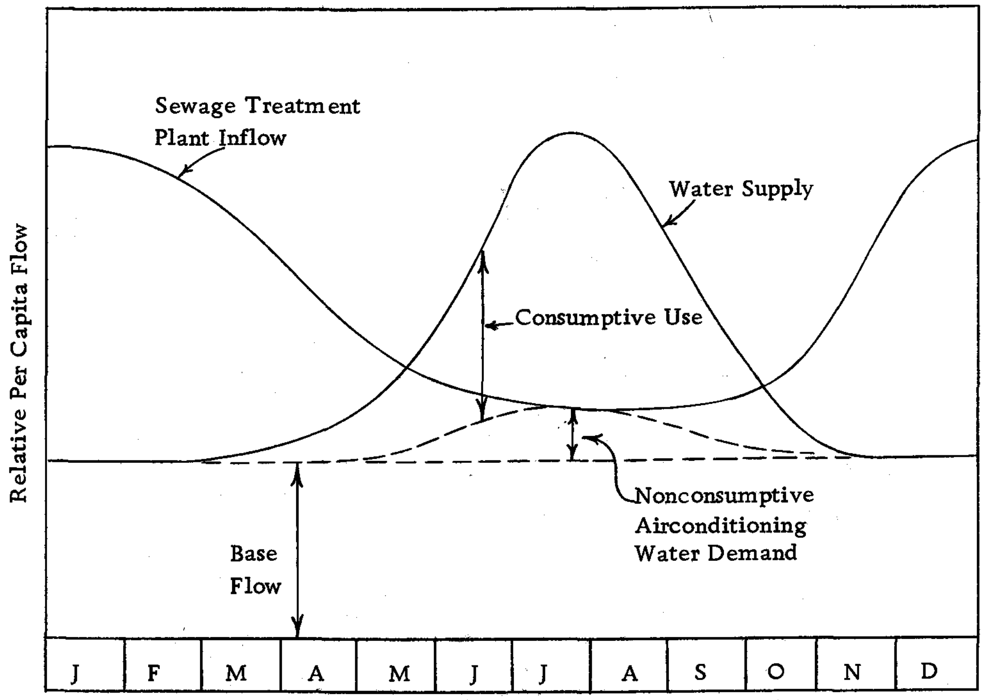


Figure 22. Effect of Large Nonconsumptive Airconditioning Demand on Consumptive Use Pattern.

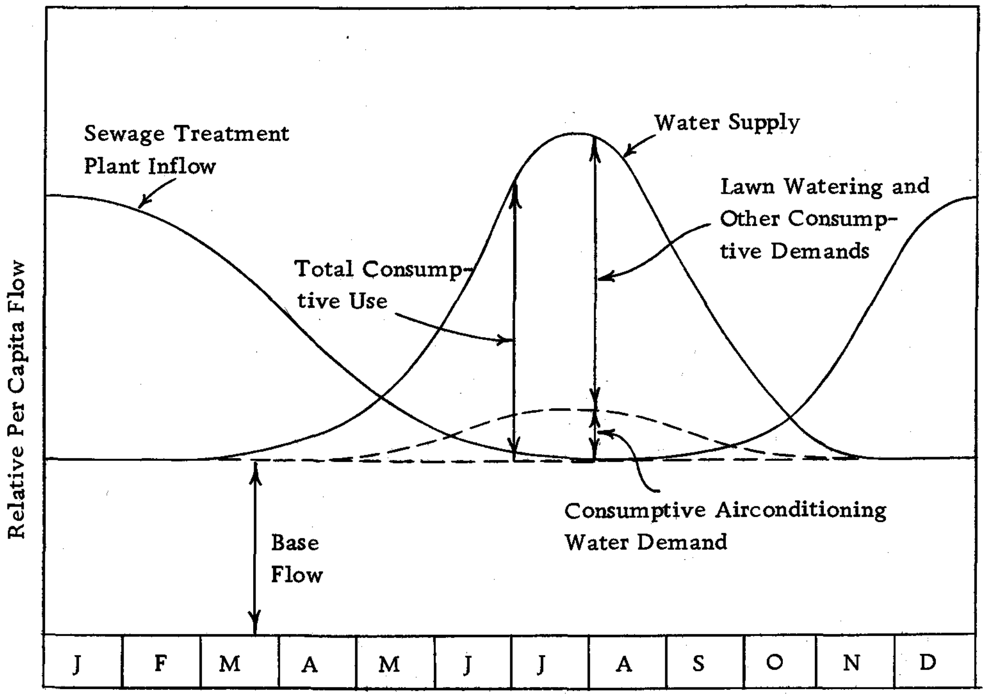
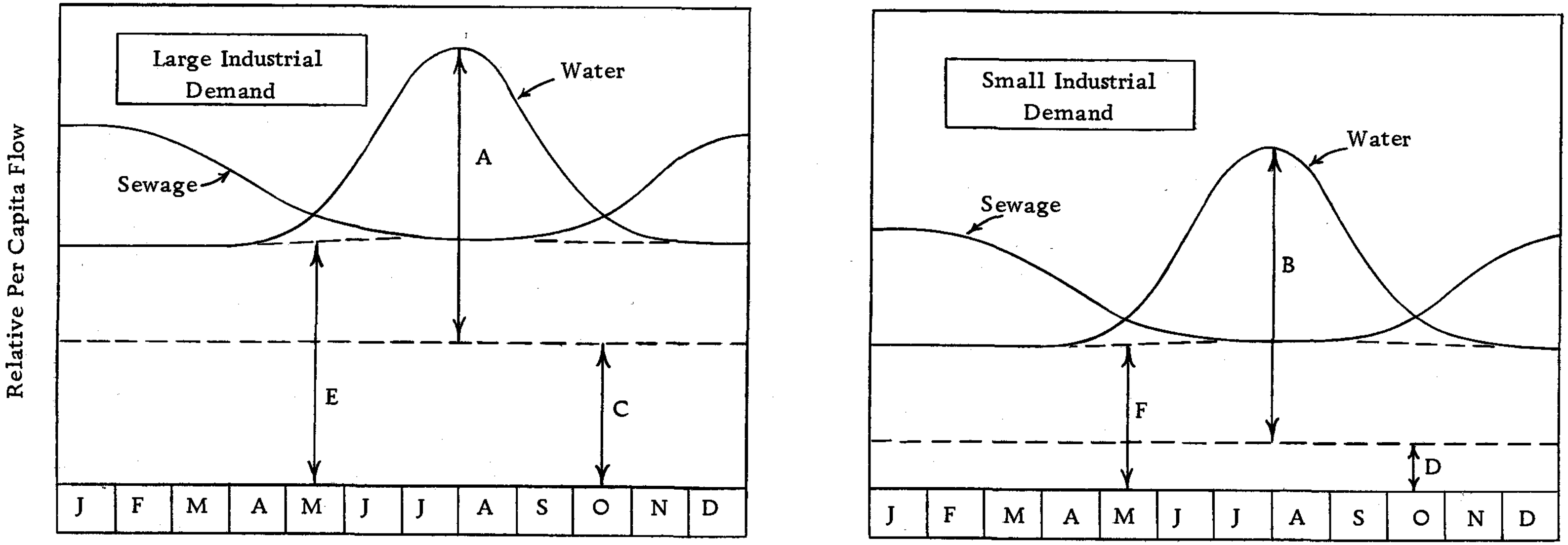


Figure 23. Effect of Large Consumptive Airconditioning Demand on Consumptive Use Pattern.



A, B = residential and commercial demands

C, D = industrial demands

E, F = base flows

where A = B

C $\gg$ D

Comparing the consumptive use ratios:

$$\frac{(A + C) - E}{A + C} < \frac{(B + D) - F}{B + D}$$

The ratio for the city with the large industrial demand is smallest.

Figure 24. Effect of Industrial Water Use on Consumptive Use Pattern and Consumptive Use Ratio.

are the wood products and food processing industries. The demand of the wood products industry is fairly constant throughout the year, but the water demand for food processing varies from almost no demand in February and March to a peak in late summer. The annual industrial water consumption curve for Salem, a city having a large food processing industry, illustrates this variation (Figure 21). Water used in food processing is largely nonconsumptive. The effect that this has on the consumptive use pattern is illustrated by Figure 25. The characteristic summer hump in the sewage inflow can easily be seen on the Corvallis, Eugene, Salem, and Forest Grove curves (Figures 9, 10, 11, and 13). Regardless of whether an industrial demand is constant over the year or seasonal, the general tendency is that the larger the relative industrial demand, the smaller the consumptive use ratio.

A city's commercial water demand, although normally relatively small compared to the residential and industrial demand, would be largely nonconsumptive in the absence of an appreciable airconditioning load (6). Thus, the commercial demand would have the same general effect on the consumptive loss ratio as the industrial demand. The Salem commercial demand curve (Figure 21) shows that a definite summer peak is reached, although less marked than the residential and industrial peaks.

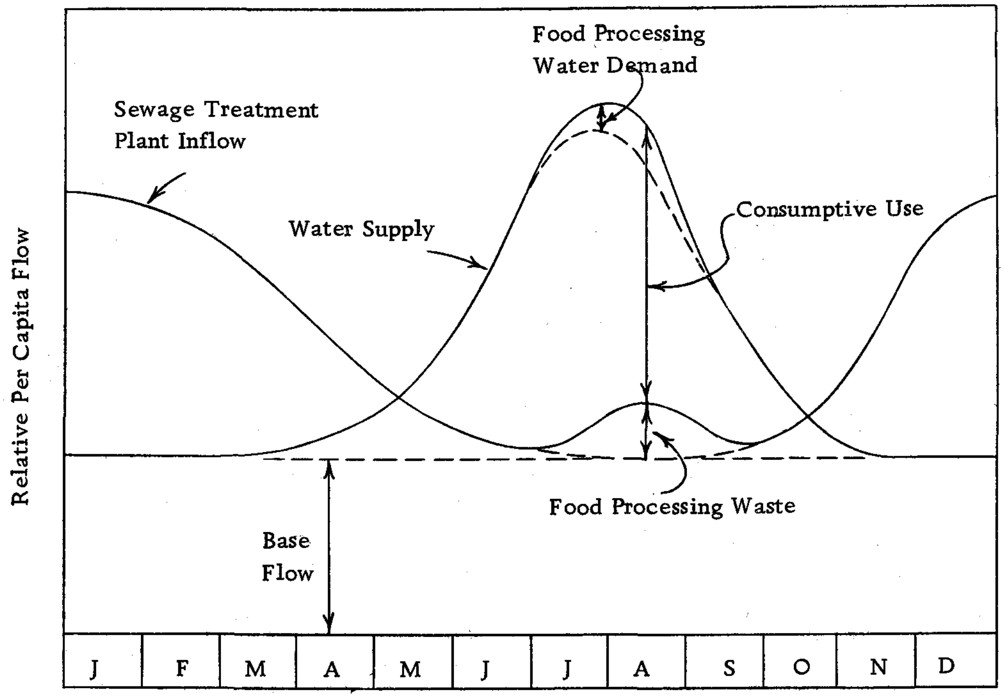


Figure 25. Effect of Seasonal Food Processing Industry on Consumptive Use Pattern.

