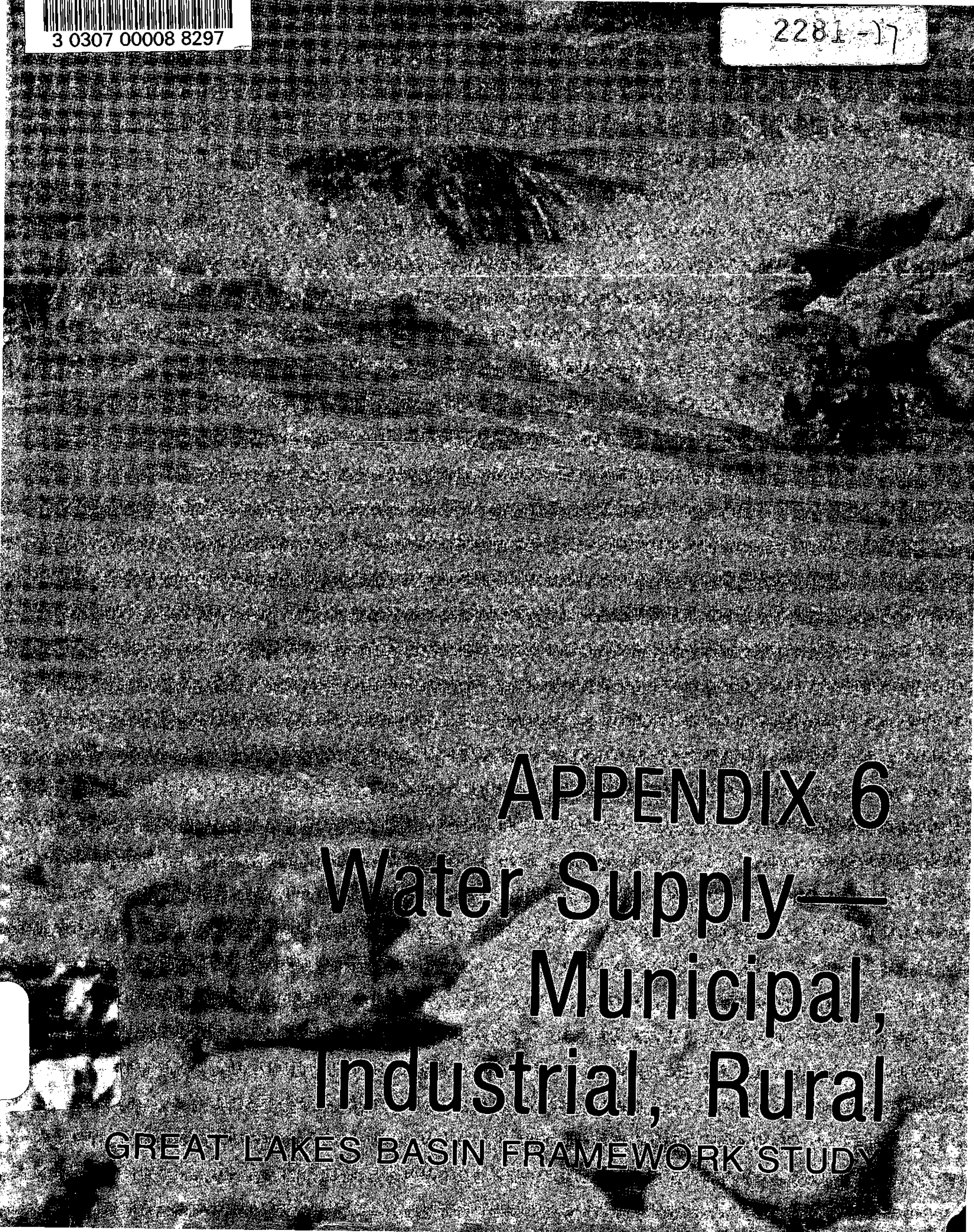

APPENDIX 6
Water Supply— Municipal, Industrial, Rural

GREAT LAKES BASIN FRAMEWORK STUDY

Great Lakes Basin Framework Study

APPENDIX 6

WATER SUPPLY—MUNICIPAL, INDUSTRIAL, AND RURAL

GREAT LAKES BASIN COMMISSION

Prepared by Water Supply Work Group

Sponsored by Water Supply Section

U.S. Environmental Protection Agency, Region V

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Cover photo by Kristine Moore Meves.

This appendix to the *Report* of the *Great Lakes Basin Framework Study* was prepared at field level under the auspices of the Great Lakes Basin Commission to provide data for use in the conduct of the Study and preparation of the *Report*. The conclusions and recommendations herein are those of the group preparing the appendix and not necessarily those of the Basin Commission. The recommendations of the Great Lakes Basin Commission are included in the *Report*.

OUTLINE

SYNOPSIS

Appendix 6, *Water Supply—Municipal, Industrial, and Rural,* is concerned with quantitative requirements for water used by communities, manufacturing industries, and rural residents of the Great Lakes Basin. Although water quality is important as a determinant of water sources, types of water treatment to be applied, and the ultimate uses to be made of water, the quality of water available for these uses has not been assessed in this appendix. Instead, it has been assumed that the quality of water, if it has not been a constraint to use in the past, generally will not restrict the use of the Basin's water resources in the future.

Each of three uses—municipal, industrial, and rural—has been studied and is reported separately. Municipal water supply includes communities of all sizes that are served by central water service systems. Municipal supply and uses, which are reported as the sum of all requirements, are also reported in two major user categories: domestic-commercial, and industrial.

Industrial water supply pertains only to manufacturing industries and does not include electric power generation by public or privately owned utilities. Under the Standard Industrial Classification System (SIC), manufacturing is classified under the major industry groups SIC 19 through SIC 39. This study is addressed to the activities of industries in those groups. Approximately 10 percent of the total manufacturing water supply needs in the Great Lakes Basin are now supplied by municipal systems. The remaining 90 percent is self-supplied. The fact that the manufacturing sector as a whole is relatively self-sufficient in meeting its water requirements is ample justification for studying this sector separately from the municipal supply. In addition, separate discussion of this subject is justified by the size of its total requirements, the variety of its uses of water, and the practice and feasibility of recycling water in manners not adaptable to domestic use.

Rural water use covers the farm and rural nonfarm uses of water not supplied through central systems. Irrigation water requirements are not included in this study and are reported separately in Appendix 16, *Irrigation.* Rural communities, farms, and isolated rural dwellings on small plots of land comprise this user category, which includes domestic and commercial uses and the watering of yards, gardens, and livestock.

For the 1970 base year, withdrawal requirements for the three user categories in the Great Lakes Basin are estimated to be 4,300 million gallons per day (mgd) for the municipal users, 500 mgd for rural users, and 11,800 mgd for industrial users. Approximately 1,200 mgd of the industrial requirement is believed to be provided by municipal systems, while the remainder is self-supplied.

By the year 2020, municipal withdrawal requirements are projected to be approximately 9,200 mgd, rural requirements approximately 740 mgd, and industrial requirements approximately 12,800 mgd. In developing the projections of the water withdrawal requirements for municipal and rural water use, it has been assumed that the rural population will remain constant. All increases in population and the attendant water needs would be met by municipal water systems. Changes in per capita water use in the rural and municipal projections should also reflect the increased use of water-using home appliances with increasing affluence, as well as improvements in water systems management.

Projections of the industrial water requirements are based on estimates of the growth of the sector and its large water-using industries. These projections are strongly influenced by projections of the impact of government and industry actions to abate environmental pollution. It is assumed that industry will attempt to reduce or recover costs related to pollution control, and that recirculation and reuse of water in the manufacturing plants will become a common practice. The assumption that industry groups in the Great Lakes Basin will recirculate their water by 2000 at rates at least equal to the highest recirculation rates presently practiced by similar groups is applied in the development of projected requirements for future years. As a consequence, water requirements for industry are projected to decline for some industry groups and planning subareas during the midterm projection period. Eventually all withdrawal requirements will begin to rise again when industrial production gains begin to outpace the economies in water use that can be realized through recirculation. For most plan areas this event may occur around 2000.

Water consumption by the three user categories is also assessed and projected. In this appendix, consumption is the estimated quantity of water that becomes unavailable for immediate reuse in a river basin as a result of its domestic use, its incorporation in farm produce and manufactured products, evaporation, transpiration, and other losses. Consumptive losses are estimated by using the difference between withdrawals and discharges of water and general assumptions that relate climatic factors to water use and storage.

In 1970, consumptive losses from municipal, industrial, and rural use were estimated at 1,400 mgd in the Great Lakes Basin. Approximately 60 percent of the losses resulted from industrial usage. By the year 2020 approximately 7,600 mgd of water should be consumed, of which 80 percent will be used by manufacturers.

Although the consequences of increasing consumptive losses were not investigated in the study preceding this appendix, it is noted in this report that consumption may be highly relevant to future planning.

FOREWORD

The Water Supply Section of the Environmental Protection Agency (EPA) was assigned the task of assessing the present and future water requirements of municipal, industrial, and rural users in the Great Lakes Basin. The U.S. Department of Commerce, Bureau of Domestic Commerce, and the U.S. Department of Agriculture, Economic Research Service, were responsible for preparing the industrial water-use assessments and projections. The U.S. Department of Agriculture prepared the rural water-use assessments and projections.

Members of the Water Supply Work Group represented various agencies of the eight Basin States, seven Federal agencies, municipal governments, and industrial associations.

Acknowledgements are extended to Robert Brewer of the U.S. Department of Commerce, Bureau of Domestic Commerce, for his effort in the preparation of the industrial water-use sections of the appendix and for general assistance. Acknowledgements are also extended to Gordon Anderson of the Michigan Department of Natural Resources, who contributed much time and effort in preparing the section on alternative possibilities related to future water-use prospects and a portion of the section discussing methodology. The contributions of Lee Christensen of the U.S. Department of Agriculture, Economic Research Service, were of great value in the preparation of the rural water-use sections of the report.

The assistance from the staff of the U.S. Environmental Protection Agency, Water Supply Section, Region V, was invaluable in the preparation of this appendix.

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INTRODUCTION

The objective of this appendix is to prepare a comprehensive appraisal of water supply requirements for municipal, industrial, and rural sectors, so as to outline characteristics of projected water supply problems, and to suggest general solutions. Municipal, industrial, and rural water uses have been assessed for the base year, 1970, and projected to the years 1980, 2000, and 2020.

This appendix includes current and projected water supply requirements for municipal, industrial, and rural water-using sectors of the Great Lakes Basin. A water supply report for each of the five plan areas and water use projections for each of the 15 planning subareas are also included.

The work is based entirely on State and Federal reports and file data. No new information on water supplies was collected. The Water Supply Work Group has prepared projections for water-use requirements by using economic, demographic, and water resource projections reported in other appendixes of the *Great Lakes Basin Framework Study*. Water-use requirements were also based on an analysis of present and historical factors, and institutional and legislative changes affecting water use in the Great Lakes Basin.

The Framework Study is a broad guide to the best use or combination of uses of water and related land resources of the Great Lakes Basin in order to meet short- and long-term needs. This appendix contains an analysis of the present situation and a projection of water-use demands for 1980, 2000, and 2020, based on economic and demographic projections.

Economic projections of population and employment used in this appendix were taken from Appendix 19, *Economic and Demographic Studies*, and unpublished data from the Office of Business Economics and the Economic Research Service (OBERS). Other data were obtained from Appendix 2, *Surface Water Hydrology*, and Appendix 3, *Geology and Ground Water*.

Section 1

METHODOLOGY

1.1 Municipal Water Supply Requirements

1.1.1 Introduction

Although the Great Lakes Region occupies only four percent of the nation's area, it accounted for approximately 15 percent of the United States population from 1940 to 1970. Population density for the region is four times the national average. There is considerable variation between Lake basins in population distribution and urban-rural balance. The Lake Michigan and Lake Erie plan areas have accounted for approximately 46 and 39 percent of the total population for the Great Lakes Basin in the period from 1940 to 1970. The remaining 15 percent of Basin population is distributed as follows: Lake Ontario, 9 percent; Lake Huron, 4 percent; and Lake Superior, 2 percent.

Most of the 29 million people in the Great Lakes Basin live in urban port areas along the lower Great Lakes. Major urban complexes accounting for a dominant share of the Region's population include Milwaukee, Wisconsin; Chicago, Illinois; Gary-Hammond, Indiana; Detroit, Michigan; Cleveland, Ohio; and Buffalo, New York. More than 80 percent of the population is classified as urban. The land in the northern and inland portions of the Basin is more sparsely populated than the southern counties situated along or near the Great Lakes shoreline.

Several urbanized areas around the world deserve the title of megalopolis, a unified grouping of urban and metropolitan clusters interconnected by numerous ties, usually in a linear formation. However, this interconnection does not involve the continuity of the built-up area, which may well be distributed over widely separated clusters within each megalopolis. The megalopolis is functionally interconnected by multiple ties of transportation, communication, public utilities, and economic and social links. Ten megalopoles that fit this preliminary definition will someday exist throughout the world. It is anticipated that one of the more important of these will develop in the Great Lakes Basin.

The concept of the emerging Great Lakes megalopolis has some interesting implications in relation to water resources management and an evaluation of public water supply needs during the next 50 years. One of the major problems in public water supply is the existence of multiple small water treatment operations, each of which is generally inadequate to perform its task of providing an economical, safe, and efficient water supply. The promotion and planning of regional water supply systems would eliminate some of the problems in the emerging urban cluster of the Region from Buffalo to Milwaukee.

Regionalization of public water systems is the grouping of water supply systems within a regional area for management purposes and, when feasible, for physical connection and integration for supplementation of supply and services. Regional water supply systems would insure efficient and economical use of available supplies and would minimize problems of water quality. It is recognized that in some areas the existing political and social structure could inhibit the development of regional water supply system.[38]

The benefits of regional organization for the purpose of water supply management, waste disposal, and storm drainage facilities have been realized in several areas of the Basin. In Detroit a 1,200 mgd intake tunnel in Lake Huron has been constructed to serve as the source for a regional system to meet water supply needs in the southeastern Michigan area through the year 2000.[13]

Other regions in the Basin have formulated similar plans for regional water-use management. Multipurpose regional water resources management plans have been developed for northeastern Illinois,[48] northeastern Ohio,[30] and northwestern Ohio,[47] and each contains regional water supply systems as an integral part of the plan.

It is only in the recent past that problems of water resources management have become of major concern to metropolitan areas. Institutional arrangements that were designed for an agricultural society have proven ineffective in meeting the needs of the emerging urban complexes, and new institutional entities must be created to meet the demands of the 21st century. Innovative approaches to solving the resource problems and needs of an urban society are now being attempted in some areas of the Basin in efforts to cope with these problems.[48] It is anticipated that similar approaches will be required as various agricultural regions in the Great Lakes Basin become heavily urbanized.

Future population increases in major metropolitan areas will tend to accelerate the need for and the trend to regionalization of water supply developments. No longer will the typical community be able to go its own way, but it will look instead to a major regional development in the establishment of its water supply. Because an adequate water supply is necessary for the economic growth and development of an area, regional systems will play a dominant role in any water resources management plan that emerges as a solution to ease the growing pains of a metropolitan area.

Estimates of municipal and domestic daily per capita water use for a typical community in the U.S. portion of the Great Lakes Region are shown in Table 6–1. Domestic water use can be broken down as follows: 41 percent, flushing toilets; 37 percent, washing and bathing; 6 percent, kitchen use; 5 percent, drinking water; 4 percent washing clothes; 3 percent, general household cleaning; 3 percent, watering lawns and gardens; 1 percent, washing cars.[53]

In addition to meeting domestic demands, municipalities use water for fire protection, street cleaning, public swimming pools, irrigation of lawns and gardens, heating and air conditioning, removal of offensive and potentially dangerous wastes from households (sewage) and industry (industrial wastes), and industrial and commercial needs. A typical municipality is served either by a private or public water utility.

Commercial establishments in a community often support a sizeable portion of the local economy and require varying quantities of water. Hotels, office buildings, shopping centers, restaurants, food processors, laundromats, and service stations are some of the many commercial establishments that use water from a municipal water supply system.

Figures 6–9 through 6–13 show that the quantities of water used by industry vary widely. Water withdrawals are affected by many factors, such as cost and availability of water, industrial wastewater disposal requirements, management, and the type of process employed. Major industrial water users include producers of primary metals, petrochemical products, pulp and paper products, beverages, textiles, chemicals, and food. In many instances industries develop their own water supply systems, and under these circumstances they impose no demand on the local municipal system.

TABLE 6–1 Municipal Water Use (gallons per capita daily)

Class of Usage	Quantity: Normal Range	Quantity: Average
Domestic	20 to 90	55
Commercial	10 to 130	20
Industrial	20 to 80	50
Public	5 to 20	10
Water unaccounted for	5 to 30	15
Total	60 to 250	150

Source: Fair, Geyer, and Okun, Elements of Water Supply and Wastewater Disposal, 1971.

The source of water determines the nature of the collection, purification, and distribution works. Sources of water and their development may be classified as follows:[54]

(1) rain water

(a) from roofs, stored in cisterns for small individual supplies

(b) from larger, prepared caches, stored in reservoirs for large communal supplies

(2) surface water

(a) from streams, natural ponds, and lakes of adequate capacity, by continuous draft

(b) from streams with adequate flood flow; by intermittent, seasonal, or selective draft of clean floodwaters; and storage in reservoirs adjacent to the stream or otherwise readily accessible to the stream

(c) from streams with inadequate dry-weather flow but adequate annual discharge; by continuous draft made possible through the storage of the necessary proportion of flows in excess of daily use in an impounding reservoir created by a dam thrown across the stream valley

(3) ground water

(a) from natural springs

(b) from wells

(c) from infiltration galleries, basins, or cribs

(d) from wells or galleries and possible springs. Flow that is increased by water from another source can be spread on the surface of the gathering ground, carried into charging basins of ditches, or led into diffusion galleries or wells.

(e) from wells or galleries. The flow is maintained by recharging the ground with the water previously removed from the area for cooling and related purposes.

Water withdrawals may differ between cities having nearly the same populations. An area supporting industries that are heavy users of municipally supplied water, such as the pulp and paper industry, would have a much greater withdrawal rate than a comparably populated area without heavy industrial water users. The quantities delivered in U.S. communities are similar to the values shown in Table 6–1, but with wide variations, because of differences in climate; standard of living; extent of sewerage; type of mercantile, commercial, and industrial activity; cost of water; availability of private water supplies; quality and availability of water for various uses; distribution-system pressures; extent of meterage; system management; and population.

The total water withdrawn from a municipal supply for domestic, industrial, commercial, and public use divided by the population served is a measure of average water use, commonly expressed as gallons per capita daily (gpcd). The average per capita water use within the Great Lakes Basin in 1970 was approximately 183 gpcd, ranging from approximately 202 gpcd in Planning Subarea 2.2 (Chicago-Milwaukee) to approximately 121 gpcd in Planning Subarea 3.1 (the northern portion of Michigan's Lower Peninsula). The national average within the conterminous United States in 1965 was approximately 157 gpcd.[46] A review of the many factors influencing municipal water use offers some insight into the wide variation in per capita usage in the Great Lakes Basin.

1.1.2 Forecasting Municipal Water Use

Projections of municipal water requirements are based primarily upon population forecasts and projections of per capita trends in the rates of municipal water use by domestic, commercial, public, and industrial users. These projections are often based upon many of the factors discussed in the preceding section.

Population projections for the Great Lakes Basin are presented in Appendix 19, *Economic and Demographic Studies*.[15] The population projections were prepared as a part of a program of national economic analysis and projection instituted under the aegis of the U.S. Water Resources Council and performed by the Office of Business Economics of the U.S. Department of Commerce and the Economic Research Service of the U.S. Department of Agriculture. This is referred to as the OBERS program. The OBERS population projections were presented by planning subarea, and were based on a continuation of national economic development.

Water-use forecasts are difficult to formulate because of the numerous variables that influence use. Various water-use management programs, land-use changes, and technological advances can individually or in combination drastically influence future municipal water-use requirements. However, thorough analysis of the effects of variation in water-use management programs, land-use changes, and technological advances on municipal water demands is limited by the small amount of available data.

To adequately determine future municipal water-use requirements, historical and present water-use data on a per capita basis were thoroughly analyzed. Projections are conditional because current problems may be eliminated through project action.

Numerous water and related land resources planning studies in areas within and adjacent to the Great Lakes Basin were researched to estimate the domestic and commercial daily per capita usage factor. In these planning studies, engineers, economists, social scientists, and regional planners have analyzed several interrelated variables and determined future rates of per capita usage of water.

Although broad variations in per capita usage may exist in the Great Lakes Basin, a general rate of change can be applied in this appendix. The gallons per capita daily (gpcd) domestic and commercial water usage was assumed to change at the rate of 1 percent per year to 108 gpcd, above which the rate of increase of 0.25 percent per year was applied until a maximum of 130 gpcd was attained.

An exception to this rule occurs in the Chicago area (Planning Subarea 2.2), where per capita water usage is expected to decrease because of improved leak detection techniques. The domestic and commercial per capita water usage factor in the Chicago service area was assumed to decrease at the rate of 0.67 gpcd per year to the year 2020.[40]

It was assumed that present and future population increases will continue to be served for the time of this study (1970 to 2020).

Conversely the population currently not served by municipal water supply systems has not been projected to be served in the future. However, an increased percentage of the population will be served by central municipal systems because population generally is increasing in the water service areas that were studied. This is consistent with the trend towards increased urbanization and the extension of central municipal water supply systems to serve new areas in the Great Lakes Basin.

To determine if a water supply need exists, or when such a need will occur, each planning subarea must be evaluated for projections of future water requirements, capabilities of existing water supplies, and ongoing programs in a particular planning subarea.

Because industrial water use varies, projections for municipal water-use demands cannot be accurately forecast on the basis of the product of the projected population served by a municipal water supply system and the daily per capita usage factor. However, it was considered justifiable on a broad-scale planning subarea basis to assume that industry would continue to use the same proportion of total municipally supplied water for the duration of the study as it used in 1970. The amount of industrial water used in 1970 was subtracted from the average demand for individual supplies to obtain the domestic and commercial average daily demand and per capita water-use factor. This figure was then used for forecasting municipal water-use requirements for the projected years 1980, 2000, and 2020.

For communities where specific information on industrial development and related water use was not available, it was assumed that a per capita water-use factor greater than 100 gpcd was due to industrial water users. The excess was credited to industrial water users and subtracted from the total municipal average demand to obtain the domestic and commercial average demands. Exceptions were made for areas known to State personnel as not having any significant industrial water users, but a per capita usage of greater than 100 gpcd.

Municipally supplied industrial water use for 1970 was determined by summarizing individual supply data. Projections were calculated by using an assumed constant ration of municipally supplied industrial water use to domestic and commercial municipal water use.

The maximum monthly demands for municipal water use in 1970 were obtained by summarizing maximum monthly demands as reported by individual systems in the basin or region being studied. This figure was converted to millions of gallons per day. To make projection systems without maximum monthly demand data the average daily demand during the months of maximum demand was estimated to be 1.2 times the average daily demand during the year.

The maximum daily demand for municipal water use in 1970 and for future years under consideration was derived in a similar way, except that when data were unavailable, peak daily demands were estimated to be 1.5 times the average daily demand for the year.

Consumptive loss of water is water lost through evaporation or transpiration, incorporation with products or crops, or removal from the Basin's water resources.

Consumption of domestic and commercial municipal water supply was assumed to average 10 percent, and the consumed portion of the industrial water supply was determined from the Bureau of Domestic Commerce, U.S. Department of Commerce, projections of industrial water requirements.

An estimate of the total capacity of currently developed municipal water sources is given for each planning subarea. The method used to obtain these estimates varied according to the judgment of State participants in this study. Source capacity reported for some planning subareas is the total design capacity for all existing water treatment plants, but for other planning subareas the developed source capacity was considered equal to the maximum day demand estimate for 1970. This method is based upon three observations. It is a generally acknowledged principle that water supplies should be designed to meet maximum day demands for target years. Actual shortages are usually remedied promptly. Most communities, especially those relying on wells, ordinarily operate at nearly total capacity and expand as the need arises.

Municipal water supply capacity should be increased when demand exceeds supply, when existing facilities become inoperative, or when it is economically expedient to increase excess capacity units rather than deferring construction until it is needed.

Needs are defined as future requirements (resulting from increases in population and economy) for development of water supply facilities beyond the capacity that currently exists or the capacity that is programmed for development (without additional authorization). In practice it has seemed reasonable and convenient to estimate these additional capacity needs indirectly by considering them to be equal to the projected municipal water demands of the area's total increase in population and the accompanying increases in commercial and industrial activity. In Planning Subarea 1.2, where declines in population were projected, it was assumed that the portion of the total population that was served municipally would remain constant throughout the projection period.

In an area as large as a planning subarea, it is normal that some communities will approach their facility capacity and will have to plan for new facilities; that other communities will have some excess capacity; and that still other communities will install new excess capacity that can fulfill more than is immediately needed. To project conservatively on the basis of past experience, it is assumed that water capacity in future years will be similar in local abundance, adequacy, and imminent need across any sizeable area. Therefore, at any projected time, an apparent cushion of excess capacity will necessarily exist over any planning subarea as a whole. However, this cushion is an aggregate of local surpluses, and cannot be used by the planning subarea as a whole. Therefore, it will not significantly reduce the need for additional capacity elsewhere in the planning subarea. Consequently where population continues to grow, additional needs for municipal water supply capacity for a large area have been projected by assuming that there would be continued presence of excess capacity in future years.

Additional capacity is assumed necessary for the water needs of net population growth since 1970, and an intermediate maximum month estimate of water used was developed to reflect possible water conservation practices, staggered timing of peak demands over large areas, and any other conditions that may tend to make maximum day values an unrealistically high estimate of demand. Future capacity needs for a planning subarea in a target year can be calculated for each source of supply (the Great Lakes, inland surface waters, and ground water) from the following equation:

$$N = \frac{[(gpcd)\quad(f)\quad(\triangle P)]}{10^6} \qquad (1)$$

where,

N = future capacity needs in the target year (mgd)

gpcd = daily per capita water use factor

f = two-significant-digit water-use coefficient given by the following product, f = ab (dimensionless)

a = (daily water use, maximum monthly/average daily use)

b = (total municipal use/domestic-commercial use)

$\triangle P$ = additional population from the base year 1970 to the target year, projected to be served by municipalities (thousands)

This relationship, which is independent of the base year source capacity, is applied for each source of water supply so that the total future needs of a planning subarea in a given target year are the sum of the needs for each of the sources. Thus, total future needs in a given target year can be expressed by the following equation:

$$N_T = N_{GL} + N_{IS} + N_{GW}$$

where,

N_T = total future needs (mgd)

N_{GL} = needs for Great Lakes source (mgd)

N_{IS} = needs for inland lakes and streams (mgd)

N_{GW} = needs for ground water (mgd)

A sample calculation of total future needs is given to clarify the water supply needs projections that are presented for each planning subarea. Refer to Table 6–67 for the values that appear in the example.

Sample Calculation of Total Future Needs for the Year 2000 in Planning Subarea 2.4

Source	P_{1970}	P_{2000}	(gpcd)	a	b	f
GL	169.8	298.9	122.6	(52.7/43.9) = 1.2	(43.9/36.7) = 1.2	1.4
IS	25.9	37.4	122.6	(6.6/ 5.5) = 1.2	(5.5/ 4.6) = 1.2	1.4
GW	92.1	30.8	122.6	(22.6/19.1) = 1.2	(19.1/16.0) = 1.2	1.4

N_{GL} = [(122.6) (1.4) (298.9–169.8) (10^3)]/10^6 = 22.2 mgd

N_{IS} = [(122.6) (1.4) (37.4– 25.9) (10^3)]/10^6 = 1.0 mgd

N_{GW} = [(122.6) (1.4) (130.8– 92.1) (10^3)]/10^6 = 6.6 mgd

N_T = 22.2 + 2.0 + 6.6 = 30.8 mgd

In this way the measure of additional municipal water supply capacity needed is taken as a function of the net population increase. Implicit in this method of computation is a decrease in the total capacity cushion for each planning period by an amount equal to the added future water use by the existing (1970) population in the area plus the capacity attributed to present and future facilities that become outmoded and require replacement. Because future population growth may be concentrated in communities with existing excess water supply capacity, such an implied reduction of the need for extra capacity contains an element of realism. Also, this effect is in general agreement with the observation that as an area matures, the rate of population growth and per capita water use normally tend to level off and stabilize, and with the corollary observation that as the rate of growth decreases, the amount of needed excess capacity or cushion becomes less.