Customers Not Served by Both Utilities

In most cities there are a few water customers who are not served by sewers, and occasionally there is a sewer customer who has his own water supply. The more common situation of the two is that where municipal water customers are not served by sewers. This can arise for a number of reasons:

a) sewer construction has not kept up with water service hook-ups

b) it is impractical or impossible to serve some areas within the city with sewers

c) water customers are served outside of the city limits

d) large industrial water-users prefer or are required to treat their own waste.

The first two factors are usually unavoidable and will be present to some extent in nearly any municipal system. Many cities now require that sewers be in place before annexations will be approved. On the other hand, cities are sometimes forced to annex adjacent areas so that sewers can be installed to relieve unsafe sanitation conditions. Listed below are the percentages of households not served by sewers as calculated from data from the 1960 census (64):

Corvallis	1.4%
Eugene	not listed
Forest Grove	12.6%
McMinnville	6.3%
Salem	3.2%
Sweet Home	17.7%.

While the third factor listed above (water service outside the city limits) could cause difficulties in computing consumptive use factors, for most of the cities studied it was not a problem. Salem and Eugene sell only to incorporated cities or water districts, and records are available which enable these out-of-town demands to be deducted. With the exception of Corvallis' Philomath customers, which are easily corrected for, comparatively few out-of-town customers are served by the Corvallis, Forest Grove, and McMinnville systems. In Sweet Home, however, out-of-town accounts totalled 111 in 1961, representing possibly 300 to 400 people served in addition to the municipal population of 3,630.

Some large industrial water users, notably pulp and paper mills, are required to process their own waste. Lumber mills sometimes utilize the waste from certain processes, such as debarking, to supply make-up water for their log holding ponds. While these water users often provide their own water supply, in some cases they utilize city water, and that portion of the waste which is not returned to the city sewers shows up as a consumed loss, although not actually consumed at all. The Boise-Cascade pulp mill in Salem, for example, is the city's largest single water-user, but processes all of its own industrial water. This could account for Salem's base sewage flow being somewhat lower than the winter base water demand (Figure 13).

The overall effect of the consumptive use pattern of having large numbers of customers served with city water but not connected to sewers is illustrated by Figure 26. Sweet Home (see Figure 14) provides a good example of a situation where all of the factors discussed above appear to be present. In 1960, 17.7 percent of its residential population was not on the sewer system. In 1961 it served an unsewered population outside of its city limits equal to about 10 percent of its own population. And it is very probable that some of the city water supplied to the lumber mills located in Sweet Home is wasted to their log ponds. These factors combine to give a gpcd summer sewage base flow that is barely half of the winter base water demand. It is interesting to note that at no time during the year does Sweet Home's average gpcd sewage inflow exceed the water demand. This is due partly to the fact that a portion of the high winter sewage inflows bypass the treatment plant.

The problem of customers served by sewers but not by water is not as significant. As is illustrated by the following table listing

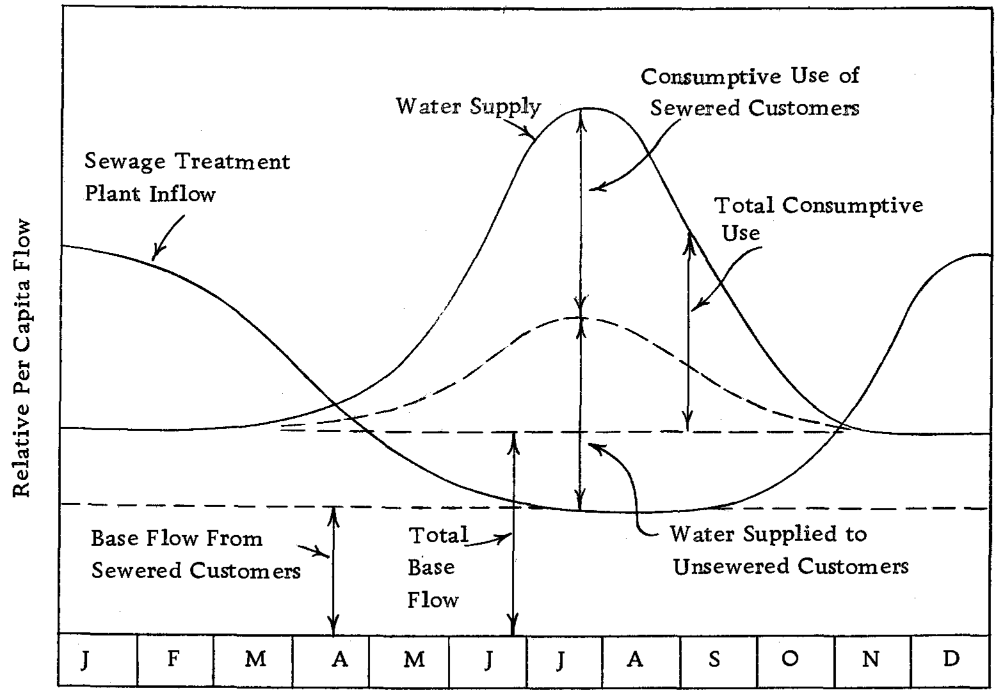


Figure 26. Effect on Consumptive Use Pattern of a Large Percentage of Unsewered Municipal Water Users.

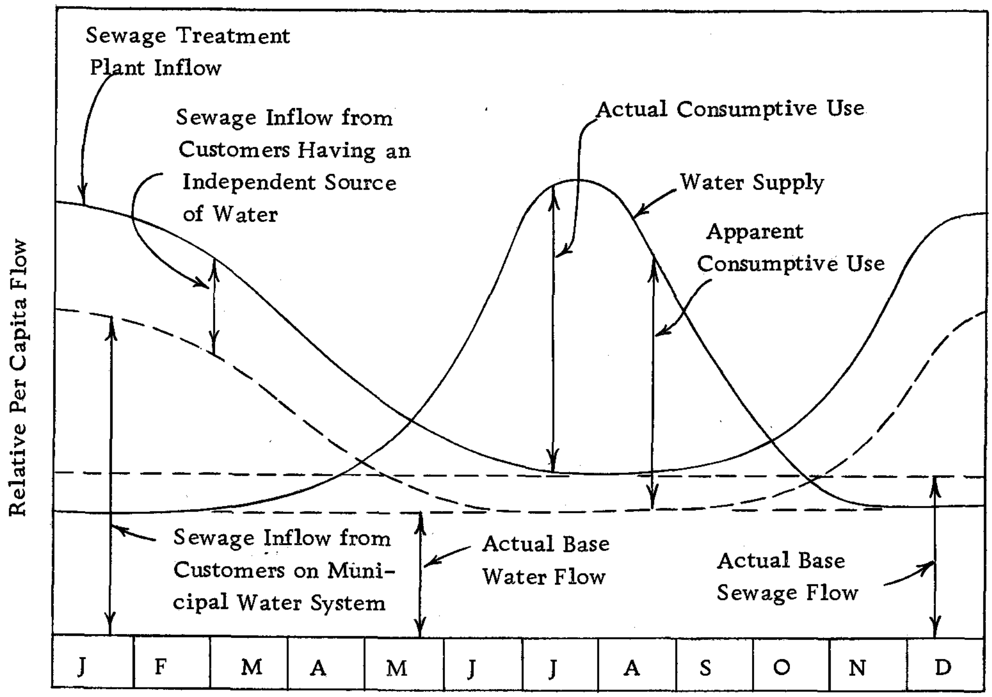


Figure 27. Effect of a Large Number of Customers on Sewer System Who Do Not Obtain Their Water from the Municipal System.

the percentages of dwellings served by city water in 1960, very few city residents did not receive city water (64).

Corvallis	99.8%
Eugene	not listed[4]
Forest Grove	100.0%
McMinnville	99.2%
Salem	99.0%
Sweet Home	98.7%

Occasionally, however, a self-supplied industrial water user may find it advantageous to dispose of his waste through a city sewer system. The effect of this is illustrated by Figure 27.

In the calculations made in Chapter V it was assumed that the number of people served by the municipal sewer and water systems was approximately equal to the city's estimated population. It can be seen from the data presented above that this assumption is valid for McMinnville and for Corvallis and Salem once their out-of-town water demands are deducted. Although the data sources referred to do not list the percentages of Eugene's population served by the municipal water and sewer systems, it can reasonably be assumed that virtually 100 percent of its population is served by city water and at least 90-95 percent is served by sewers. Therefore, the

[4] Should be very close to 100 percent.

assumption made in Chapter V is reasonably accurate for Eugene also, providing the demands of its suburban water districts are deducted. For Forest Grove, the assumption is valid with respect to the water system but marginal with respect to the percentage of the population served by the sewer system (however, it can be seen from Figure 11 that Forest Grove still has a high per capita sewage inflow). For Sweet Home, the assumption is not valid. Nearly 20 percent of the city's dwellings are unsewered, and a large number of unsewered out-of-town customers are served with city water. An attempt to adjust for these discrepancies is described in the next section of this chapter.

Summary

The major factors influencing the consumptive use pattern are summarized in Table 9. Of the items listed, household, industrial, and commercial water use and lawn watering have the greatest influence on the dry season consumptive use ratios developed in this study. Storm runoff and infiltration, while important contributors to winter sewage flows, would not normally be significant during the dry season. An exception could occur in an area where substantial infiltration occurs even during the dry season. Flows attributable to customers not served by both utilities could cause problems but it is usually easy to correct for this.

Table 9. Factors Affecting Consumptive Use Pattern.

Factor	Effect on Flows	Consumptive or Nonconsumptive Use?	Effect on Consumptive Use Ratio	Relative Importance in Willamette Basin
Storm runoff	increases winter sewage flows	--	none	major (in winter)
Sewer infiltration	increases sewage flow, especially in winter	--	very little unless summer infiltration is high	major (in winter)
Sewage flowmeter error	none	--	could increase or decrease	normally minor
Unaccounted-for water loss				
-- customer meter error	none	not really a loss	none	common but minor
-- master meter error	none	not really a loss	usually decreases	normally minor
-- leakage	increases water demand	apparently consumptive	increases (very little)	probably minor
-- hydrant use	increases water demand	either or both	increases (very little)	minor
-- park irrigation	increases summer water demand	consumptive	increases	usually minor
-- unauthorized use	increases water demand	either or both	normally very little	usually minor
Lawn watering	increases summer water demand	consumptive	increases	major
Car washing	increases water demand	mostly consumptive	increases	relatively minor
Airconditioning				
-- evaporative	increases summer water demand	consumptive	increases	minor
-- nonconservative*	increases summer water demand and sewage flows	nonconsumptive	decreases	minor
-- conservative*	increases summer water demand	consumptive	increases	minor
Normal household use	increases both	nonconsumptive	decreases	major
Industrial use	increases both	mostly nonconsumptive	decreases	major
Commercial use	increases both	mostly nonconsumptive	decreases	major
Customers served by water but not sewers	increases water demand	apparently consumptive	increases	major
Customers served by sewers but not water	increases sewage flow	--	decreases	normally minor

* Using some type of intermediate evaporative medium for cooling the air.

Sewer flowmeter and master water supply error could have a major influence on the results, and examples of unreliable flowmeters have been found. However, it has been established that, with one possible exception, the flowmeters providing the data used in this study are reasonably accurate.[5] It is expected that a detailed check as to the reliability of flowmeters would be made before any consumptive use study would be attempted for design purposes.

The remaining factors are normally less significant, although in some cases leakage or unauthorized use could be important, as was demonstrated in the case of Dallas. Car washing could also be important; however, it generally follows the same seasonal pattern as lawn watering and can for all practical purposes be included with it.

For cities of comparable size, the household and commercial demands would be about the same. Thus, variations in the relative volume and seasonal distribution of the industrial demand would have the greatest influence on the consumptive use ratio. Lawn watering demands should also be similar for cities having similar climatic characteristics, but restrictions due to an inadequate source of water supply may reduce this demand, and hence the

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[5] In 1964 it was found that the McMinnville master water meter read somewhat high. A new calibration curve was prepared and has been used since then. However, there does not appear to be any major change in the monthly demand values since recalibration (see Tables 15 and 22); so it is assumed that the error was small.

consumptive use ratio.

Adjusted Consumptive Use Characteristics

In previous sections, factors which caused the water supply and sewage curves of certain of the cities to deviate from the usual pattern were pointed out. An attempt was made to adjust these curves to compensate for such irregularities in hopes of making them more consistent with the curves of the other cities. These adjustments are described below by city. Figures 28 through 31 show the revised curves, and Figure 32 shows the six-city average consumptive use pattern developed from these revised curves.

Forest Grove (Figure 28). The unusually large food processing plant waste flow volume shown on Figure 11 was removed from the sewage inflow curve as it had a distorting effect on the consumptive use ratio (see Figure 24). However, if this volume is removed from the sewage curve, an equivalent volume must be removed from the water demand curve, assuming no consumptive use (see Figure 25). Removing the latter volume leaves a very low net residential/commercial water demand. This can be explained by the fact that lawn watering has been curtailed sharply in recent years due to an inadequate municipal water supply. To compensate for this, the water demand curve was adjusted upward for the summer months. The adjusted curve is similar in shape to the summer water demand curves

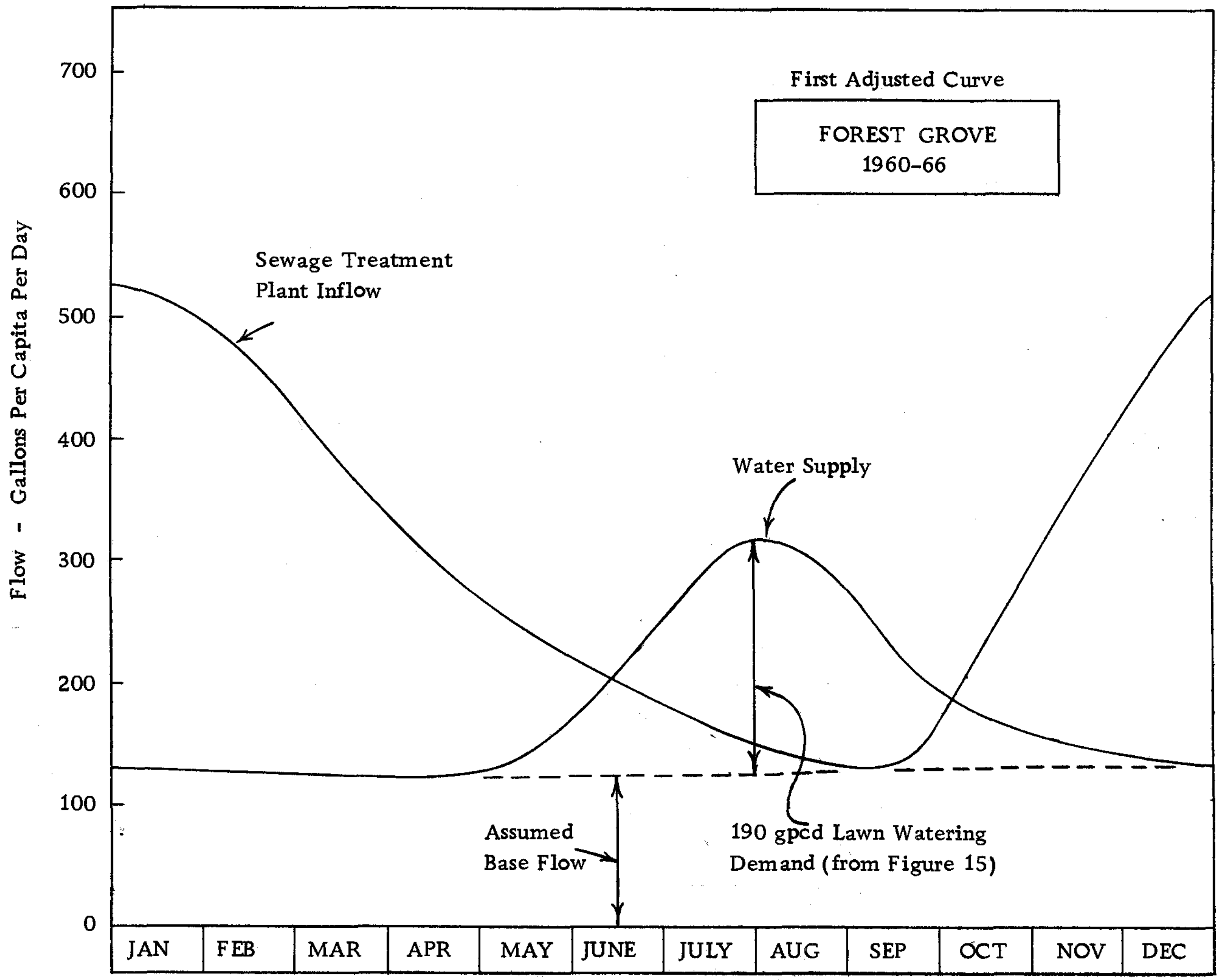

Figure 28. First Adjusted Consumptive Use Pattern, Forest Grove, 1960-66.

of the other cities, reaching a peak of 190 gpcd more than the base flow about July 31 (from Figure 15). A second adjusted curve (Figure 29) was plotted for Forest Grove, with adjustments being made only for the lawn watering restrictions.

Salem (Figure 30). The sewage treatment plant inflow curve was moved upward to compensate for industrial wastes not treated by the municipal plant. The curve was raised so that the summer base sewage flow equalled the winter base water demand.

Sweet Home (Figure 31). The sewage treatment plant inflow curve was adjusted upward to compensate for water users not returning waste water to the sewer system. The curve was shifted up until the summer base sewage flow equalled the winter base water demand.

While these adjustments were made in an attempt to put the consumptive use characteristics of all of the cities on the same base, they do not all serve to improve the validity of the results. Adjustment to compensate for the Forest Grove lawn watering restrictions is logical as it is expected that in a few years an additional source of water supply will be developed and the restrictions removed. Adjusting the Salem and Sweet Home sewage flows to compensate for unsewered water customers is also reasonable as it puts all of the cities on approximately the same base in this respect. However, it would be well to qualify any average consumptive use