Data concerning present municipal water supply use in each planning subarea were obtained from the records of State and local organizations and the U.S. Environmental Protection Agency Water Supply Section. The data were compiled and used to forecast municipal water use requirements by Water Supply Work Group representatives from State water supply and water resource agencies.

As the data on municipal water use in the Great Lakes Basin were compiled and analyzed, it soon became apparent that the data from some areas were more complete than from others. When more detailed information was available for a particular planning subarea, it was substituted for the computation methods.

1.2 Projected Cost Estimates for Municipal Water Supplies

1.2.1 Summary

The guidelines state, "General cost estimates for broad components of the framework plan will be of reconnaissance quality and detail based primarily on experience in the study region."[24] Estimated costs for municipal water supply include costs of conveying the supply to, but not including, the distribution system. As directed by the Water Resources Council, the costs of water treatment are included in the cost estimates reported in this appendix. The estimated costs are those of developing, operating, maintaining, and replacing municipal water supply intakes or wells, low lift pumping stations, water transmission lines, and water treatment facilities.

To prepare estimates of the costs incurred in the development of municipal water supply facilities for the time period of this study, it was necessary to review available data pertaining to the cost of developing facilities in the Great Lakes Basin and to determine unit cost figures. Unit cost estimates (roughly, the cost of establishing the capacity for, and continuing to provide, one mgd of new municipal water supply) were calculated for the development of surface- and ground-water supplies, including capital costs, annual operation, maintenance, and replacement costs.

The cost estimates presented in this appendix are the expenditures required for construction, operation, maintenance, and replacement of new facilities to satisfy projected needs in municipal water supply. The municipal needs and associated costs are related only to the additional water use resulting from population increases and economic growth within the municipal water-using sector of the region. Cost estimates do not include the cost of debt financing, water distribution systems, development of surface water reservoirs, or the expenditures incurred for the operation, maintenance, and replacement of water supply facilities constructed prior to the base year, 1970.

Expenditures incurred for the normal operation, maintenance, and replacement (OMR) of existing water supply facilities are not reflected in the cost estimates in this appendix. Rather, these reported costs reflect expenditures resulting from the development of additional municipal water supplies. Therefore, to present a more realistic outlook of costs required for municipal water supply facilities, the following discussion of expenditures required for the OMR of existing water supply facilities is presented.

It is estimated that $255,450,000 will be needed to provide additional water supplies between 1970 and 1980 in Michigan, or $25,545,000 per year. During 1970, a year of average activity, $87 million of projects were proposed, of which $48 million was for water mains and $39 million for other water system improvements. If it is assumed that $25,545,000 was included in the "other system improvements" it can be concluded that the $14 million difference was spent on replacement of existing facilities. This is a substantial addition—14/25 or 56 percent of the sum estimated for new or additional sources. It is also evident that a second additional amount of money is spent for water distribution mains —48/25 or 192 percent of the costs estimated in this study.[64]

Operation, maintenance, and replacement costs of existing municipal water supply facilities in Michigan can be assumed to be representative of OMR costs in the other Basin States because Michigan represents a substantial portion of the Great Lakes Basin. Using the information presented for the State of Michigan, an estimate of the expected costs of replacement for new or additional facilities and for water distribution mains can be calculated for any of the planning subareas. Estimated capital expenditures presented in this report must be averaged on an annual basis in order to obtain estimates of monies expended for replacement and water distribution mains. For Planning Subareas 2.3, 3.2, and 4.1, published information contains cost data for the construction, operation, and maintenance of long-distance water mains for the transfer of water resources within the Basin.[13] The costs of providing for this transfer are considered part of the projected costs associated with additional water use as a result of new growth. These costs have been included in the estimates for these three planning subareas.

All cost estimates are adjusted to the January 1970 price level. The adjustment is based on an average of Handy-Whitman Water Utility Construction Cost Indexes in the North Atlantic and North Central Divisions[25] and the *Engineering News-Record* Construction Cost Index[19] (Table 6–5).

The unit cost for the development of surface- and ground-water supplies (apart from long-distance pipeline costs) was estimated by assuming the following:

(1) The cost for the water supply intake tower and dewatering conduit is approximately 7.5 percent of the total reservoir project cost.[11]

(2) The cost of electric energy is $0.02 per kWh.

(3) The average total head pumped against is 200 feet for surface water supplies. Appendix 3, *Geology and Ground Water*, presents computations of ground water pumping costs assuming continuous pumping with lift at 70 percent of available drawdown.

(4) The average transmission distance is 0.25 miles for surface-water supplies and 1,000 feet for ground-water supplies.

(5) Water treatment includes coagulation, sedimentation, filtration, and disinfection for surface-water supplies, and iron removal, softening, and disinfection for ground-water supplies.

(6) Water treatment plant capacity averages 10 mgd for surface-water supplies and 5 mgd for ground-water supplies.

A summary of the computed unit cost estimates for the development of municipal water supply facilities is presented in rounded figures in Table 6–2.

TABLE 6–2 Summary of Unit Costs Required for the Development of Municipal Water Supplies (dollars per mgd)

Source	Capital	Annual OMR
Surface Water	299,000	29,800
Ground Water		
Wells and Pumping	(See Figure 6-4 for estimates for each Lake Basin)	
Transmission and Treatment	120,000	7,600
Long distance transport ($/mgd-mile)	6,500	220

1.2.2 Rationale

To derive unit cost estimates for the development of municipal water facilities, it was necessary to review available information pertaining to costs of municipal water supplies in the Great Lakes Basin. The primary reference sources were technical letters published by the Illinois State Water Survey (references 1 through 4) discussing the costs of developing municipal water supply facilities. The Proceedings of the Eighth Sanitary Engineering Conference, "Cost Aspects of Water Supply," at the University of Illinois, were also used as reference material in preparing the unit cost estimates. A detailed derivation of the unit costs of developing 1 mgd of municipal water supply facilities is presented in the following sections.

1.2.2.1 Development of Surface Water Supply Facilities

(1) Inland Lakes and Streams—Intake Structure

Van Praag has shown that cost for the water supply intake tower and dewatering conduit runs between 9 percent and 38 percent of the total reservoir project cost.[11] An analysis of six reservoirs in the Great Lakes Region (assuming 7.5 percent) has shown the following average costs of the intake structure and de-

TABLE 6–3 January 1970 Reservoir Costs

Sponsor	Reservoir Project	Total Cost: Capital $ million	Total Cost: OMR $1000/yr.	Water Supply Cost: Capital: Report $ million	Water Supply Cost: Capital: 7.5% total $ million	Water Supply Cost: OMR $1000/yr.
CoE	Louisville (Wabash R., Ind.)	36.8	413.8	5.0	2.8	17.8
CoE	Helm (Wabash R., Ind.)	28.7	325.1	6.5	2.2	26.7
CoE	Big Walnut (Wabash R., Ind.)	46.5	654.0	11.3	3.5	26.7
CoE	Big Blue (Wabash R., Ind.)	37.1	482.6	2.8	2.8	7.6
CoE	Downeyville (Wabash R., Ind.)	42.8	397.5	15.6	3.2	36.8
CoE	Utica (Licking R., Ohio)	42.9	248.3	10.6	3.2	8.3
	Totals	234.8	2539.3	51.8	17.7	123.9

Sponsor	Reservoir Project	Water Supply Allocation mgd	Water Supply Capital $ million	Costs/mgd OMR $1000/yr	Water Supply Capital Costs/mgd excluding storage $ million*
CoE	Louisville (Wabash R., Ind.)	27.7	0.18	0.64	0.10
CoE	Helm (Wabash R., Ind.)	36.7	0.18	0.73	0.06
CoE	Big Walnut (Wabash R., Ind.)	84.9	0.13	0.31	0.04
CoE	Big Blue (Wabash R., Ind.)	29.6	0.09	0.26	0.09
CoE	Downeyville (Wabash R., Ind.)	82.3	0.19	0.45	0.04
CoE	Utica (Licking R., Ohio)	28.0	0.38	0.3	0.11
	Average		0.18	0.43	0.06

*The cost for intake tower and dewatering conduit (i.e. excluding storage) were computed as being 7.5 percent of the total project cost.

Source: "Handy-Whitman" Water Utility Plant Cost Indexes and "Engineering-News Record" Construction Cost Index.

watering conduit (Table 6–3): capital cost, $60,000; annual OMR cost, $400/yr (Table 6–4).

(2) Great Lakes Source—Intake Structure

Richardson analyzed the costs of subaqueous intakes constructed into the Great Lakes.[68] The cost figures expressed in dollars per inch of diameter per foot at 1968 price levels were checked against the costs of five more recent intakes constructed into Lakes Michigan and Winnegago (Wisconsin) and found to be in general agreement. To arrive at dollar costs per mgd, the following assumptions were made: the intake length into the Great Lakes would be 4,000 feet; and the velocity within the intake would be five feet per second. The capital cost was increased from 1968 to 1970 price levels and determined to be $30,000 per mgd, not including the shorewell which will be covered in the pump costs. Economies of scale play a leading role in Great Lakes intake costs and the intakes are invariably designed for greater capacity and longer time periods than the other facilities. In fact, the annual OMR cost for these intakes would be only $200 per year.

(3) Pumps

Crawford[11] has given estimated cost for

TABLE 6–4 Summary of Unit Costs Required for the Development of Municipal Surface-Water Supplies (dollars per mgd)

	Capital	Annual OMR
Intake	60,000	400
Pumps	11,000	14,200
Transmission	12,000	240
Treatment	216,000	15,000
Total	299,000	29,840

pumps and their contract installation. If pump capacity is three times average annual demand, the pump cost for a 3-mgd pump capacity is $3,300. An additional cost of $5,000 is assumed for pump-related piping, electrical work, and housing. The costs have been adjusted to reflect January 1970 cost levels:

capital cost: 1.35 ($3,300 + $5,000) = $11,000

assume 20 percent of the capital cost expenditure as the annual OMR costs: $/yr = 0.20 ($11,000) = $2,200/yr

Included in the annual OMR costs are the annual costs of providing electric power to operate the pumps. The assumptions made in deriving the annual pumping costs were:

(a) rate of pumping, 694.4 gpm
(b) cost of electric energy, $0.02 kWh
(c) total head pumped against, 200 ft
(d) wire-to-water efficiency, 50 percent

The annual costs of providing power for pump operation are derived from the following general relationship given by Ackermann:[2]

Cost of pumping 1,000 gallons per year:

$/yr = (value from Figure 6–1 for wire-to-water efficiency of 50 percent) × (cost/kWh) × (total head/100 ft) × (quantity desired/1000 gpm) × (5.256 × 10^5 min/yr)

The annual costs of providing power for pump operation, assuming the conditions stated previously, is given by

$$\$/\text{yr} = (\text{kWh}) \times \frac{(\$)}{(\text{kWh})} \times \frac{(\text{ft})}{(100\ \text{ft})} \times \frac{(\text{gpm})}{(1000\ \text{gpm})} \times \frac{(\text{min})}{(\text{yr})}$$

$$= (0.628) \times (0.02) \times \frac{(200)}{(100)} \times \frac{(694.4)}{(1{,}000)} \times (5.256 \times 10^6)$$

$$= \$9{,}197/\text{yr (1964 price levels)}$$

Adjusted to 1970 price levels:

$/yr = (1.35) ($9,197) = $12,000/yr

(4) Water Transmission

These basic assumptions were used in computing the unit cost estimates:

(a) pipe diameter = 10 inches
(b) transmission distance = 0.25 mile
(c) right-of-way cost = $0.50/ft
(d) transmission pipe cost (installed) = $33,000/mile

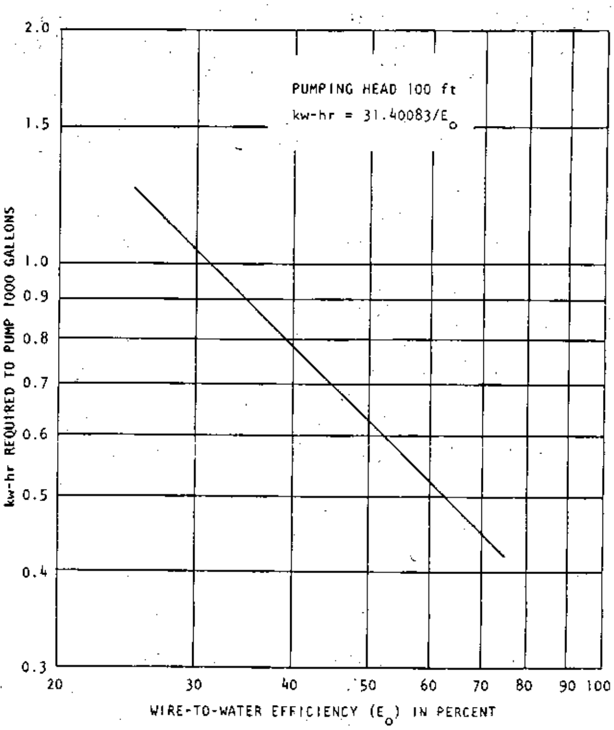


FIGURE 6–1 Wire-to-Water Efficiency in Percent

Source: W. C. Ackermann, "Technical Letter 7, Water Transmission Costs," Illinois State Water Survey, Urbana, Illinois, July 1968.

Costs derived for 1964 price levels:

transmission line cost: ($33,000/mi) (0.25 mi) = $8,250

right-of-way cost: ($0.50/ft) (0.25 mi) (5,280 ft/mi) = $660

total capital cost: $8,910

Cost adjusted to January 1970 level:

capital cost: 1.35 ($8,910) = $12,028

annual OMR cost: assume 2 percent of the capital cost expenditure as the annual OMR cost: $/yr = .02 ($12,028) = $240/yr

(5) Water Treatment

The following basic assumptions were used in computing the cost estimates for water treatment:

(a) Basic water treatment includes coagulation, sedimentation, filtration, and disinfection as unit processes.