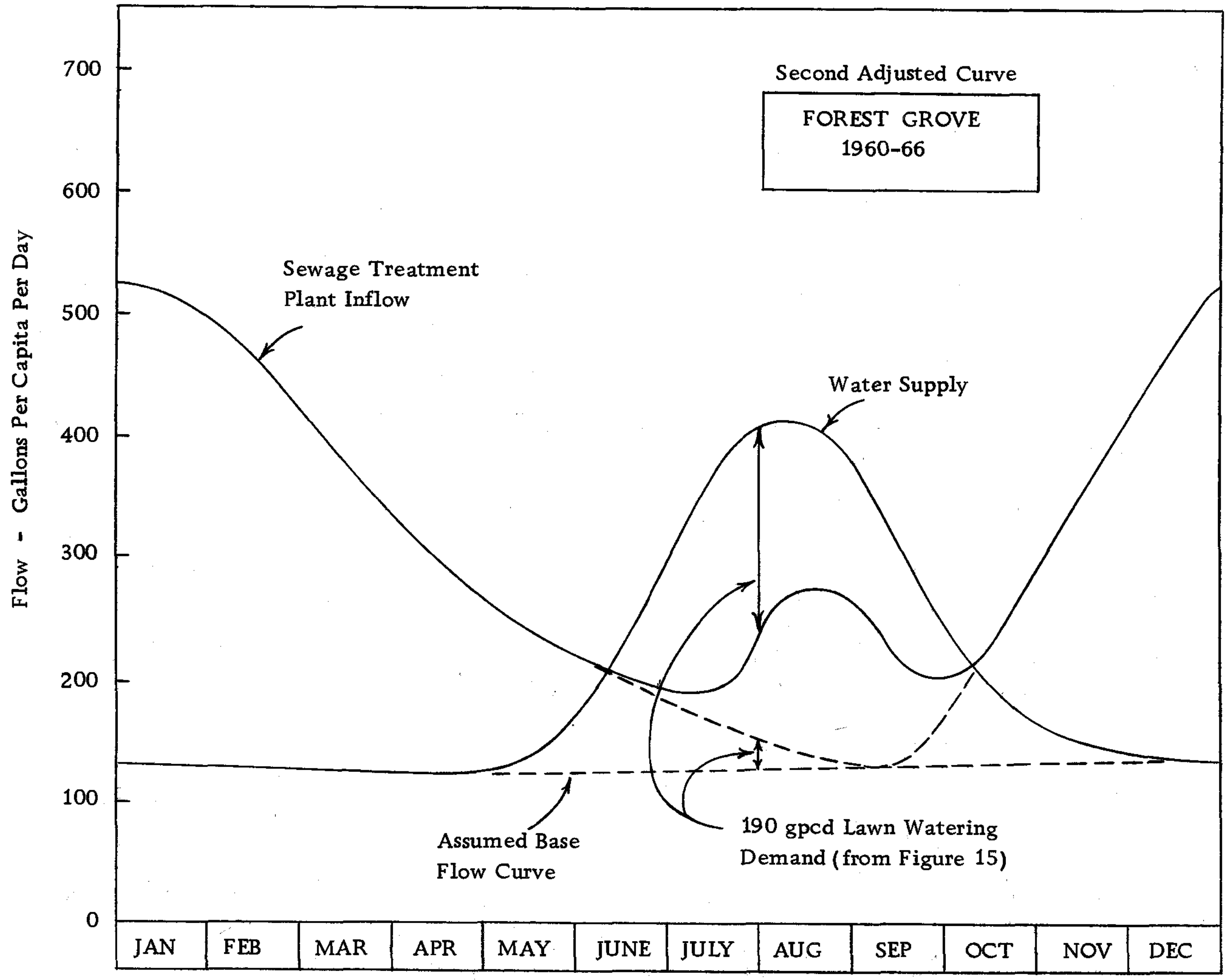

Figure 29. Second Adjusted Consumptive Use Pattern, Forest Grove, 1960-66.

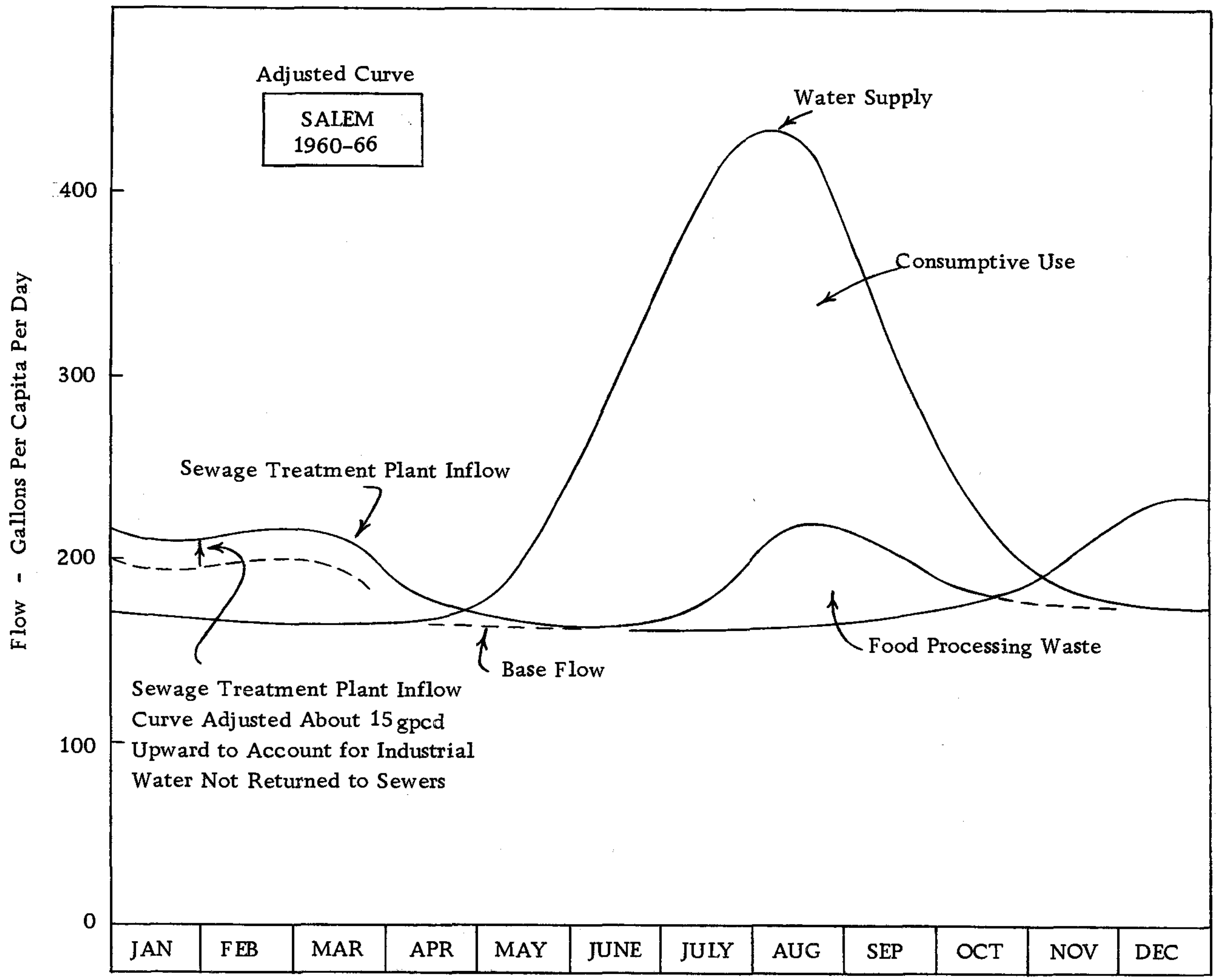

Figure 30. Adjusted Consumptive Use Pattern, Salem, 1960-66.

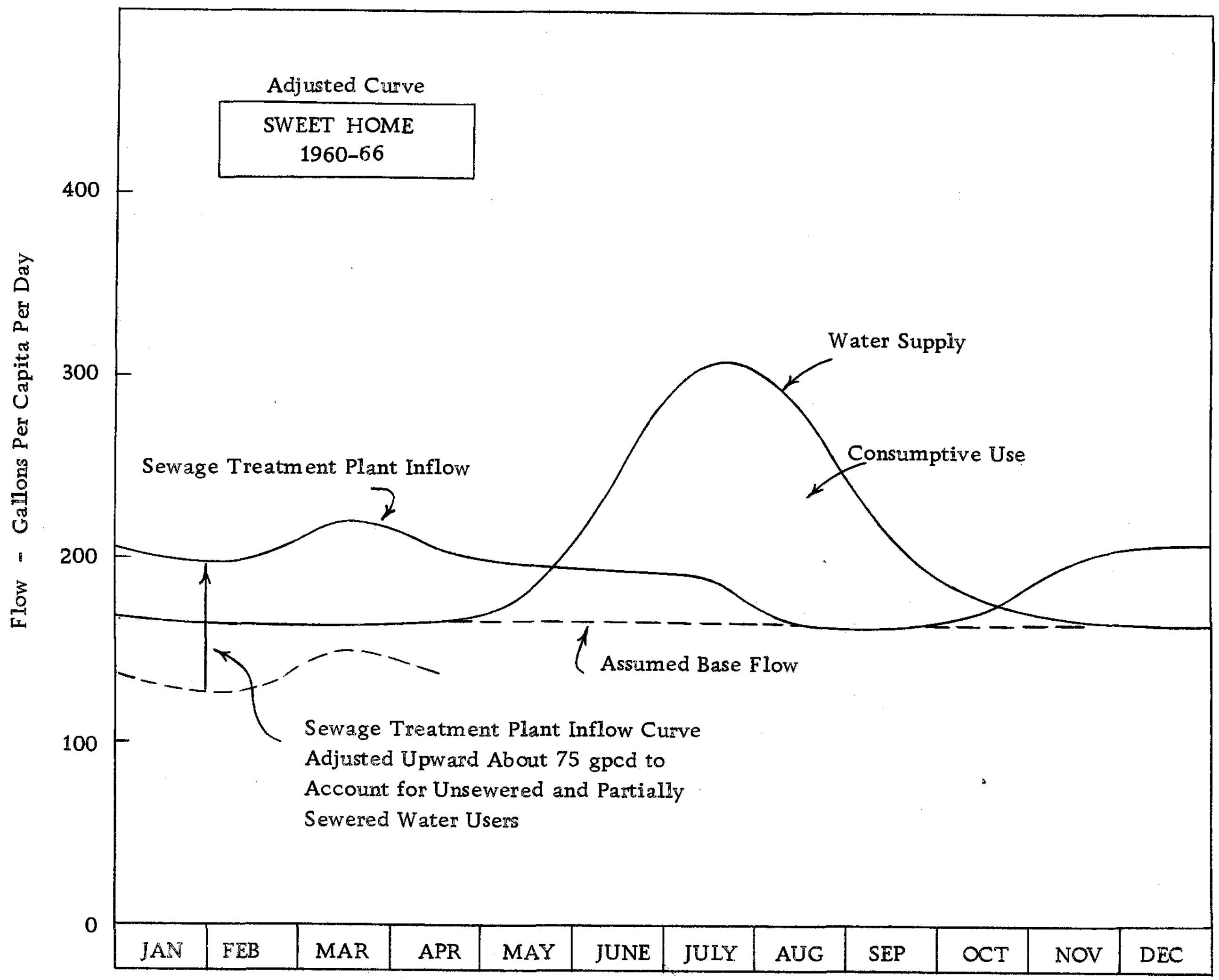

Figure 31. Adjusted Consumptive Use Pattern, Sweet Home, 1960-66.

factor developed in this way by specifying that it is not valid for cities having a substantial unsewered population.