(b) Water treatment plant capacity is rated at 10 mgd.

Figure 6–2 shows that the water treatment plant investment cost will be approximately $1.6 million for a 10 mgd plant. Figure 6–3 shows that the cost of a 10 mgd plant is approximately $0.061/1000 gal for treatment. The total cost of producing 1,000 gallons of water consists of 50 percent capital investment cost, and 50 percent annual operation, maintenance, and replacement cost.[4] Unit costs are adjusted to 1970 price levels.

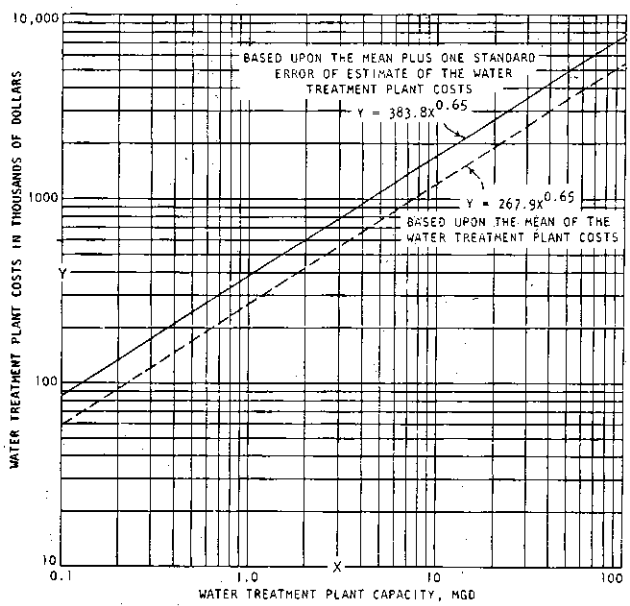


FIGURE 6–2 Investment Costs for all Types of Treatment of Surface Waters

Source: W. C. Ackermann, "Technical Letter 11, Cost of Water Treatment in Illinois," Illinois State Water Survey, Urbana, Illinois, October 1968.

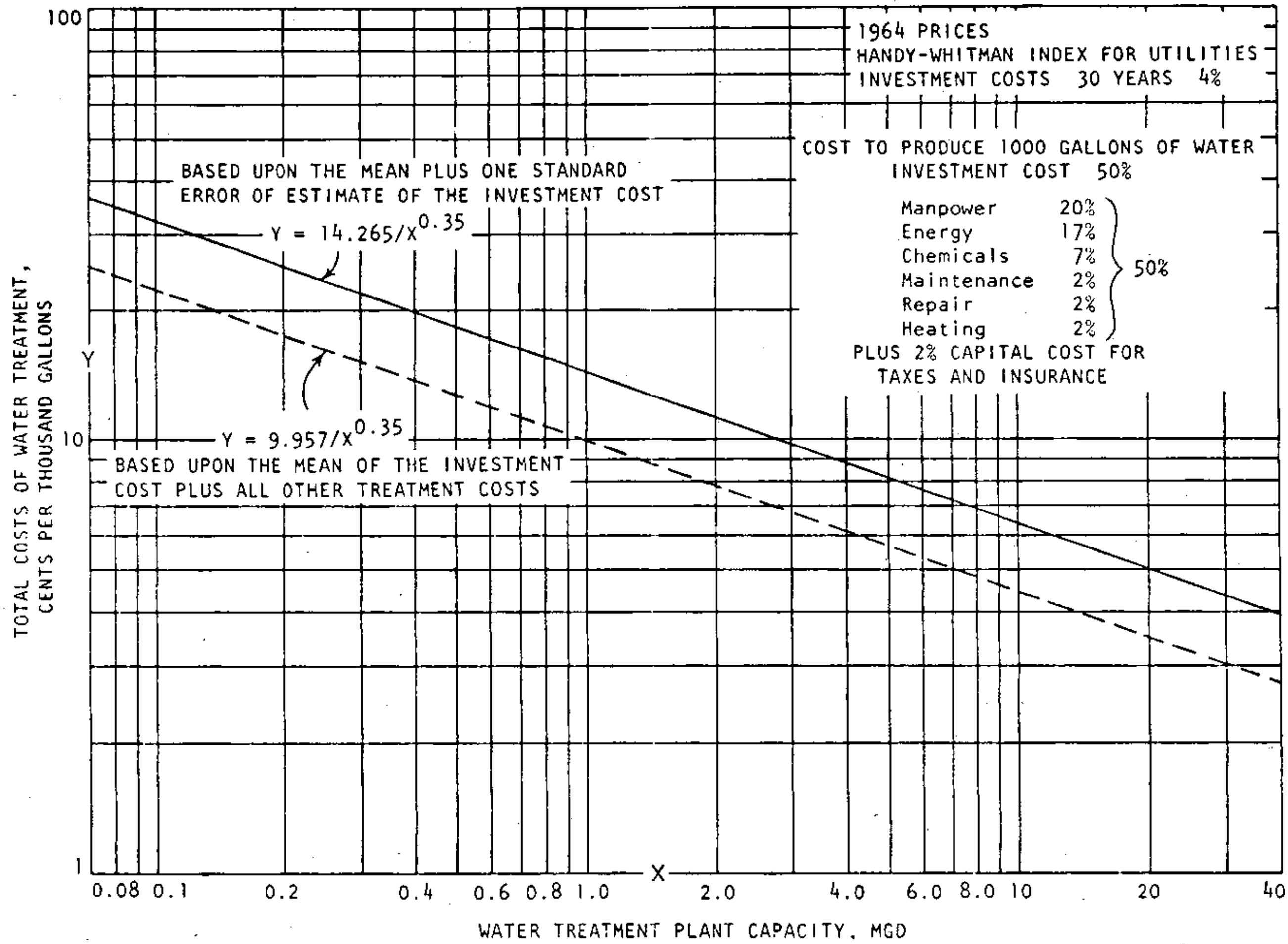


FIGURE 6–3 Surface-Water Treatment Costs

Source: W. C. Ackermann, "Technical Letter 11, Cost of Water Treatment in Illinois," Illinois State Water Survey, Urbana, Illinois, October 1968.

capital cost: (1.35) ($1.6 × 10^6) = $2.16 × 10^6
per 1 mgd: $216,000
annual OMR cost: $\$/\text{yr} = (0.50)\ \frac{(\$0.061)}{1000\ \text{gal}}\ (10 \times 10^6\ \text{gpd})\ \frac{(365\ \text{day})}{\text{yr}}\ (1.35) = \$150{,}000/\text{yr}$
per 1 mgd: $15,000

(6) Long Distance Transport of Water Supply

Cost estimates for long distance transport of large quantities of water were derived from the Detroit Metropolitan Water Services development program.[13] Information included total cost, design capacity, diameter, length of a number of large transmission lines, overall annual pumping costs, average head provided, and the design head loss in transmission systems. Construction costs for large transmission lines are $10,560/inch (diam) mile. From the data available, the following cost figures were used to prepare estimates:
capital cost: $6,500/mgd-mile
annual OMR cost: $220/mgd-mile

1.2.2.2 Development of Ground Water Supply Facilities

(1) Well and Pumping Costs

Appendix 3, *Geology and Ground Water*, presents cost estimates of developing ground water in each of the five Lake basins of the Great Lakes Basin (Figure 6–4). The well costs shown in Figure 6–4 include the total cost of drilling and providing the pumps needed to produce 1 mgd. The annual OMR costs of pumping ground water are also presented in Figure 6–4. A summary of unit cost required for the development of municipal ground

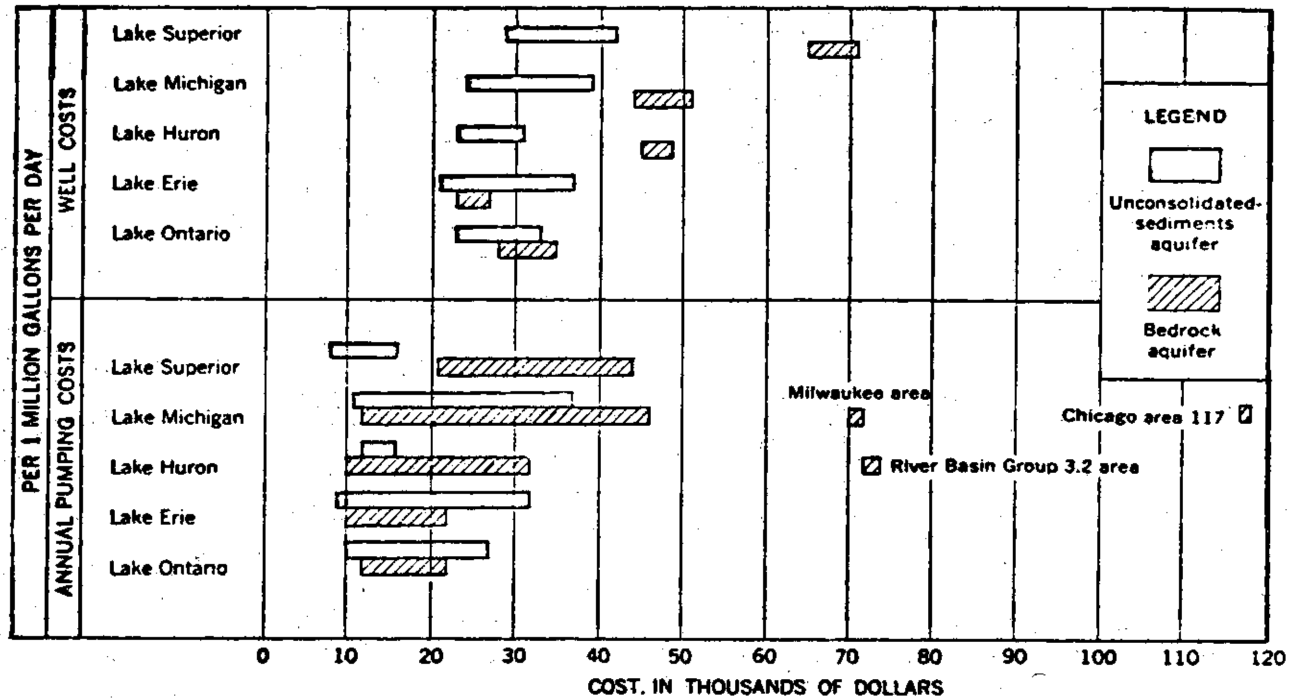


FIGURE 6–4 Cost of Producing Ground Water in the Great Lakes Basin

Assumptions:

(1) Number of wells needed to produce 1 mgd is based on 60 percent of the maximum yield range for typical high-capacity wells.

(2) A test well is needed for each production well in unconsolidated and carbonate aquifers.

(3) Well depths are based on 75 percent of the maximum well depth of the range for all wells.

(4) Pump costs are based on 70 percent of the available drawdown with the pump intake 10 feet off the bottom of the well or the top of the screen.

(5) Pumping costs are based on 50 percent wire-to-water efficiency, electric power at 2 cents per kWh, and continuous pumping with lift at 70 percent of available drawdown. (See text explanation in Appendix 3, *Geology and Ground Water*.)

(6) Transmission-line costs for well house to distribution system are not included. (The 1970 total costs are estimated to be $11.00 per foot of 10-inch line.)

(7) Operations and maintenance costs are not included, but they generally are estimated at 2 percent of capital costs.

Source: Appendix 3, *Geology and Ground Water, Great Lakes Basin Framework Study.*

water supplies is given in Table 6–5. A summary of municipal water supply cost indices is presented in Table 6–6.

(2) Water Transmission

The following basic assumptions were used in computing the unit cost estimates:

(a) pipe diameter = 10 inches
(b) transmission distance = 1000 ft
(c) right-of-way cost = $0.50/ft
(d) transmission pipe cost = $33,000/mi

Costs derived for 1964 price levels:

transmission line cost (installed): ($33,000/mi) × (1000 ft) × (1 mi/5280 ft) = $6,250

right-of-way cost: ($0.50/ft) × (1000 ft) = $500

total capital cost: $6,750

Costs adjusted to January 1970 levels:

capital cost: 1.35 ($6,750) = $9,100

annual OMR cost: assume 2 percent of the capital cost expenditure as the annual OMR cost: $/yr = 0.02 ($9,100) = $200/yr

TABLE 6–5 Summary of Unit Costs Required for the Development of Municipal Ground-Water Supplies (dollars per mgd)

	Capital	Annual OMR
Wells and Pumping	(See Figure 6-4)	
Transmission	9,000	200
Treatment	111,000	7,400
Total	120,000	7,600

TABLE 6–6 Municipal Water Supply Cost Indices

Year	Handy-Whitman[25] Average Index	Handy-Whitman[25] Ratio (1) of 1970 to:	Engineering News-Record[19] Construction Index	Engineering News-Record[19] Ratio (2) of 1970 to:	Average of Ratios 1 & 2
Jan. 1950	198	2.12	509.62	2.57	2.35
Jan. 1960	259	1.62	811.84	1.61	1.62
Jan. 1965	332	1.27	947.56	1.38	1.33
Jan. 1966	344	1.22	987.94	1.32	1.27
Jan. 1967	359	1.17	1039.05	1.26	1.22
Jan. 1968	372	1.13	1107.37	1.18	1.16
Jan. 1969	388	1.08	1216.13	1.08	1.08
Jan. 1970	420	1.00	1308.61	1.00	1.00

(3) Water Treatment

The basic assumptions used in computing the unit cost estimates were:[4]

(a) Treatment of ground-water supplies includes iron removal, softening, and disinfection.

(b) Ground-water treatment plant capacity is rated at 5 mgd. For a water treatment plant rated at 5 mgd, the investment cost is approximately $410,000 (Figure 6–5). The total costs of water treatment are approximately $0.03 per 1,000 gallons for a 5-mgd plant. The total cost is 50 percent investment cost and 50 percent annual OMR cost.[4] The following costs are adjusted to January 1970 price levels:

capital cost: 1.35 ($410,000) = $555,000

per 1 mgd: 555,000/5 = $111,000

annual OMR cost: $\$/yr = (0.50)\ \underline{(0.03)}$ / 1000 gal

$(5 \times 10^6 \text{ gpd})\ \underline{(365 \text{ day})}/\text{yr}\ (1.35) = \$36{,}960/\text{yr}$

per 1 mgd: 36,960/5 = $7,500/yr

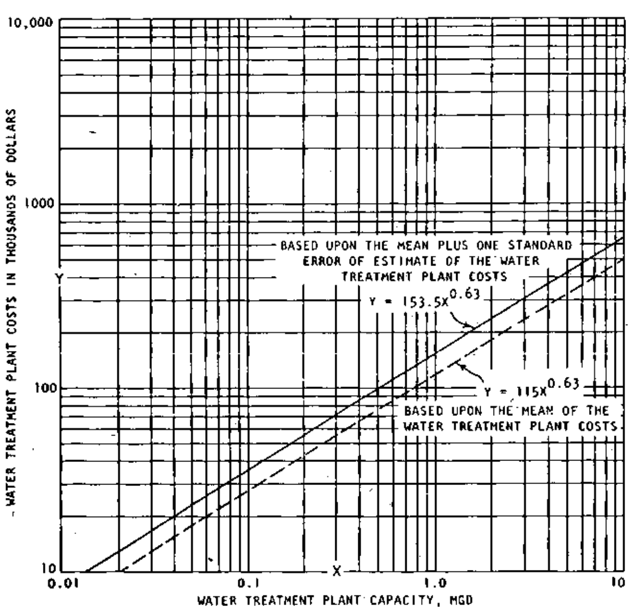


FIGURE 6–5 Investment Costs for all Types of Treatment of Ground Water

Source: W. C. Ackermann, "Technical Letter 11, Cost of Water Treatment in Illinois," Illinois State Water Survey, Urbana, Illinois, October 1968.

1.2.3 Computation Method

A set of equations has been derived to show the methodology used to estimate capital OMR and total OMR costs required to satisfy the needs projected for those functional elements being considered in the Framework Study. An estimation of one portion of municipal water supply costs is used as an example.

It should be emphasized that these costs apply to facilities constructed after 1970. Thus, OMR costs presented in this appendix do not relate in any way to the OMR costs for facilities constructed before 1970.

Costs have been estimated for a given time period in the following manner:

$$C_i = (N_i - N_{i-1}) \times U \qquad (2)$$

$$AOMR_i = \tfrac{1}{2}(N_i + N_{i-1}) \times P \qquad (3)$$

$$OMR_i = AOMR_i \times (Y_i - Y_{i-1}) \qquad (4)$$

where i is an integer corresponding to the target year of interest ($i = 1, 2, 3$). The target year 1980 would be the end of the first time period, and the subscript, i, would be $i = 1$. The same reasoning would apply to target years 2000 and 2020, where $i = 2$ and $i = 3$, respectively. The base year, 1970, is denoted by a zero subscript.

The variables of interest and their respective units are:

C_i = capital costs estimated for a given time period of study from the $i^{th}-1$ year to the i^{th} target year ($)

N_i = needs projected for a given time period of study from the base year to the i^{th} target year (mgd)

U = unit capital cost of developing the water supply facility ($/mgd)

$AOMR_i$ = annual operation, maintenance, and replacement costs estimated for a given time period of study from the $i^{th}-1$ to the i^{th} target year ($/yr)

P = unit annual OMR cost of supplying needed additional water ($/mgd-yr)

OMR_i = total operation, maintenance, and replacement costs estimated for a given time period of study from the $i^{th}-1$ year to the i^{th} target year ($)

Y_i = the i^{th} target year

The total capital cost incurred for a given time period in the development of a raw water source is obtained by multiplying the incremental need projected for each source category (Great Lakes, inland lakes and streams, or ground water) for that time period by the unit capital cost of development.

The annual OMR cost incurred by supplying the needed additional water to a municipality for a given time period is obtained by multiplying the average incremental need projected for each source category by the unit annual OMR cost. It should be noted that the methodology accounts for the annual OMR cost associated with water supply facilities constructed in the previous time period and still in use in the specified time period of interest. As mentioned elsewhere, annual OMR costs pertaining to capacity existing in 1970 are excluded from this study.

The total OMR costs incurred during any given time period in the delivery of needed additional water to a municipality is obtained by multiplying the annual OMR costs computed for the given time period by the number of years in that time period.

The cumulative costs of developing the necessary municipal water supply facilities from the base year 1970 to the i^{th} target year are estimated by simply adding the costs estimated for the given time periods. This can be described by the following set of equations, where i = 1:

$$\sum^{3} C_i = C_1 + C_2 + C_3 \quad (5)$$

$$\sum^{3} AOMR_i = AOMR_1 + AOMR_2 + AOMR_3 \quad (6)$$

$$\sum^{3} OMR_i = OMR_1 + OMR_2 + OMR_3 \quad (7)$$

The variables are identical to those described previously and the symbol $\sum$ indicates the summation of the estimated incremental costs over the time period of the study from the base year to the target year of interest.

The costs estimated to meet the needs of municipal water supplies in the three target years are divided into three raw water source categories: Great Lakes, inland lakes and streams, and ground water. This set of equations was used to calculate the cost estimates for each type of source. The unit cost figures for capital cost and annual OMR costs are constant for the development of surface water supplies for the Great Lakes Basin, but they vary from one planning subarea to another for the development of ground water. Figure 6–4 reflects this variance and presents the unit costs for the development of ground water in each Great Lakes basin.

1.2.3.1 Illustrative Example of Cost Estimate Computation

Table 6–7 presents a sample computation of the costs estimated to meet the projected needs of municipal water supplies from all sources in Planning Subarea 2.4. A detailed example is also presented to demonstrate the methodology used in calculating the cost estimates presented in Table 6–7 and in this appendix. In this example the costs incurred for the Great Lakes surface-water source for Planning Subarea 2.4 are computed for all time periods.

In the example the total capital, annual OMR, and the total OMR costs are estimated. These costs are required to meet the needs from the Great Lakes surface-water source in Planning Subarea 2.4 projected for the time periods 1970 to 1980, 1980 to 2000, 2000 to 2020, 1970 to 2000, and 1970 to 2020.

Given: Cumulative needs

N_1 = 6.4 mgd (1970 to 1980)
N_2 = 22.2 mgd (1970 to 2000)
N_3 = 48.6 mgd (1970 to 2020)

Unit capital cost (U): = $299,000/mgd

TABLE 6–7 Sample Computation of Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Planning Subarea 2.4

Source	Cost	Unit Cost ($/mgd)	Needs (mgd) 1970-1980	Needs (mgd) 1970-2000	Needs (mgd) 1970-2020	Estimated Costs (million 1970 $) 1970-1980	Estimated Costs (million 1970 $) 1980-2000	Estimated Costs (million 1970 $) 2000-2020	Estimated Costs (million 1970 $) 1970-2000	Estimated Costs (million 1970 $) 1970-2020
Great Lakes	Capital	299,000				1.91	4.72	7.89	6.63	14.53
	Annual OMR	29,800	6.4	22.2	48.6	0.095	0.43	1.05	0.52	1.57
	Total OMR	29,800				0.95	8.52	21.09	9.47	30.57
Inland Lakes and Streams	Capital	299,000				.24	.36	.42	.60	1.02
	Annual OMR	29,800	0.8	2.0	3.4	.01	.04	.08	.05	.13
	Total OMR	29,800				.12	.83	1.61	.95	2.56
Ground* Water	Capital*	153,000				.26	.75	.67	1.01	1.68
	Annual OMR	35,300	1.7	6.6	11.0	.03	.15	.31	.18	.49
	Total OMR	35,300				.30	2.93	6.21	3.23	9.44

* GW Unit cost assumptions are as follows:

	Capital Cost ($/mgd)	Annual OMR ($/mgd-yr)
Transmission	120,000	7,600
Wells & Pumping	33,000	27,700
Total	153,000	35,300

Unit Annual OMR Cost (P): = $29,800/mgd-yr

1970 to 1980

$$\begin{aligned} C_1 &= (N_1) \times U \\ &= 6.4 \times 299{,}000 \\ &= \$1.91 \text{ million} \\ AOMR_1 &= \tfrac{1}{2}(N_1) \times P \\ &= \tfrac{1}{2}(6.4) \times 29{,}800 \\ &= \$0.095 \text{ million/yr} \\ OMR_1 &= AOMR_1 \times (Y_1 - Y_0) \\ &= 0.095 \times (1980\text{–}1970) \\ &= \$0.95 \text{ million} \end{aligned}$$

1980 to 2000

$$\begin{aligned} C_2 &= (N_2 - N_1) \times U \\ &= (22.2 - 6.4) \times (299{,}000) \\ &= \$4.72 \text{ million} \\ AOMR_2 &= \tfrac{1}{2}(N_2 + N_1) \times P \\ &= \tfrac{1}{2}(22.2 + 6.4) \times (29{,}800) \\ &= \$0.43 \text{ million/yr} \\ OMR_2 &= AOMR_2 \times (Y_2 - Y_1) \\ &= 0.43 \times (2000\text{–}1980) \\ &= \$8.52 \text{ million} \end{aligned}$$

2000 to 2020

$$\begin{aligned} C_3 &= (N_3 - N_2) \times U \\ &= (48.6 - 22.2) \times (299{,}000) \\ &= \$7.89 \text{ million} \\ AOMR_3 &= \tfrac{1}{2}(N_3 + N_2) \times P \\ &= \tfrac{1}{2}(48.6 + 22.2) \times (29{,}800) \\ &= \$1.05 \text{ million/yr} \\ OMR_3 &= AOMR_3 \times (Y_3 - Y_2) \\ &= 1.05 \times (2020\text{–}2000) \\ &= \$21.09 \text{ million} \end{aligned}$$

1970 to 2000 ($i = 1$)

$$\begin{aligned} \sum^{2} C_i &= C_1 + C_2 \\ &= 1.91 + 4.72 \\ &= \$6.63 \text{ million} \end{aligned}$$

$$\begin{aligned} \sum^{2} AOMR_i &= AOMR_1 + AOMR_2 \\ &= 0.095 + 0.43 \\ &= \$0.52 \text{ million/yr} \end{aligned}$$

$$\begin{aligned} \sum^{2} OMR_i &= OMR_1 + OMR_2 \\ &= 0.95 + 8.52 \\ &= \$9.47 \text{ million} \end{aligned}$$

1970 to 2020 ($i = 1$)

$$\begin{aligned} \sum^{3} C_i &= C_1 + C_2 + C_3 \\ &= 1.91 + 4.72 + 7.89 \\ &= \$14.53 \text{ million} \end{aligned}$$

$$\begin{aligned} \sum^{3} AOMR_i &= AOMR_1 + AOMR_2 + AOMR_3 \\ &= 0.095 + 0.43 + 1.05 \\ &= \$1.57 \text{ million/yr} \end{aligned}$$

$$\begin{aligned} \sum^{3} OMR_i &= OMR_1 + OMR_2 + OMR_3 \\ &= 0.95 + 8.52 + 21.09 \\ &= \$30.57 \text{ million} \end{aligned}$$

1.2.4 Federal Assistance Available for the Development of Municipal Water Supply Facilities

Federal loans and grants will undoubtedly be important to the development of municipal water supply in the Basin. Although it is not possible to determine the portions of Federal and non-Federal costs without analyzing each individual project, the following description and summaries of Federal assistance programs reveal the existing policy.

Financial assistance for the development of municipal water supplies is available to qualified municipalities through grant programs of three Federal agencies. The U.S. Department of Agriculture assists rural areas through the Farmers Home Administration (FHA), the U.S. Department of Commerce assists underdeveloped regions through the Economic Development Administration (EDA), and the Department of Housing and Urban Development (HUD) offers financial assistance to qualified municipalities for the acquisition of land and the construction of facilities.

1.2.4.1 Farmers Home Administration

FHA administers a program of loans and grants to public and nonprofit organizations to help rural residents plan and develop domestic water supply systems in rural areas. To reduce user charges applicants may obtain development grants for up to 50 percent of the development cost of a water system. Comprehensive planning grant funds may be used for technical and professional services; salaries of technical, professional, and clerical assistants employed specifically to work on the plan; pertinent administrative costs; and necessary test wells and soil and water investigations.

Public or quasi-public bodies and nonprofit corporations serving residents of open country and rural towns and villages with populations of not more than 5,500 and that are not part of an urban area are eligible for FHA assistance when:

(1) they are unable to obtain needed credit elsewhere at reasonable rates and terms

(2) they have the legal capacity to borrow and repay money, to pledge security for loans, and to operate the facility or services installed under the loan

(3) they are financially sound and effectively organized and managed

(4) the proposed improvements will primarily serve farmers, ranchers, farm tenants, farm laborers, and other rural residents

Applications for loans and grants are made at the local county office of the FHA.

1.2.4.2 Economic Development Administration

EDA provides grants of up to 50 percent of the development cost for public facilities such as water systems. Severely depressed areas that cannot match Federal funds may receive supplementary grants of up to 80 percent of the project cost.

Loans from EDA are also available for public works and development of facility projects. These loans may cover the full cost of a project and may run for as long as 40 years, the interest being determined by government borrowing costs. A community that is unable to raise its share of the eligible project cost may receive a grant of 50 percent or more of the project cost and a Federal loan for the remainder of the cost.

States, local subdivisions thereof, Indian tribes, and private or public nonprofit organizations or associations representing a redevelopment area or an Economic Development Center are eligible to receive EDA grants and loans. Redevelopment areas located within designated economic development districts may be eligible for a 10 percent bonus on grants for Public Works Projects, but they are subject to the 80 percent maximum Federal grant limit.

Since 1966 EDA has disbursed approximately $12.8 million for development of municipal water supply facilities within the Great Lakes Basin.[66] This figure represents 55 percent of the total cost of the projects funded. These data do not include disbursement of funds in Planning Subareas 4.4, 5.1, 5.2, and 5.3.

1.2.4.3 Department of Housing and Urban Development

HUD provides grants for construction of community water facilities that are essential for efficient and orderly areawide community growth and development. HUD grants cover up to 50 percent of land and construction costs for new water facilities. The facilities must be consistent with programs for comprehensive areawide water facilities systems. Cities, towns, counties, Indian tribes, and public agencies of one or more States or one or more municipalities established to finance specific capital improvement projects are eligible for HUD grants.