On the other hand, removing the industrial sewage flow and water demand volumes from the Forest Grove curve may not be reasonable. The intent of this study is to develop an average consumptive use factor based on a variety of cities. Therefore, the actual demands for cities such as Sweet Home and Forest Grove, whose industrial demands are quite large compared to their residential and commercial demands, should be included. For this reason, Figure 29, which compensates only for the lawn watering restrictions, was adopted as the Forest Grove adjusted curve.

The adjusted consumptive use ratios for the six cities are listed on Table 10. Figure 32 shows the adjusted average consumptive use patterns.

By comparing the five-month values in Table 10 with the original values of Table 6, it can be seen that the Forest Grove and Salem consumptive use ratios were brought closer to the average. The Sweet Home ratio was merely displaced below the average about the same amount as it was above the average originally. It should be noted, however, that the lower consumptive use ratio for Sweet Home reflects more accurately the effect of the large water demand of the forest products industry (see Figure 24). The net effect of the adjustments was to reduce the six-city average annual ratio

Table 10. Adjusted Consumptive Use Factors for the Period 1960-66, by City, in Percent Consumptive Use.

City	Annual Factor	5-Month Mean	Factors for the Five Dry-Season Months					Reference
			May	June	July	Aug.	Sept.	
Corvallis[1]	24	40	16	40	51	51	29	Figure 9
Eugene[1]	33	49	27	56	62	54	36	Figure 10
Forest Grove	26	33	12	44	41	36	28	Figure 29
McMinnville[1]	36	54	38	55	65	60	38	Figure 12
Salem	27	44	16	47	56	49	35	Figure 30
Sweet Home	18	33	8	32	46	41	23	Figure 31
Average[2]	26	42	18	45	53	49	32	Figure 32

[1] No adjustments made, same values as listed in Table 6.

[2] Values obtained from six-city average curve, Figure 32.

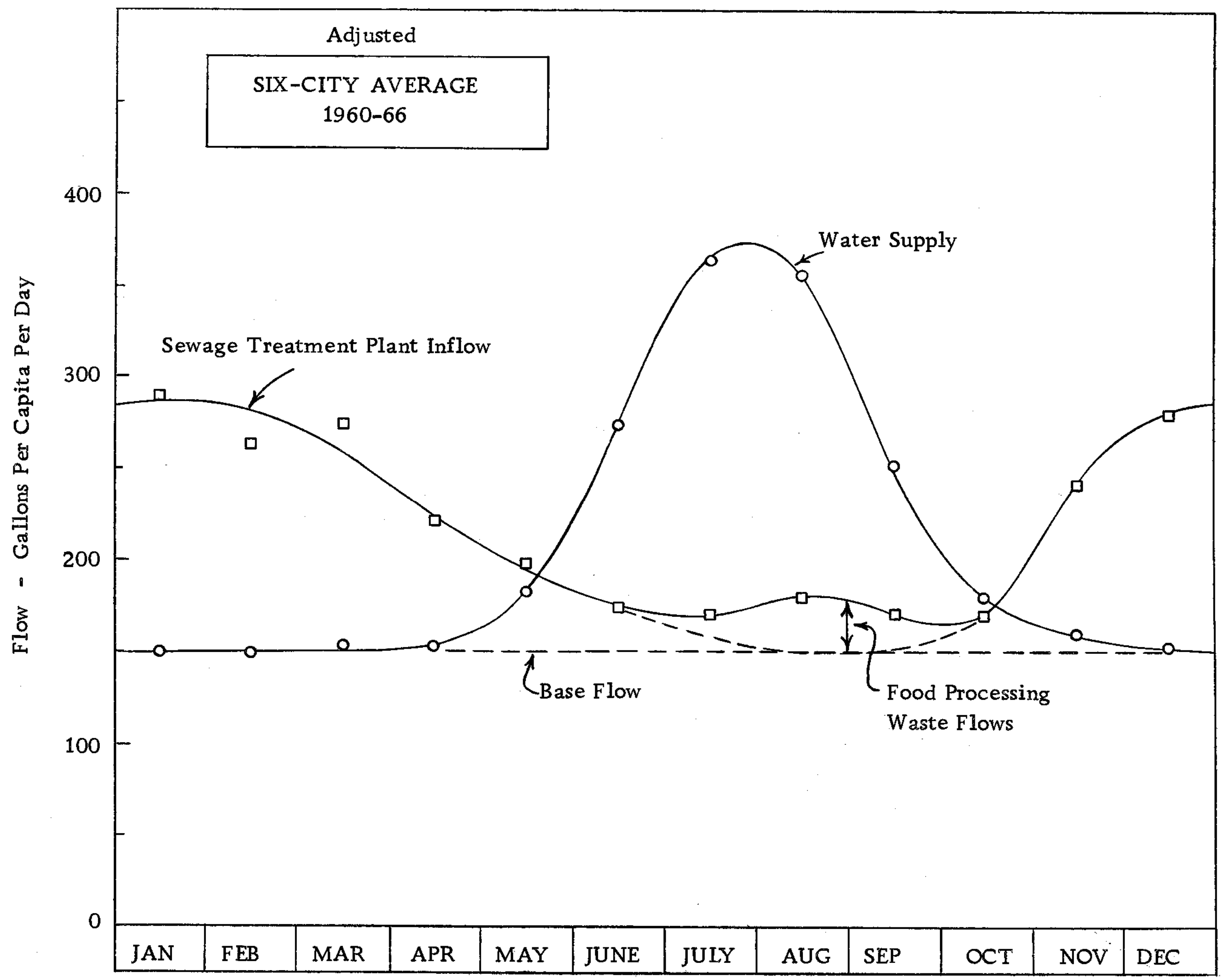

Figure 32. Adjusted Six-City Average Consumptive Use Pattern, 1960-66.

from 27 to 26 percent. In summary, the average consumptive use values presented in Table 10 are considered to represent the consumptive use characteristics for Willamette Basin municipalities.

VII. CONCLUSIONS

The average annual municipal consumptive use for the six Willamette Basin cities was 26 percent. The average monthly consumptive use values ranged from essentially zero in the winter months to 53 percent in July. The maximum, minimum, and average consumptive use values from Table 8 are summarized as follows.

Period	Maximum Single-City	Minimum Single-City	Six-City Average
Annual	36%	18%	26%
Dry Season (May through Sept.)	54%	33%	42%
May	38%	8%	18%
June	56%	32%	45%
July	65%	41%	53%
August	60%	36%	49%
September	38%	23%	32%

These figures represent the consumptive use characteristics of a number of cities of different sizes in the Willamette Valley, several having proportionately high industrial water demands, at least one having a primarily residential/commercial demand, and others having a fairly normal distribution of industrial and residential/commercial demands. All of the cities have similar climatic characteristics, and all of the water systems are metered. The summer airconditioning water demand is low for all of the cities studied. The data were adjusted where necessary so that the results would describe the consumptive use of cities having fairly complete sewer systems and no lawn watering restrictions. In addition, an attempt was made to analytically remove wet season storm runoff and infiltration from the sewage flows used in developing these values, so that the results would accurately describe the consumptive use of the municipal water supplied to the cities.

As can be seen from Table 9, many different factors affect consumptive use. For this reason care must be taken in applying published consumptive use ratios. For example, to apply the values listed above to a specific situation, adjustments would have to be made to account for any deviations from the characteristics described in the preceding paragraph.

While the average annual consumptive use ratio for the six cities was 26 percent, the annual ratios for individual cities ranged from 18 percent to 36 percent. It is interesting to note that such a large range of values exists for a series of cities where such important factors as climate and percentage of water customers sewered are essentially identical. An even wider range of

Table 11. Effect of Various Factors on Consumptive Use.

Influencing Factor	Relationship to Consumptive Use
1. Percentage of water customers sewered[1]	inversely proportional[2]
2. Dryness of climate (or, in individual years, weather)[1]	directly proportional
3. Average summer temperature[1]	directly proportional
4. Cost of water	inversely proportional
5. Flat rate water charge	higher consumptive use[3]
6. Proportion of nonconsumptive industrial water demand	inversely proportional
7. Proportion of residential/ commercial water demand	directly proportional
8. Height of water table in summer	inversely proportional
9. Amount of airconditioning[1]	4
10. Lawn watering restrictions[1]	lower consumptive use
11. Proportion of residents living in multiple-family dwellings	inversely proportional
12. Age of city[1]	inversely proportional
13. Water system leakage	directly proportional[2]
14. Amount of storm sewage included in sewage flows[1]	inversely proportional[5,6]
15. Amount of sewer infiltration[1]	inversely proportional[5,6]

[1] common for all of the Willamette Basin cities studied.

[2] affects short-term consumptive use only.

[3] higher than for metered water system

[4] could be directly or inversely proportional, depending on type of equipment used.

[5] an attempt should be made to remove these flows before developing consumptive use factors.

[6] affects apparent consumptive use only.

consumptive use ratios would be obtained if cities located in varying climates were included. The wide range of possible values explains in part the wide range of estimates cited in the literature (see Table 1).

Annual consumptive use ratios of 15-40 percent can be expected for Willamette Basin cities having fairly complete sanitary sewer systems (see Table 8). The ratios for cities having proportionately high industrial water demands would fall in the lower part of the range (15-30 percent). The consumptive use for the months of July and August could be as high as 60-70 percent, while in the winter it would be close to zero.

The monthly values developed in this study are short-term consumptive use factors. As such, they can be used whenever it is desired to know the approximate daily, weekly, or monthly return flows. For example, they could be used when estimating return flows for sewer system and sewage treatment plant design, when estimating return flows for design of reuse facilities, and when determining daily, weekly, and monthly streamflow depletions.