The Community Resources Development Administration of HUD also administers a program that provides long-term loans to finance the construction of public works. Loans for up to 40 years and covering up to 100 percent of the project cost are made to finance the construction of water facilities. Loans are available only for those parts of a project not covered by aid provided under other Federal agency programs. Priority is given to small communities requesting assistance in constructing basic public works.

Those eligible for the HUD Public Facility Loans include local units of government such as cities, towns, villages, townships, counties, public corporations or boards, sanitary or water districts, and Indian tribes having the legal authority to build public works and issue bonds to pay for them. The applicant community must have a population of less than 50,000. In designated development areas the population may be up to 150,000. Areas near research and development installations of the National Aeronautics and Space Administration are not subject to a population limit. Nonprofit private corporations serving communities of less than 10,000 are also eligible for assistance.

During fiscal year 1971 HUD disbursed $18.7 million for water and sewer improvements to counties within the Great Lakes Basin,[57] not including Planning Subareas 4.4, 5.1, 5.2, and 5.3.

Federal funds available through FHA, EDA, and HUD are also used to help finance the construction of sewage facilities. Until now the bulk of these funds has been directed toward wastewater treatment works.

1.2.5 American Water Works Association Statements of Policy on Public Water Supply Matters Pertinent to Financing

Federally supported financing of public water supply systems, in the form of grants or loans, will undoubtedly play a part in the development of the water resources in the Great Lakes Basin. Funding by the private sector of the Basin will also be important. In this section the policy of the American Water Works Association (AWWA) that is pertinent to the financing of public water supplies is presented.

The public water supply industry in 1970 processed and served approximately 4,354 mgd of potable water to 24 million people in the Great Lakes Basin. For a long time the service has been performed largely on a self-supporting basis.

The Board of Directors has adopted and published in the 1971–1972 Annual Yearbook the following Principles of National Water Policy as the policy of the AWWA:

> The responsibility for water resources projects, of which public and industrial water supplies are a primary consideration, should rest with that echelon of government or of private interests closest to those people benefited. This broad management responsibility includes sponsoring, planning, development, financing, ownership, operation, and maintenance. The cost of such projects should be borne proportionately by those who are benefited.
>
> . . . the American Water Works Association sets forth the following principles by which the water supply industry can best meet its responsibilities to the public. These principles are consistent with the best processes of intergovernmental action in a free economy and are based on a long history of demonstrated ability of the public water supply industry to support and finance itself with a minimum of public assistance.
>
> Role of Federal Government
>
> The role of the federal government in water resource programs and projects should be supportive and cooperative not preemptive . . .
>
> The federal government should assume the initiative in development only when:
>
> (1) An economically justifiable project is of such magnitude as to be definitely beyond the capacity of local groups.
>
> (2) A project is so complex that no clearly defined local or state group or groups can be identified as principal beneficiaries.
>
> (3) The participation of the federal government is necessary to assure the maximum feasible development in keeping with a comprehensive regional or basin plan.
>
> Role of Local Agencies
>
> Historically, local entities have served the population with public water supplies, efficiently and economically. Agencies, public or private, such as water districts, cities, towns, villages, investor owned water companies, commissions, and authorities should be responsible under state law for:
>
> (1) Planning, financing, constructing, and operating system for public and industrial water supplies for all uses.
>
> (2) Managing the systems as self-sustained, utility-type enterprises.[5]

The Board of Directors has adopted the following Statement on Financing and Rates as the policy of the AWWA:

> AWWA believes that the interests of the public and of individual customers of water supply systems serving the public can be served best by self-sustained, utility-type enterprises, adequately financed, and with rates to the public and customers based on sound engineering and economic principles designed to avoid discrimination between classes of, or individual customers.
>
> Ideal Standards
>
> To this end, AWWA establishes, as an ideal toward which each water supply utility should strive, the standards set out in the paragraphs that follow:
>
> . . . (2) Such a water supply utility should receive sufficient gross revenue from those using the service to enable it to pay all operating and maintenance expenses, all fixed charges on capital investment, employ and compensate trained and competent personnel for operating and maintenance functions, and have sufficient funds to develop and perpetuate its system in accordance with sound technical and economic principles.[5]

The Board of Directors has adopted the following Statement on Practices in Organization and Management of Publicly Owned Water Utilities as the official policy of the AWWA:

> The American Water Works Association recognizes an urgent and growing need for community guidance in the choice of management for community-owned water utilities. For this reason the Association has prepared this. . ., so that communities may have the benefit of the experience of hundreds of well-run, adequately financed water utilities.
>
> Fundamental Philosophy of Organization
>
> (1) Publicly owned water utilities should be operated on a self-sustained and businesslike basis. The AWWA recognizes that water utility operations can be managed effectively under many types of organizations, however, the form of organization should be such as to identify the utility as a buisness entity. Further, the utility organization should have the responsibility of developing policies and should maintain its own funds and accounting separate from those of the governmental body.[5]

1.3 Industrial Water Supply Requirements

1.3.1 Introduction

The Great Lakes Basin is one of the most heavily industrialized of the nation's 20 water resource regions. There are approximately 49,000 factories, mills, refineries, and other manufacturing plants in the Region, and they employed four million people in 1967. This represents one-third of the total employment in the Great Lakes Basin. Manufacturing is its largest economic sector, accounting for more than 41 percent of the total earnings of the Region, and in terms of earnings, it is more than twice as large as the next largest sector, wholesale and retail trade. In addition to its importance to the Basin economy, manufacturing contributes immensely to the economic vitality of the nation. In 1967 the total value added by all U.S. manufacture was $262 billion, of which $58 billion was provided by the Great Lakes Basin manufacturing sector. Nearly 40 percent of the nation's total steel production occurs in this Region, and one of its mills is the largest in the world. The largest oil refinery, the largest food processing plants, and the numerous immense manufacturers of motor vehicles and parts are in the Region.

Although superlatives of size seem to best describe many of the manufacturing industries, the sector is comprised mainly of small establishments with extremely diversified activities and products. With few exceptions, every industrial activity found in the United States is also found in the Great Lakes Basin. In the 1967 Census of Manufactures more than 60 percent of the 48,591 manufacturing establishments in the Basin employed less than 20 persons each. However, each year during the past decade the number of small establishments has declined while the number of plants employing 20 or more persons has increased. Between 1963 and 1967, while the total number of establishments decreased from 49,123 to 48,591, the number of large plants increased by 1,748 and total employment increased by 500,000.

Every county in the Basin has some manufacturing plants, although in several counties manufacturing employment is less than 100 persons and value added by manufacture is less than $1 million per year. At the other end of the spectrum, there are 11 heavily industrialized counties, each of which recorded more than $1 billion of value added in 1967 (Table 6–8). The total value added by manufacture by those 11 counties in 1967 was $35.5 billion, or more than 60 percent of that reported for the entire Great Lakes Basin. In one of the 11, Cook County, Illinois, the value added by manufacture was greater than that of 44 of the States.

Figure 6–6 illustrates the distribution of manufacturing activity in the Region. There is a heavy concentration of manufacturing in Planning Subareas 2.2 and 2.3 at the southern end of Lake Michigan, in Planning Subareas 3.2 and 4.1 along the southwest shore of Lake Huron and the western end of Lake Erie, and in Planning Subareas 4.2, 4.3, and 4.4 along the entire southern shore of Lake Erie. These seven planning subareas account for approximately 88 percent of the total value added by manufacture of the entire Basin and approximately 90 percent of the manufacturing water withdrawals.

Contributing significantly to the development of the manufacturing sector are the Great Lakes themselves, with vast quantities of good quality water, advanced shipping systems, and port facilities. Raw materials and manufactured products are shipped between lake ports, and by way of the St. Lawrence Seaway between world ports. The excellent rail, highway, and air transportation facilities and the proximity of the Region to the large markets of the Eastern Seaboard and the Midwest have encouraged and will continue to provide impetus to the expansion of the manufacturing sector.

TABLE 6-8 Major Manufacturing Counties in the Great Lakes Basin

County	Number of Establishments	Total Employment	Total Value added by Manufacture (Million 1967 $)
Milwaukee, Wisc.	1,838	181,100	2,464.6
Cook, Ill.	11,870	831,100	11,640.4
Lake, Ind.	354	98,000	1,698.4
Genesee, Mich.	286	82,300	1,584.0
Macomb, Mich.	1,302	94,100	1,131.9
Oakland, Mich.	1,576	94,100	1,457.4
Wayne, Mich.	4,222	396,200	5,908.8
Cuyahoga, Ohio	3,658	277,300	3,911.7
Summit, Ohio	723	92,500	1,281.8
Erie, N. Y.	1,417	134,400	1,903.2
Monroe, N. Y.	946	133,000	2,564.1

Source: 1967 Census of Manufactures.

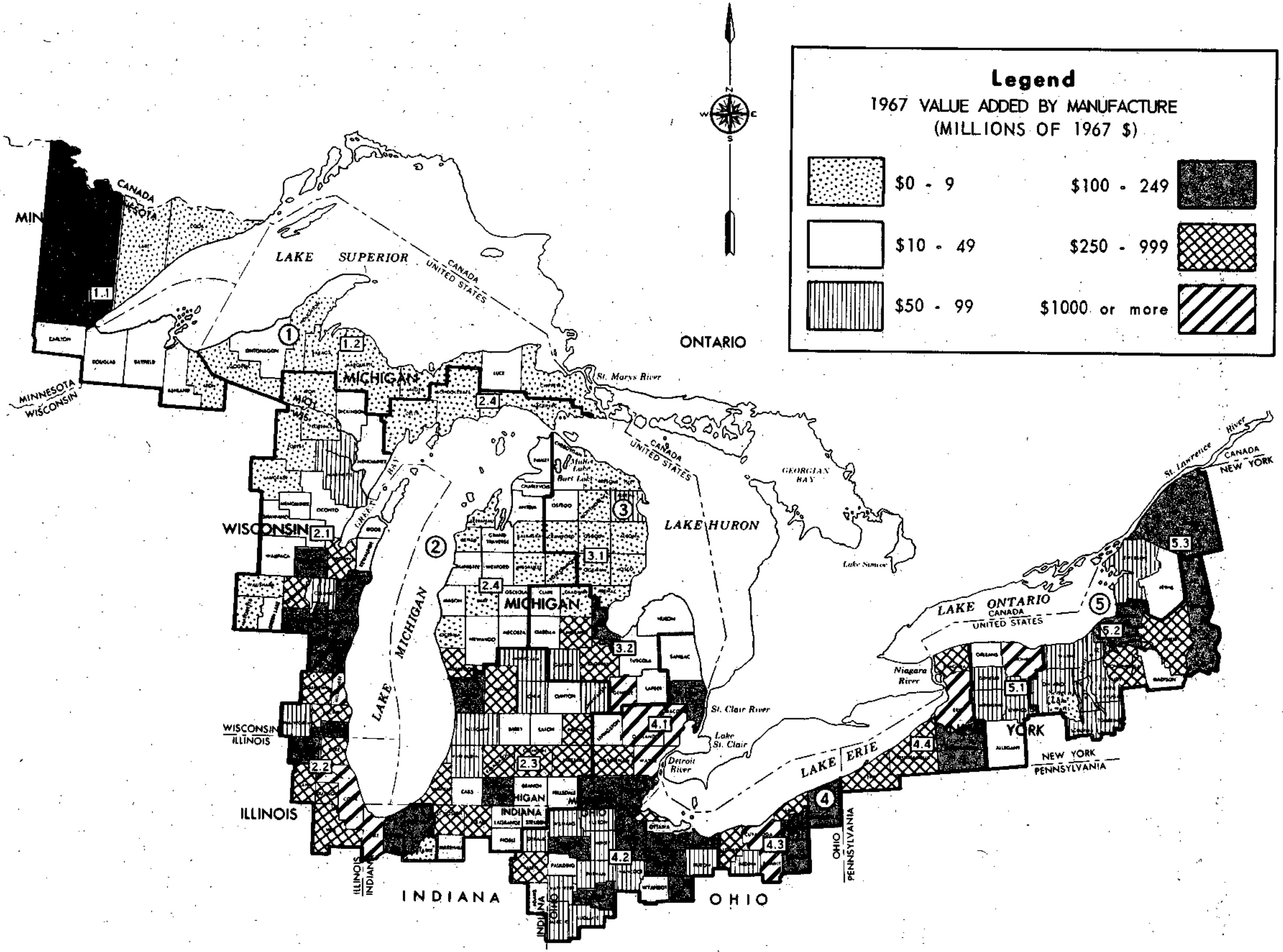
1.3.2 Forecasting Industrial Water Use

If the projected economic growth occurs, the output of the Basin's manufacturing sector, measured in terms of value added by manufacture, will be 600 percent larger in the year 2020 than in 1970. If the present relationships of water withdrawals to manufacturing output persist throughout the same period, by 2020 manufacturers in the Great Lakes Basin would withdraw nearly 80 billion gallons of water daily, or nearly twice as much water as the total U.S. manufacturing sector withdraws today. If such large quantities of water were needed, this unlikely problem would occupy the time of water and land resource planners to the exclusion of other matters. Although it is not expected that the present relationships will persist to bring about this large water demand, it is obvious that a 600 percent increase in industrial activity will have serious impact on planning effort. It is important that estimates of accompanying requirements be determined as rationally as existing data and understanding permit. The water or land resource problem, its magnitude, the time and place of occurrence, and the actions to be taken are dependent upon the method used to produce the forecast.

The forecasting of industrial water requirements is a new procedure, and it is complicated by the inadequacy of data, the lack of similarity of growth rates of industries, the introduction of new materials, products, and technology, and changes in policies and priorities assigned to social, political, and economic goals. In this study, four conventional forecasting methods were examined: two based upon employment/water-use relationships, and two based upon value added/water-use relationships. The wide array of projections that resulted from the application of the four methods led to the development of a fifth method that incorporates both employment and value-added relationships applied to new assumptions.

Very early in the study it became clear that the only relatively constant relationship that exists between water-use and manufacturing activity was the ratio of value added by manufacture to gross water use. This was to be expected because value added is a dollar statement of production, and water use would be likely to increase or decrease with the rise and fall in production. Because gross water use is the sum of the quantity of water withdrawn and the quantity recirculated, it contains a key projection parameter, withdrawal, which can be derived with relevant coefficients.