In studies where the annual effects of municipal diversions must be known, long-term consumptive use factors must be used. The long-term factors account for that water which appears to be lost (in that it doesn't return via the sewer system) but eventually finds its way back to surface waters via the ground water system.

The average long-term annual consumptive use ratio for the Willamette Basin would be somewhat less than the short-term value of 26 percent developed in this study, perhaps on the order of 20 percent. This would agree with the values proposed by Green and Gladwell and the Select Senate Committee on Water Resources (65, p. 17; 77, p. IV-3). The consumptive use (or return flow) figures quoted in sanitary engineering textbooks and most other sources are usually annual averages based on sewage return flows and must be classified as short-term values. These annual short-term figures are only of interest for purposes of comparison, as designers require short-term monthly consumptive use values and planners need long-term annual averages.

The extent to which a municipal water right is consumptive is not specified under Oregon water law. The fact that a portion of a city's water is normally returned to the watercourse in the form of sewage treatment plant effluent tends to make the municipal right appear to be only partially consumptive. However, a city has the right to recapture and fully consume these return flows, providing they are put to use in the manner specified in the water right permit.

Other water users have the right to appropriate municipal return flows. While they cannot force a city to maintain the return flows, they can prohibit it from diverting its return flow for uses not specified in its permit. A city planning the eventual reuse of its return flows would be wise to insure that its water right allows the reuse of the water for all contemplated purposes before another water user appropriates the return flow.

While the consumptive use ratios obtained from this study apply chiefly to a comparatively small geographical area, the procedures used in developing the values can be applied wherever sewage and water flow data are available. Among the most important facts brought out by this study are (1) that the consumptive use has a wide seasonal variation and, (2) that many factors have an influence on an individual city's consumptive use. As very little data on monthly and seasonal consumptive use (and return flow) are presented in the literature, it is recommended that more effort be expended in developing and disseminating information of this nature. Furthermore, the values quoted in the literature (including textbooks) should be fully identified with respect to type of value (short-term or long-term), method by which derived, geographic area to which applicable, and any other factors which would either limit or extend their usefulness.

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APPENDICES

APPENDIX I

Table 12. Monthly water supply flows for Corvallis, Oregon, 1960-1966, in millions of gallons.

	1960	1961	1962	1963	1964	1965	1966
January	92.5	92.4	101.8	126.5	118.7	124.0	139.7
February	89.4	81.2	103.6	110.7	112.8	124.0	124.0
March	92.5	92.2	103.2	124.1	115.8	140.1	130.6
April	90.1	95.5	103.4	119.0	118.5	139.2	142.7
May	92.6	110.7	107.4	132.6	147.9	165.2	196.9
June	164.0	158.9	171.2	172.3	154.9	219.0	234.0
July	202.9	197.7	238.6	189.6	217.0	282.4	271.4
August	166.9	201.1	200.2	211.6	209.1	236.3	304.8
September	110.1	129.6	130.4	148.1	153.4	184.4	170.7
October	96.5	114.3	122.2	131.9	145.2	146.9	147.1
November	90.2	99.0	112.0	118.0	129.4	130.4	133.1
December	95.0	99.0	118.2	113.5	119.6	132.2	144.6

Table 13. Monthly water supply flows for Eugene, Oregon, 1960-1966, in millions of gallons.

	1960	1961	1962	1963	1964	1965	1966
January	252.9	243.9	274.9	300.4	289.1	348.5	367.4
February	232.1	222.1	246.0	264.3	276.6	305.4	352.3
March	246.6	246.0	268.7	283.8	306.1	358.8	384.4
April	245.7	264.0	278.7	280.0	305.9	336.5	437.3
May	259.5	291.4	283.5	415.6	432.4	471.0	682.7
June	553.5	574.9	537.2	519.0	522.4	736.7	949.7
July	821.9	763.7	861.8	596.4	814.8	1054.3	1001.5
August	635.2	762.5	596.9	797.2	741.1	816.8	1096.8
September	392.8	397.9	516.4	501.1	554.5	695.5	674.8
October	313.6	319.1	310.9	351.1	393.0	436.0	470.4
November	254.4	278.8	294.6	309.5	342.7	373.7	412.4
December	256.1	270.2	294.6	306.8	349.0	335.5	382.6

Table 14. Monthly water supply flows for Forest Grove, Oregon, 1960-1966, in millions of gallons.

	1960	1961	1962	1963	1964	1965	1966
January	27.5	24.5	26.6	32.8	24.2	16.2	20.4
February	21.9	21.2	26.7	25.2	22.2	17.3	21.2
March	24.0	23.2	27.6	26.1	22.4	21.7	22.3
April	23.1	24.2	23.7	24.3	20.3	20.4	21.3
May	25.3	27.0	26.4	30.2	23.9	25.6	28.3
June	41.8	49.2	39.1	39.8	28.2	41.1	24.2
July	64.7	59.1	57.6	37.5	46.1	54.3	53.9
August	57.4	74.8	57.7	60.1	59.5	55.9	74.6
September	46.6	45.6	44.3	41.0	37.9	38.6	44.8
October	38.3	37.8	35.6	36.9	32.9	28.8	40.2
November	28.3	30.6	34.1	27.0	22.5	22.9	38.9
December	24.7	24.2	28.9	24.0	19.5	24.2	26.0

Table 15. Monthly water supply flows for McMinnville, Oregon, 1960-1966, in millions of gallons.

	1960	1961	1962	1963	1964	1965	1966
January	35.9	36.7	43.1	44.9	43.6	---	51.9
February	33.3	34.7	39.5	37.9	41.7	16.0*	47.9
March	41.3	40.8	46.0	44.7	45.0	79.3	55.4
April	41.7	43.2	49.0	42.9	47.1	42.8	59.4
May	46.0	49.2	56.0	61.9	67.4	95.8	87.4
June	78.5	80.4	90.1	87.4	85.7	105.0	119.2
July	123.0	110.3	134.0	84.6	122.6	143.6	133.2
August	89.4	102.7	92.7	104.8	103.3	106.2	140.2
September	56.3	53.2	72.2	67.3	69.8	77.3	57.9
October	41.8	44.0	43.5	49.2	57.2	42.4	52.4
November	36.5	38.7	47.9	42.3	45.4	48.7	44.5
December	36.4	41.7	45.0	43.2	4.5*	51.8	49.5

*Meter out of service 28 days in December, all of January, and 18 days in February.

Table 16. Monthly water supply flows for Salem, Oregon, 1960-1966, in millions of gallons.

	1960	1961	1962	1963	1964	1965	1966
January	183	239	229	366	370	335	345
February	163	241	199	298	349	299	312
March	179	307	233	322	359	350	311
April	201	208	225	323	348	335	333
May	211	205	288	387	402	408	490
June	403	494	515	477	441	620	664
July	639	619	744	517	668	905	766
August	567	773	672	741	718	787	968
September	404	465	535	557	519	650	586
October	327	320	383	392	418	449	458
November	199	263	301	323	366	345	370
December	204	229	338	366	367	342	332

Table 17. Monthly water supply flows for Sweet Home, Oregon, 1960-1966, in millions of gallons.

	1960	1961	1962	1963	1964	1965	1966
January	18.8	16.4	---	21.4	18.7	19.7*	20.8
February	15.1	14.0	18.3	19.1	17.3	18.7	19.2
March	16.8	16.6	20.2	18.8	18.2	22.9	20.3
April	16.9	15.8	18.5	17.3	18.5	---	21.7
May	18.0	17.3	18.5	21.3	21.4	21.7	27.8
June	25.5	28.1	25.4	23.4	21.6	32.8	34.1
July	35.7	35.6	38.6	24.3	31.2	42.1	38.0
August	27.7	34.2	27.1	33.6	29.7	31.8	42.0
September	19.1	20.3	21.6	24.7	24.2	27.8	27.6
October	18.4	19.0	18.2	20.9	21.2	24.0	22.1
November	17.9	17.5	35.5	18.5	20.2	23.8	19.5
December	16.9	---		18.6	19.2*	22.1	18.7

*Meter out of service five days in December and three days in January.

Table 18. Monthly sewage treatment plant inflows for Corvallis, Oregon, 1960-1966, in millions of gallons.

	1960	1961	1962	1963	1964	1965	1966
January	138.7	180.1	173.4	132.8	241.3	253.7	173.7
February	146.5	192.0	174.3	180.8	157.0	169.1	188.3
March	156.6	207.0	220.6	171.4	189.8	136.3	229.5
April	133.4	156.2	176.0	196.9	110.6	136.3	134.4
May	141.9	158.1	153.7	152.0	99.2	129.2	125.0
June	86.4	109.1	110.6	96.6	96.2	122.4	110.0
July	74.7	111.5	120.3	89.4	102.5	126.7	121.5
August	83.3	115.7	117.5	95.6	97.4	111.9	132.8
September	71.0	104.2	115.1	89.3	86.6	97.4	120.0
October	96.5	121.6	139.0	109.9	93.2	114.3	126.2
November	167.7	155.7	165.4	189.4	174.3	171.2	149.2
December	153.7	208.3	177.0	107.8	269.8	163.6	198.9

Table 19. Monthly sewage treatment plant inflows for Eugene, Oregon, 1960-1966, in millions of gallons per day.

	1960	1961	1962	1963	1964	1965	1966
January	9.7	8.4	7.0	7.5	9.5	17.0	16.0
February	8.2	8.2	10.5	10.0	8.4	9.5	13.2
March	9.0	---	10.5	8.9	10.1	7.9	15.0
April	11.0	7.5	10.6	5.2	7.0	9.2	11.5
May	8.8	6.9	9.2	10.0	6.1	7.6	12.0
June	6.4	6.1	7.8	8.1	6.6	7.9	9.2
July	7.7	8.0	8.5	7.4	7.7	9.3	11.0
August	7.8	9.6	9.1	9.0	8.2	9.9	11.6
September	7.4	9.7	9.3	9.2	7.3	9.1	11.8
October	6.7	7.5	8.8	7.9	6.7	9.0	9.6
November	9.0	10.0	10.2	8.9	8.7	15.0	13.7
December	8.8	12.8	7.7	8.7	16.0	11.4	17.5

Table 20. Monthly sewage treatment plant inflows for Forest Grove, Oregon, 1960-1966, in millions of gallons per day.

	1960	1961	1962	1963	1964	1965	1966
January	2.78	2.51	2.71	2.13	4.26	4.47	4.30
February	2.65	2.89	3.05	3.10	2.16	2.00	2.07
March	2.71	3.10	3.08	2.39	2.33	1.65	3.96
April	2.59	1.83	2.47	2.32	1.08	1.34	1.00
May	2.06	1.53	2.07	2.07	0.85	1.10	0.82
June	1.36	1.27	1.50	1.13	0.86	1.05	1.92
July	1.04	1.28	1.46	0.97	0.91	0.78	1.44
August	1.33	2.11	1.88	1.49	1.46	1.14	2.50
September	1.16	1.66	1.63	1.20	1.11	0.87	2.12
October	1.20	1.68	2.11	1.30	1.01	0.76	1.67
November	2.48	1.88	3.33	2.35	2.13	1.37	1.60
December	2.18	2.47	2.96	2.59	3.29	2.37	4.38

Table 21. Monthly sewage treatment plant inflows for McMinnville, Oregon, 1960-1966, in millions of gallons per day.

	1960	1961	1962	1963	1964	1965	1966
January	3.95	2.96	2.49	2.20	4.41	3.24	3.70
February	3.58	4.06	2.94	3.29	2.13	1.89	2.80
March	3.47	3.87	3.20	2.78	2.98	1.92	3.51
April	3.02	2.30	2.72	3.30	2.11	1.94	2.05
May	2.50	2.19	2.24	2.85	1.92	1.86	1.87
June	1.90	1.90	1.86	1.95	1.96	1.80	1.66
July	1.75	1.73	1.80	1.87	2.00	1.84	1.60
August	1.41	1.46	1.50	1.75	1.48	1.58	1.48
September	1.14	1.13	1.38	1.65	1.38	1.32	1.28
October	1.18	1.36	2.06	1.73	1.34	1.29	1.34
November	2.69	1.83	3.48	3.21	2.47	2.49	2.09
December	2.47	3.30	2.37	3.20	3.82	2.79	3.69

Table 22. Monthly sewage treatment plant inflows for Salem, Oregon, 1960-1966, in millions of gallons.

	1960	1961	1962	1963	1964	1965	1966
January	205.1	258.5	282.8	221.7	346.2	284.5*	610
February	217.8	360.4	228.4	252.5	262.5	453.8	437
March	184.3	422.9	285.3	84.4*	349.7	303.7	573
April	206.3	249.4	208.8	302.6	229.1	332.9	360
May	232.2	254.6	214.4	245.2	221.9	305.9	352
June	204.8	214.8	200.9	192.1	248.5	324	379
July	225.2	235.9	226.4	189.7	281.5	386.4	417
August	276.3	321.5	300.1	271.3	300.8	447.9	542
September	254.6	252.4	246.9	158.3*	272.2	426	485
October	213.6	227.8	252.6	---	238.7	369	423
November	237.0*	226.6	285.4	155.5*	185.3*	455	473
December	277.3	279.3	271.8	269.2	481.5*	469	592

*Flowmeter out of service as follows: 11/60, 2 days; 3/63, 22 days; 9/63, 13 days; 10/63, 31 days; 11/63, 11 days; 11/64, 8 days; 12/64, 10 days; and 1/65, 13 days.

Table 23. Monthly sewage treatment plant inflows for Sweet Home, Oregon, 1960-1966, in millions of gallons.

	1960	1961	1962	1963	1964	1965	1966
January	13.3	14.6	15.5	---	15.5	11.1*	13.6
February	13.7	11.7	14.1	---	13.7	12.3	---
March	14.9	14.3	15.7	---	15.9	13.7	29.0
April	13.3	15.3	14.6	14.3	13.9	13.7	17.5
May	14.3	15.9	15.0	13.0	13.6	13.9	10.9
June	14.4	12.1	14.2	15.0	13.4	11.2	9.8
July	13.2	18.9	11.2	15.2	12.1	11.6	9.2
August	12.3	9.5	9.6	12.2	10.8	10.8	8.9
September	10.7	11.0	8.1	10.0	9.0	9.1	10.4
October	12.3	11.8	10.8	10.0	10.7	---	8.4
November	14.5	14.8	13.4	13.4	13.5	10.2	16.2
December	15.0	14.0	14.2	14.2	10.3*	8.8	27.6

* Flowmeter out of service as follows: 12/64, 10 days; and 1/65, 7 days.

APPENDIX II

Table 24. Per capita municipal water use for Corvallis, Oregon, 1960-1966, gallons per capita per day.

	1960	1961	1962	1963	1964	1965	1966	Mean
January	135	126	121	147	133	124	145	134
February	140	122	137	142	135	148	143	138
March	135	126	123	144	130	151	136	135
April	136	134	127	143	137	155	153	141
May	136	151	128	154	166	178	205	160
June	248	224	211	206	179	244	251	223
July	297	269	284	220	243	305	282	271
August	244	374	239	245	234	255	317	273
September	167	182	161	177	178	206	183	179
October	141	156	146	153	162	159	153	153
November	136	139	138	141	150	146	143	142
December	139	135	141	132	134	143	150	139

Table 25. Per capita municipal water use for Eugene, Oregon, 1960-1966, gallons per capita per day.

	1960	1961	1962	1963	1964	1965	1966	Mean
January	130	123	128	132	112	131	133	127
February	127	124	127	128	114	127	142	127
March	127	124	125	124	118	135	139	127
April	130	138	134	127	122	131	164	135
May	133	147	132	182	167	177	248	169
June	294	301	259	235	209	286	356	277
July	422	386	402	261	315	396	363	364
August	326	386	279	349	286	307	398	333
September	208	208	249	227	221	270	253	234
October	161	161	145	154	152	164	171	158
November	135	146	142	140	137	145	155	143
December	131	137	138	134	135	126	139	134

Table 26. Per capita municipal water use for Forest Grove, Oregon, 1960-1966, gallons per capita per day.

	1960	1961	1962	1963	1964	1965	1966	Mean
January	157	135	143	168	121	80	99	129
February	134	128	159	143	119	94	114	127
March	138	128	149	134	112	108	108	127
April	137	138	132	129	105	104	107	122
May	145	149	142	155	120	126	138	139
June	247	280	218	211	146	209	122	205
July	371	326	310	193	231	268	262	280
August	329	413	311	309	298	275	363	328
September	276	260	246	218	196	196	225	310
October	220	208	192	189	165	142	196	187
November	167	168	190	143	116	116	145	150
December	142	189	156	123	98	119	126	136

Table 27. Per capita municipal water use for McMinnville, Oregon, 1960-1966, gallons per capita per day.

	1960	1961	1962	1963	1964	1965	1966	Mean
January	151	149	171	174	166	180	188	168
February	150	156	173	163	170	186	192	169
March	174	166	182	173	171	297	201	195
April	186	182	200	172	185	166	222	188
May	194	200	222	240	257	359	317	256
June	342	338	368	350	337	407	446	370
July	518	449	530	328	467	539	483	473
August	377	418	367	406	393	398	508	410
September	245	224	295	270	275	300	217	261
October	176	179	172	191	218	159	190	184
November	159	163	196	169	179	189	167	175
December	153	170	178	168	177	194	179	174

Table 28. Per capita municipal water use for Salem, Oregon, 1960-1966, gallons per capita per day.

	1960	1961	1962	1963	1964	1965	1966	Mean
January	120	156	146	233	191	174	168	170
February	114	173	142	210	191	167	169	167
March	117	200	149	206	185	177	152	169
April	137	140	148	212	184	175	168	166
May	138	134	184	247	207	206	239	194
June	274	332	340	314	234	324	334	307
July	419	403	475	330	344	458	374	400
August	372	503	429	472	370	398	472	431
September	275	313	353	366	275	340	295	318
October	215	208	244	250	216	227	224	226
November	135	177	199	212	194	180	186	183
December	134	149	216	234	189	173	162	180

Table 29. Per capita municipal water use for Sweet Home, Oregon, 1960-1966, gallons per capita per day.

	1960	1961	1962	1963	1964	1965	1966	Mean
January	181	154	---	186	153	174	164	168
February	156	146	175	184	151	165	167	163
March	162	156	187	164	149	182	160	166
April	168	154	177	156	156	---	176	164
May	173	162	171	185	175	173	219	180
June	254	273	244	210	183	270	277	244
July	344	335	358	211	255	336	299	305
August	267	322	251	292	243	253	330	280
September	190	197	207	222	205	229	224	211
October	177	179	169	182	173	191	174	178
November	178	170	165	166	171	196	185	172
December	163	---	170	162	187	176	147	167

Table 30. Per capita sewage treatment plant inflows, Corvallis, Oregon, 1960-1966, gallons per capita per day.

	1960	1961	1962	1963	1964	1965	1966	Mean
January	216	260	218	162	284	288	190	231
February	244	307	243	244	198	213	228	240
March	244	299	278	209	224	155	251	237
April	215	233	230	248	135	160	152	196
May	221	228	193	185	117	147	137	175
June	139	163	144	122	117	144	124	136
July	117	161	151	109	121	144	133	134
August	130	167	145	117	115	127	145	135
September	115	155	150	113	105	114	136	127
October	151	176	175	134	110	130	138	145
November	270	232	216	239	212	201	169	220
December	240	301	223	132	318	186	217	231

Table 31. Per capita sewage treatment plant inflows, Eugene, Oregon, 1960-1966, gallons per capita per day.

	1960	1961	1962	1963	1964	1965	1966	Mean
January	190	160	126	129	135	234	212	169
February	161	156	189	172	120	131	175	158
March	177	---	189	153	144	109	199	158
April	216	143	191	90	100	127	153	145
May	173	131	166	172	87	105	159	142
June	126	116	141	139	94	109	122	121
July	151	152	153	127	110	128	146	138
August	153	183	164	155	117	136	154	152
September	145	185	168	158	104	125	157	149
October	131	143	159	136	95	124	127	131
November	177	191	184	153	124	207	182	174
December	172	244	139	150	228	157	232	189

Table 32. Per capita sewage treatment plant inflows, Forest Grove, Oregon, 1960-1966, gallons per capita per day.