FIGURE 6–6 Industrialized Counties—Great Lakes Basin



The task of preparing the water demand projections was subdivided into the following areas:

(1) translating the Office of Business Economics (OBE) drainage area employment projections[16] into an economic output measure that would be further transformed into a value added figure

(2) discovering historic relationships between value added, gross water used, withdrawals, and consumption for the industries and geographic areas under consideration, casting their relations into numeric coefficients, and predicting future changes in the relationships

(3) combining the results of operations (1) and (2) to yield the actual volume projections.

Because the projection model was dependent on a forecast of physical production, it was necessary to rework OBE's industry employment projection series for planning subareas into an equivalent economic output series by multiplying employment by an employee productivity measure. OBE had earlier prepared long-term forecasts of employee productivity by Standard Industrial Classification (SIC) two-digit industries using a measure called economic output per employee, varied by industry and by economic area. Because the projections of industrial water use are presented by two-digit SIC codes in this appendix, a discussion and a listing of the SIC codes and their major industry group have been reproduced from the *Standard Industrial Classification Manual.* The discussion of the system codes follows this section, and a listing of the codes appears in the Addendum.

Because the economic areas do not coincide with the boundaries of the planning subareas, it was necessary to construct an economic output per employee measure for the planning subareas that incorporate segments of more than one economic area. This was done for the industries SIC 20, 26, 28, 29, and 33 (in which manufacturing water use is concentrated) by constructing an average weighted-by-county employment. The weighted productivity average was multiplied by the employment figure for each planning subarea. This economic output measure was then related to the value-added parameter. Examination of a time series of value added and gross product did not reveal any consistent trend in the relationship between these two measures. However, it did reveal important differences between the two measures. The ratio of gross product and value added by manufacture varied in time and between industries, and therefore could not be used directly as a proxy for value added by manufacture. The economic output per employee and the employment series were extrapolated between 1960 and 1970 to obtain a 1963 output figure.

In the 1963 Census of Manufactures, Volume III,[7] the Standard Metropolitan Statistical Areas (SMSAs) were grouped according to planning subarea, and information was tabulated for employment and value added for each of the SIC two-digit industries reported and for total manufacturing. SMSA statistics rather than county statistics were used because of the lack of SIC two-digit data for most counties. In each planning subarea the SMSAs accounted for a very high portion of that manufacturing employment. The ratio of value added to economic output was calculated for each plan area for each of the SIC two-digit industries present. For total manufacturing the ratio of value added for the total planning subarea to value added for the SMSAs, and the ratio of value added for the SMSA to economic output for the total planning subarea were calculated. It was then possible to convert the employment projections by plan areas into a projected value added series for each of the SIC two-digit industries in these plan areas.

Because a productivity measure was not supplied in the economic base study for the manufacturing industries other than the above-mentioned five SIC two-digit industries, it was necessary to construct one. This was achieved for the large water users by using information from the water use in manufacturing value-added-per-employee figures for other manufacturing for 1964 for the Eastern and Western Great Lakes Census Water Use Regions. A large water user was defined to include only those manufacturing establishments which had an annual intake of at least 20 million gallons per year. A similar value-added-per-employee figure was calculated for the small water-using manufacturers in the residual category of other manufacturing. Using the 1963 Census of Manufactures, a value added per employee for the small water-using establishments for other manufacturing was calculated for the United States and the Middle Atlantic and Eastern North Central Divisions by netting out the five SIC two-digit industries. The latter two geographic measures were weighted to approximate a Great Lakes value-added-per-employee figure. These factors were deflated to 1958 dollar value and projected at a 3.2 percent compound growth rate. A ratio of 0.28 was calculated as the ratio between employment of large water users in other manufacturing to total employment in other manufacturing. It was then possible to construct a value added series for this industrial category.

It should be noted that employee productivity varied considerably between the large and the small water-using establishments within the same planning subarea. As in the case of the economic output per employee for the delineated industries, the productivity measures for both large and small users in the other manufacturing category varied significantly between planning subareas.

In general the ratios for the base year of the projections were selected from the available State, regional, or national ratios that most closely reflected the industrial nature and geography of the planning subareas. These ratios were developed for the five SIC two-digit industries, other manufacturing, and total manufacturing. For some industries and regions the reliability of the data was highly questionable, and therefore there were some exceptions to this rule. The trend and value for each of these ratios were examined for each industry for various geographic areas. The ratios of gross water to value added, intake to gross water, and consumption to gross water were calculated from the source material for all of the States, the Eastern Great Lakes, the Western Great Lakes, and the Basin States.

Of the water parameters tested, gross water use retained the most constant relationship to value added. Most of the water used in production is not consumed in the production process and is available for recycling. A manufacturer's options range from adopting a completely closed system having practically no discharge with intake only to replace that which is lost in the production process through evaporation or incorporation in the product, to the once-through method, in which the intake water is neither recirculated nor cascaded into uses accepting declining quality.

In preparing the projections an attempt was made to incorporate the so-called technological factor. The magnitudes and the relative growth rate of the SIC four-digit industries within each SIC two-digit industry on a national and regional basis were examined. However, incorporation of a technological factor in industrial water projections adds to their uncertainties, because it is extremely difficult to isolate this factor from others. It was decided that technological changes would be reflected in three measures of water-use efficiency: water consumption per unit product, water intake per unit product, and gross water applied per unit product. Expected changes in applied technology altered each of these measures in both a positive and negative manner (negative changes indicating increasing efficiency). These changes can occur individually or in combination because these measures are not mutually exclusive. For example, while a decrease in gross water applied per unit product given a constant reuse factor automatically reduced water intake per unit product, a reduction in the water intake requirement per unit product as a result of increased recirculation did not necessarily reduce either of the other two measures. Each of these efficiency measures has a product and an applied technology determinant. Rather than attempt a composite technological coefficient, the Water Supply Work Group accounted for changes in water-use technology by altering each of the three measures of water-use efficiency.

For the most part, the relationship between gross water and value added held fairly constant. For some industries, such as food processing, a downward trend was indicated by recent census data. For primary metals industries, regional trends indicated a convergence at a certain value at an approximate time.

For determining water intake requirements the fundamental assumption was that future incentives such as water pollution control and cost minimization will encourage manufacturers to expand the practice of water recirculation and reuse in their plants. Water intake, then, will be a decreasing fraction of the gross water requirement, as recirculation increases. It was assumed in most cases that recirculation would be designed into new manufacturing facilities and incorporated in existing plants on such a schedule that the average plant in any industry group by the year 2000 would be reusing its intake water as much as the most efficient regional group is today. However, consumptive losses that occur in manufacturing will impose an upper limit to the amount of recirculation because consumption cannot exceed intake. The recirculation ratios were not allowed to achieve this upper limit, because it is believed that deteriorating quality conditions would limit the usefulness of the water and that the relative economics of intake water with its associated costs would be more favorable than the costs associated with additional treatment and recirculation. Another consideration was the desire to avoid the tendency to have the reuse factors reach their absolute maximum at year 2020 and the implication that all forces reach equilibrium at that magic date.

Comprehensive river basin studies are concerned with the consumption of water because depletions have a serious impact on the planned multiple uses of water in the Basin. Consumption of water, because of the physical relocation of the water in the hydrologic cycle and the uncertainty of the geographic location of its return to the water resource base, complicates the determination of levels and flows, and if losses are large they may have an effect, as yet unknown, on weather and climate. In estimating consumptive losses by manufacturing, it was noted that the ratio between gross water use and consumption has remained relatively constant. Projections were based on the maintenance of that relationship through the forecasting period, although for several industries in some planning subareas, the ratio of consumption to gross water use was increased slightly as recirculation rates for the industry increased.

1.3.3 Standard Industrial Classification System Codes for Manufacturing

The purpose of the SIC codes is explained in the following paragraphs, which appear in the *Standard Industrial Classification Manual* issued by the U.S. Bureau of the Budget:

> The Standard Industrial Classification was developed for use in the classification of establishments by type of activity in which engaged; for purposes of facilitating the collection, tabulation, presentation, and analysis of data relating to establishments; and for promoting uniformity and comparability in the presentation of statistical data collected by various agencies of the United States Government, State agencies, trade associations, and private research organizations.
>
> The Classification is intended to cover the entire field of economic activities: agriculture, forestry, and fisheries; mining, construction, manufacturing, transportation, communication, electric, gas, and sanitary services, wholesale and retail trade; finance, insurance, and real estate; services, and government.
>
> An "establishment" is an economic unit which produces goods or services—for example, a farm, a mine, a factory, a store. In most instances, the establishment is at a single physical location; and it is engaged in only one, or predominantly one, type of economic activity for which an industry code is applicable.[42]

1.4 Rural Water Supply Requirements

1.4.1 Introduction

Rural water supply requirements include domestic water requirements for nonfarm and rural farm use, and rural farm requirements for livestock, pesticide spray water, and sanitizing and cleaning water. To prepare a current assessment and projections of rural water supply requirements, the rural nonfarm category was divided into rural communities and rural nonfarm households. The rural farm category is subdivided into farm household and livestock requirements.

In rural communities, inhabitants of villages are not served by a centralized or municipal water supply. Generally, each house has its own separate supply, usually drawn from wells. Water requirements for irrigation of lawns and gardens are included.

Rural nonfarm households are composed of persons living in separate dwellings outside villages or communities. These are often close to large urban centers, with each household having its own individual water system. These separate households often include commuters who rent or own one- to five-acre plots and are engaged in limited agricultural enterprises. Wells are the most common source of water, with some springs and combination wells below reservoirs.

Rural farm household water supply requirements include all water requirements for the farm household, including watering lawns, family gardens, and noncommercial orchards. In addition, it includes water used at the farmstead, water consumed for production purposes such as washing milking parlors and equipment, cleaning farm machinery, and mixing pesticide sprays for orchards and field crops.

Rural water supply requirements for livestock include water requirements for livestock production, both on pasture and at the farm headquarters.

1.4.2 Forecasting Rural Water Use

Rural water-use budgets were developed for 1970, 1980, 2000, and 2020 (Tables 6–9, 6–10, 6–11, and 6–12). Domestic requirements were calculated by applying these budgets to projections of future population from Appendix 19, *Economic and Demographic Studies*. Similarly, livestock and spray water requirements

TABLE 6–9 Great Lakes Basin Rural, Domestic, Crop, and Livestock Basic Water Use Budget, 1970

Type of Use	Unit Size	Period of Use	Unit Use
Rural Domestic			
Family water use	1 person	365 days	50 gal/day/capita
Car and truck washing	Rural Residence		200 gal/capita
Lawn and garden	Rural Residence	10 hrs.	300 gal/hr.
Swimming pool		-	-
Hired workers and family	1 person	365 days	40 gal/day/capita
Spray Water for Disease, Insect, and Weed Control			
Vegetables and potatoes			150 gal/acre
Fruit trees			100 gal/acre
Small fruit			200 gal/acre
Corn			30 gal/acre
Soybeans, Hay & Dry Beans			20 gal/acre
Livestock			
Cows, Milk	(8,000#)	300 days	Maintenance 12 gal/day+ 1 gal/3 lbs milk
Dry cows		65 days	12 gal/day
Young stock		365 days	10 gal/day
Dairy cleaning and sanitizing		365 days	2 gal/day/cow
Liquid manure handling		-	-
Sows		365 days	3 gal/day
Pigs		180 days	1.5 gal/day
Wallow		150 days	0.5 gal/day/pig
Cleaning and sanitizing		-	-
Fogging and cooling		-	-
Laying flock + young		365 days	5 gal/day/100 hens
Egg washing		365 days	1 gal/day/100 hens
Cleaning and sanitizing		5 days	4 gal/day/100 hens
Beef cows and replacements		365 days	12 gal/day
Cattle and calves	(800#)	365 days	10 gal/day
Turkeys	(15#)	190 days	2 gal/day/100
Breeding flock		365 days	10 gal/day/100
Cleaning and sanitizing			5% of total water consumption
Sheep and lambs	(110#)	200 days	1 gal/day
Ewe flock		365 days	2 gal/day
Mortality of Young Stock*			
Dairy	5%	180 days	5 gal/day
Pigs	13%	90 days	0.8 gal/day
Chickens	10%	180 days	2 gal/day/100
Beef	5%	180 days	5 gal/day
Turkeys	10%	95 days	4.5 gal/day/100
Sheep	13%	100 days	0.5 gal/day

*Approximately 1/2 of the young stock water requirement for 1/2 the period of use.

Adapted from: Water Systems Analysis to Meet Changing Conditions, Agricultural Engineering Information Series 152, 1965, and Farm Water Systems Planning Guide, Agricultural Engineering Information Series 181, 1967, Michigan State University; Private Water Systems, Midwest Plan Service - 14, Iowa State University, 1968 and Dairy Farmstead Water Use, paper by Elmer E. Jones, USDA-ARS, Beltsville, Md., June, 1964, in consultation with Ernest Kidder, Agricultural Engineer; Michigan State University; Melville Palmer, Agricultural Engineer, Ohio State University; Donald Keech, Sanitary Engineer, Michigan Department of Public Health, and Arthur Lied, Regional Supervisor, Michigan Department of Agricultural.