	1960	1961	1962	1963	1964	1965	1966	Mean
January	494	429	453	340	660	682	648	529
February	470	484	509	494	335	305	312	416
March	482	529	514	381	361	252	596	445
April	460	312	412	370	167	204	151	297
May	366	261	346	330	132	168	124	247
June	242	217	250	180	133	160	290	210
July	185	219	244	154	141	119	217	183
August	236	361	314	238	226	174	377	275
September	206	284	272	192	172	133	320	226
October	213	287	352	207	156	116	252	226
November	441	321	556	375	330	209	241	353
December	387	422	494	413	509	362	660	464

Table 33. Per capita sewage treatment plant inflows, McMinnville, Oregon, 1960-1966, gallons per capita per day.

	1960	1961	1962	1963	1964	1965	1966	Mean
January	516	373	305	264	521	377	416	396
February	468	512	361	395	251	220	315	360
March	453	488	393	334	352	223	394	377
April	394	290	334	397	249	226	230	303
May	327	276	275	343	227	216	210	268
June	248	240	228	234	231	209	187	225
July	229	218	221	225	236	214	180	218
August	184	184	184	210	175	184	166	184
September	149	143	169	198	163	153	144	160
October	154	172	253	208	158	150	151	178
November	351	231	427	386	292	290	235	316
December	323	416	291	385	451	209	415	356

Table 34. Per capita sewage treatment plant inflows, Salem, Oregon, 1960-1966, gallons per capita per day.

	1960	1961	1962	1963	1964	1965	1966	Mean
January	133	168	181	141	178	247	298	192
February	153	260	162	178	144	254	236	198
March	121	274	175	185	180	153	280	196
April	140	167	138	199	122	174	182	160
May	152	165	137	156	114	154	172	150
June	139	144	133	127	132	169	191	148
July	148	153	144	121	145	195	204	159
August	181	209	192	173	155	226	264	200
September	173	169	163	184	145	222	250	187
October	140	148	161	---	123	186	206	161
November	167	152	188	161	134	237	238	182
December	182	181	180	171	265	237	288	215

Table 35. Per capita sewage treatment plant inflows, Sweet Home, Oregon, 1960-1966, gallons per capita per day.

	1960	1961	1962	1963	1964	1965	1966	Mean
January	128	137	144	---	127	114	107	126
February	141	104	145	---	120	108	---	124
March	143	135	146	---	130	109	228	148
April	132	149	140	128	117	113	142	132
May	153	150	139	113	111	110	86	123
June	143	118	136	135	113	95	80	117
July	127	178	104	132	99	92	72	115
August	118	90	89	106	88	86	70	92
September	106	107	78	90	76	75	85	88
October	118	111	100	87	88	---	66	95
November	144	144	128	120	114	84	132	124
December	144	132	132	123	124	70	218	135

APPENDIX III

Table 36. Salem Residential Water Use, 1960-66, Monthly Sales, Millions of Cubic Feet.

	1960	1961	1962	1963	1964	1964	1966	Mean	Adjusted Mean *
Jan.	7.3	7.6	7.8	8.6	8.5	11.3	11.3	8.9	8.6
Feb.	6.7	6.5	7.2	7.5	7.3	9.5	10.1	7.8	8.4
March	7.2	7.2	7.5	7.5	7.8	11.0	10.4	8.4	8.1
April	7.3	7.4	7.8	7.6	8.3	12.8	12.3	9.1	9.1
May	6.8	7.7	8.0	9.2	8.9	14.1	20.7	10.8	10.4
June	14.1	16.4	14.6	20.6	16.8	29.0	36.3	21.1	21.1
July	33.6	33.3	33.0	20.4	37.1	49.5	10.4	31.0	30.0
Aug.	32.5	34.6	30.3	31.0	36.5	44.2	53.8	37.6	36.4
Sept.	16.4	21.1	23.2	22.2	26.4	28.7	32.7	24.4	24.4
Oct.	10.3	9.3	9.6	10.4	15.4	17.3	13.4	12.2	11.7
Nov.	7.3	7.7	7.9	7.7	10.4	11.0	11.3	9.0	9.0
Dec.	7.0	7.5	7.5	8.1	10.3	10.8	10.4	8.8	8.5

Table 37. Salem Commercial Water Use, 1960-66, Monthly Sales, Millions of Cubic Feet.

	1960	1961	1962	1963	1964	1965	1966	Mean	Adjusted Mean *
Jan.	5.7	6.3	5.9	6.3	6.2	7.4	7.0	6.4	6.2
Feb.	5.0	5.5	5.8	6.0	5.8	6.5	7.0	5.9	6.3
March	5.4	6.0	6.0	6.3	6.3	6.9	6.9	6.3	6.1
April	5.6	6.0	6.1	6.7	6.5	7.7	7.5	6.6	6.6
May	5.4	6.0	6.2	6.9	6.5	7.8	8.3	6.7	6.5
June	6.9	7.9	7.3	8.9	8.5	9.2	11.1	8.5	8.5
July	10.6	11.4	11.3	8.8	9.7	12.8	10.0	10.7	10.4
Aug.	11.0	11.6	11.1	11.5	11.0	13.7	15.4	12.2	11.8
Sept.	9.2	10.6	10.1	10.1	10.5	12.5	14.0	11.0	11.0
Oct.	7.2	7.0	7.1	8.3	8.7	9.7	9.5	8.2	7.9
Nov.	6.2	6.6	6.5	6.8	7.2	8.2	8.5	7.1	7.1
Dec.	5.9	5.9	6.2	6.8	6.7	7.6	6.7	6.5	6.3

* Adjusted to 30-day months.

Table 38. Salem Industrial Water Use, 1960-66, Monthly Sales, Millions of Cubic Feet.

	1960	1961	1962	1963	1964	1965	1966	Mean	Adjusted Mean*
Jan.	3.8	4.6	3.5	6.7	5.8	10.2	8.2	6.1	5.9
Feb.	2.5	6.1	2.9	4.5	4.0	7.4	5.4	4.7	5.0
March	2.2	4.5	2.5	3.5	3.9	3.8	5.3	3.7	3.6
April	2.3	--	2.2	3.2	4.1	4.9	5.7	3.7	3.7
May	3.3	2.7	2.3	3.8	3.9	4.9	6.7	3.9	3.8
June	4.8	5.9	4.5	7.4	4.5	3.6	7.4	5.4	5.4
July	8.6	10.3	7.1	7.5	6.5	10.0	14.0	9.1	8.8
Aug.	15.6	21.8	20.3	17.2	17.3	18.1	24.0	19.2	18.6
Sept.	22.4	24.2	23.0	24.8	27.7	33.0	26.8	26.0	26.0
Oct.	15.7	17.0	17.2	17.9	19.5	22.9	24.3	19.2	18.6
Nov.	7.0	11.0	9.4	7.3	13.3	12.9	19.2	11.4	11.4
Dec.	4.5	4.9	7.9	6.6	10.9	8.4	12.3	7.9	7.6

Table 39. Monthly Water Sales to Suburban Municipalities and Water Districts, 1960-66, Millions of Cubic Feet.

	1960	1961	1962	1963	1964	1965	1966	Mean	Adjusted Mean*
Jan.	4.0	4.6	7.3	9.4	14.5	3.7	4.6	6.9	6.7
Feb.	4.4	4.2	6.3	11.5	12.1	3.8	4.1	6.6	7.1
March	4.2	4.7	7.2	10.4	13.1	4.1	4.4	6.9	6.7
April	4.4	4.4	7.2	11.0	12.7	4.9	4.1	7.0	7.0
May	4.2	4.9	6.7	12.6	13.4	4.9	5.4	7.4	7.2
June	7.1	7.6	12.3	11.2	8.2	8.3	9.5	9.2	9.2
July	12.5	11.1		8.3	7.7	11.5	9.5	11.5	11.1
Aug.	9.7	15.7	17.7	13.8	9.0	9.9	14.9	13.0	12.6
Sept.	7.4	10.3	13.2	8.7	7.2	7.6	7.9	8.9	8.9
Oct.	5.4	6.2	6.3	6.0	4.8	4.0	3.8	5.2	5.0
Nov.	4.5	7.4	6.9	5.4	4.5	3.5	4.0	5.2	5.2
Dec.	4.6	6.8	10.8	10.0	4.2	3.4	1.9	6.0	5.8

*Adjusted to 30-day months.

Table 40. Annual Volumes of Water Produced and Sold, by City, 1960-1966.

City		1960	1961	1962	1963	1964	1965	1966	Mean
	volume produced	1282.7	1471.6	1612.2	1697.9	1742.3	2024.1	2873.5	--
Corvallis	volume sold	1039.8	1137.5	1205.9	1253.1	1271.4	1512.0	--	--
	percent lost	24.8	22.7	25.2	26.2	21.3	25.3	--	24.2
	volume produced	595	613	631	655	708	835	958	--
Eugene	volume sold	575e	--	617e	629	689	820	894	--
	percent lost	3.4	--	4.1	4.0	2.7	1.8	6.7	3.8
	volume produced	423.7	441.0	428.4	404.9	359.8	367.0	416.0	--
Forest Grove	volume sold	317.0	337.5	310.6	323.0	306.2	367.4	402.3	--
	percent lost	25.2	23.4	27.5	20.2	15.0	0.0	3.3	16.4
	volume produced	88.0	89.7	101.0	94.8	--	118.2	--	--
McMinnville	volume sold	70.1	73.7	75.2	70.4	--	88.0	--	--
	percent lost	20.4	17.8	25.5	26.2	--	25.5	--	23.1
	volume produced	3745	4445	4780	5497	5427	5886	6001	--
Salem	volume sold	2997	3628	3588	3605	3909	4263	4572	--
	percent lost	19.8	18.3	24.8	33.3	28.0	27.4	23.7	25.0
	volume produced	--	--	--	--	--	--	--	--
Sweet Home	volume sold	--	--	--	--	--	--	--	--
	percent lost	--	28.7	--	--	--	--	--	28.7

Volumes for Eugene and McMinnville are in millions of cubic feet; for Corvallis, Forest Grove, and Salem, in millions of gallons.