TABLE 6-10 Great Lakes Basin Rural, Domestic, Crop, and Livestock Basic Water Use Budget, 1980

Type of Use	Unit Size	Period of Use	Unit Use
Rural Domestic			
Family water use	1 person	365 days	65 gal/day/capita
Car and truck washing	Rural Residence		200 gal/capita
Lawn and garden	Rural Residence	10 hrs.	300 gal/hr.
Swimming pool	(1 per 100 families)		16,030 gal + make up
Hired workers & family	1 person	365 days	55 gal/day/capita
Spray Water for Disease, Insect, and Weed Control			
Vegetables and Potatoes			100 gal/acre
Fruit trees			75 gal/acre
Small fruit			150 gal/acre
Corn			30 gal/acre
Soybeans, Hay, and Dry Beans			20 gal/acre
Livestock			
Cows, milk	(13,000#)	300 days	Maintenance 14 gal/day+ 1 gal/3 lbs milk
Dry cows		65 days	14 gal/day
Young stock		365 days	12 gal/day
Dairy cleaning & sanitizing		365 days	3.5 gal/day/cow
Liquid manure handling		365 days	0.1 gal/cow
Sows		365 days	4 gal/day
Pigs		165 days	2 gal/day
Wallow		150 days	1 gal/day/pig
Cleaning & sanitizing		180 days	1 gal/day/pig
Fogging and cooling		150 days	0.5 gal/day/pig
Laying flock		365 days	6 gal/day/100 hens
Egg washing		365 days	1 gal/day/100 hens
Cleaning & Sanitizing		10 days	4 gal/day
Beef cows & replacements		365 days	14 gal/day
Cattle and calves	(800#)	365 days	12 gal/day
Turkeys	(15#)	140 days	10 gal/day/100
Breeding flock		365 days	12 gal/day/100
Cleaning & sanitizing			5% of total water consumption
Sheep and lambs	(110#)	180 days	1.5 gal/day
Ewe flock		365 days	2 gal/day
Mortality of Young Stock*			
Dairy	4%	180 days	6 gal/day
Pigs	10%	82 days	1 gal/day
Chickens	8%	180 days	2.5 gal/day/100
Beef	4%	180 days	6 gal/day
Turkeys	8%	70 days	6 gal/day/100
Sheep	10%	90 days	0.8 gal/day

*Approximately 1/2 of the young stock water requirement for 1/2 the period of use.

Adapted from: Water Systems Analysis to Meet Changing Conditions, Agricultural Engineering Information Series 152, 1965, and Farm Water Systems Planning Guide, Agricultural Engineering Information Series 181, 1967, Michigan State University; Private Water Systems, Midwest Plan Service - 14, Iowa State University, 1968 and Dairy Farmstead Water Use, paper by Elmer E. Jones, USDA-ARS, Beltsville, Md., June, 1964, in consultation with Ernest Kidder, Agricultural Engineer; Michigan State University; Melville Palmer, Agricultural Engineer, Ohio State University; Donald Keech, Sanitary Engineer, Michigan Department of Public Health, and Arthur Lied, Regional Supervisor, Michigan Department of Agriculture.

TABLE 6–11 Great Lakes Basin Rural, Domestic, Crop, and Livestock Basic Water Use Budget, 2000

Type of Use	Unit Size	Period of Use	Unit Use
Rural Domestic			
Family water use	1 person	365 days	70 gal/day
Car and truck washing	Rural Residence		200 gal/capita
Lawn and garden	Rural Residence	20 hours	300 gal/hour
Swimming pool	(1 per 60 families)		30,000 gal + make-up
Hired workers and family	1 person	365 days	65 gal/day
Spray Water for Disease, Insect, and Weed Control			
Vegetables and Potatoes			80 gal/acre
Fruit			50 gal/acre
Small Fruit			120 gal/acre
Corn			30 gal/acre
Soybeans, Hay & Dry Beans			20 gal/acre
Livestock			
Cows, milk	(18,000#)	300 days	Maintenance 14 gal/day + 1 gal/3 lbs milk
Dry cwos		65 days	14 gal/day
Young stock		365 days	12 gal/day
Dairy cleaning & sanitizing		365 days	5 gal/day/cow
Liquid manure handling		365 days	0.5 gal/cow
Sows		365 days	4 gal/day
Pigs		155 days	2 gal/day
Wallow		150 days	0.5 gal/day/pig
Cleaning & Sanitizing		180 days	2 gal/day/pig
Fogging & Cooling		150 days	1 gal/day/pig
Laying flock		365 days	6 gal/day/100 hens
Egg washing		365 days	1 gal/day/100 hens
Cleaning & Sanitizing		15 days	4 gal/day/100 hens
Beef cows & replacements		365 days	14 gal/day
Cattle and calves	(800#)	365 days	12 gal/day
Turkeys	(15#)	125 days	12 gal/day/100
Breeding flock		365 days	14 gal/day/100
Cleaning & Sanitizing			5% of total water consumption
Sheep and lambs	(110#)	150 days	2 gal/day
Ewe flock		365 days	2 gal/day
Mortality of Young Stock*			
Dairy	3%	180 days	6 gal/day
Pigs	7%	78 days	1 gal/day
Chickens	6%	180 days	3 gal/day/100
Beef	3%	180 days	6 gal/day
Turkeys	6%	62 days	6.5 gal/day/100
Sheep	7%	75 days	1 gal/day

* Approximately 1/2 of the young stock water requirement for 1/2 the period of use.

Adapted from: Water Systems Analysis to Meet Changing Conditions, Agricultural Engineering Information Series 152, 1965, and Farm Water Systems Planning Guide, Agricultural Engineering Information Series 181, 1967, Michigan State University; Private Water Systems, Midwest Plan Service - 14, Iowa State University, 1968 and Dairy Farmstead Water Use, paper by Elmer E. Jones, USDA-ARS, Beltsville, Md., June, 1964, in consultation with Ernest Kidder, Agricultural Engineer; Michigan State University; Melville Palmer, Agricultural Engineer, Ohio State University; Donald Keech, Sanitary Engineer, Michigan Department of Public Health, and Arthur Lied, Regional Supervisor, Michigan Department of Agriculture.

TABLE 6–12 Great Lakes Basin Rural, Domestic, Crop, and Livestock Basic Water Use Budget, 2020

Type of Use	Unit Size	Period of Use	Unit Use
Rural Domestic			
Family water use	1 person	365 days	75 gal/day
Car and truck washing	Rural Residence		200 gal/capita
Lawn and garden	Rural Residence	20 hours	300 gal/hour
Swimming pool	(1 per 40 families)		30,000 gal + make up
Hired workers and family	1 person	365 days	75 gal/day
Spray Water for Disease, Insect, and Weed Control			
Vegetables and Potatoes			60 gal/acre
Fruit			30 gal/acre
Small fruit			100 gal/acre
Corn			30 gal/acre
Soybeans, Hay & Dry Beans			20 gal/acre
Livestock			
Cows, milk	(20,000#)	300 days	Maintenance 14 gal/day + 1 gal/3 lbs milk
Dry cows		65 days	14 gal/day
Young stock		365 days	12 gal/day
Dairy cleaning & sanitizing		365 days	5 gal/day/cow
Liquid manure handling		365 days	0.5 gal/cow
Sows		365 days	4 gal/day
Pigs		150 days	2 gal/day
Wallow		150 days	0.5 gal/day/pig
Cleaning & Sanitizing		180 days	2 gal/day/pig
Fogging & Cooling		150 days	1 gal/day/pig
Laying flock		365 days	6 gal/day/100 hens
Egg washing		365 days	1 gal/day/100 hens
Cleaning & Sanitizing		15 days	4 gal/day/100 hens
Beef cows & replacements		365 days	14 gal/day
Cattle & calves	(800#)	365 days	12 gal/day
Turkeys	(15#)	125 days	12 gal/day/100
Breeding flock		365 days	14 gal/day/100
Cleaning & sanitizing		-	-
Sheep and lambs	(110#)	140 days	2 gal/day
Ewe flock		365 days	2 gal/day
Mortality of Young Stock*			
Dairy	3%	180 days	6 gal/day
Pigs	5%	75 days	1 gal/day
Chickens	5%	180 days	3 gal/day/100
Beef	3%	180 days	6 gal/day
Turkeys	5%	62 days	6.5 gal/day/100
Sheep	5%	70 days	1 gal/day

*Approximately 1/2 of the young stock water requirement for 1/2 the period of use

Adapted from: Water Systems Analysis to Meet Changing Conditions, Agricultural Engineering Information Series 152, 1965, and Farm Water Systems Planning Guide, Agricultural Engineering Information Series 181, 1967, Michigan State University; Private Water Systems, Midwest Plan Service - 14, Iowa State University, 1968 and Dairy Farmstead Water Use, paper by Elmer E. Jones, USDA-ARS, Beltsville, Md., June, 1964, in consultation with Ernest Kidder, Agricultural Engineer; Michigan State University; Melville Palmer, Agricultural Engineer, Ohio State University; Donald Keech, Sanitary Engineer, Michigan Department of Public Health, and Arthur Lied, Regional Supervisor, Michigan Department of Agriculture.

were calculated on the basis of projected livestock and crop production. Irrigation water requirements are considered in Appendix 15, *Irrigation*.

1.4.2.1 Rural Nonfarm Requirements

Rural nonfarm water requirements are based on population projection and per capita domestic consumption rates. Rural nonfarm population estimates were derived by subtracting from total planning subarea population projections the estimates of farm population and the population served by municipal water systems. Per capita domestic use rates, similar to those used for rural farm domestic rates, were then applied to populations, resulting in rural nonfarm requirements.

1.4.2.2 Rural Farm Requirements

Rural farm water requirements are classified as domestic, livestock, and spray water requirements. If the water-use rate is applied to projections of each of these categories, water requirement estimates may be calculated.

Rural farm population estimates, livestock numbers, and the acreage requiring spray water are based on projections developed for Appendix 19, *Economic and Demographic Studies*.

1.4.2.3 Sources of Water

The sources of water are ground water and surface water. The primary source of rural water supply is ground water. It has been estimated that 93 percent of the rural and domestic supply in the Great Lakes Region comes from this source. The remainder comes from surface water but, of course, there is some variation between Basin States. Estimates of the percentages of water from ground water for the Basin States are: 95 percent, Michigan; 90 percent, New York and Wisconsin; 88 percent, Minnesota and Pennsylvania; 80 percent, Illinois and Indiana; and 75 percent, Ohio.

Although nearly all domestic water comes from ground water sources, livestock water is often drawn from surface water (24 percent).[62]

1.4.2.4 Consumptive Water Use

Consumptive water use is the portion of total water use that is removed from the water environment primarily through evaporation and transpiration, and is thus no longer available for use within a specific area. Consumptive use has been estimated by applying consumptive-use factors to projected rural water requirements for rural nonfarm and farm components, the latter consisting of rural domestic, livestock, and spray water uses.

Consumptive use, expressed as a percentage of water requirements, has been estimated to be 15 percent for rural nonfarm, 25 percent for domestic rural farm, 90 percent for livestock, and 100 percent for spray water.[62] It can be assumed that rural nonfarm domestic use is less than rural farm domestic use. This difference is attributed primarily to greater efficiency in the distribution and recovery systems of rural nonfarm residences.

1.4.2.5 Regional Differences in Water Requirements per Unit of Use

Rural water requirements are directly related to population and the composition of agricultural activity in a planning subarea, especially livestock numbers and cropping patterns. Both the type of farming and general climatic factors influence water use. Livestock water requirements per head are generally less in the northern planning subareas. Relatively large spray water requirements are estimated for planning subareas with large acreage in fruits, vegetables, and row crops. Greater per capita domestic requirements are projected for the more southern planning subareas. This reflects the influence of temperatures and economic activity on water requirements.

The Great Lakes planning subareas were grouped to reflect differences in per-unit requirements. A water requirement coefficient was assigned to each of the three groups to adjust the water-use requirements that had been calculated by using the water budgets. Group I includes those planning subareas where water requirements are projected to be 100 percent of those calculated using the budgets. Included are Planning Subareas 2.1, 2.2, 2.3, 3.2, 4.1, 4.2, 4.3, 4.4, 5.1, and 5.2.

Water requirements for Group II, (Planning

Subareas 2.4, 3.1, and 5.3) are projected to be 90 percent of requirements calculated using the water budgets.

Group III (Planning Subareas 1.1 and 1.3) consists of those planning subareas where climatic factors and the levels of agricultural activity are assumed to have the greatest impact on the water budget calculations. Water requirements were projected to be 80 percent of direct water budget calculations.

Section 2

SUMMARY OF GREAT LAKES BASIN WATER USE

2.1 Present and Projected Municipal Water Use

2.1.1 Great Lakes Basin

In general the northern portion of the Basin is largely rural. The southern portion is heavily industrialized and urbanized (see Subsection 1.1.1). The OBERS population projections forecast that the total population of the Great Lakes Basin will be 33.5 million in 1980, 42.3 million in 2000, and 53.5 million by 2020. This represents an 84 percent increase in population during the 50-year period of this study.

During the base year of this study, 1970, it is estimated that municipal water supplies served 4,356 mgd to meet the domestic, commercial, and industrial water-use demands of 23.6 million people in the Great Lakes Basin, an average per capita usage of 184 gpcd. Eighty-two percent of the total population of the Basin is served by municipal facilities. Municipal water supplies obtained their supply of raw water from surface water and ground water sources that accounted for the following percentages of total withdrawal: surface waters of the Great Lakes, 78 percent; inland lakes and streams, 9 percent; and ground water, 13 percent (Tables 6–13 and 6–14).

The presently developed capacity of all municipal water supply facilities for each of the sources within the Great Lakes Basin is approximately 7,409 mgd.

By 1980 municipal water supplies are expected to serve 5,217 mgd to 27.9 million people, an average per capita usage of 187 gpcd (Table 6–15). Eighty-three percent of the total population of the Great Lakes Basin will be served by municipal water supplies. Projected Basin needs resulting from additional water-use demands of new growth are estimated to be 872 mgd. From 1970 to 1980 the estimated costs of developing the necessary water supply facilities to meet the projected needs are $419 million for capital expenditures and $192 million for total OMR expenditures.

By the year 2000 municipal water supplies are expected to serve 6,950 mgd to 36.7 million people (87 percent of the Basin population), an average per capita usage of 189 gpcd. Projected needs resulting from the additional water-use demands of new growth are estimated at 2,810 mgd in the Great Lakes Basin. To meet these projected needs, it is estimated that capital expenditures of $1,085 million and total OMR expenditures of $1,416 million will be required during the period 1970 to 2000.

In 2020 municipal water supplies are expected to provide 9,196 mgd to 47.8 million people (89 percent of the Basin population), an average per capita usage of 192 gpcd. Projected needs resulting from the additional water use demands of new growth are estimated at 5,398 mgd in the Great Lakes Basin. To provide the facilities to meet these needs, it is estimated that capital expenditures of $2,001 million and total OMR expenditures of $4,229 million will be required from 1970 to 2020 (Table 6–16). In this appendix estimates of existing and potential yields of groundwater and inland surface-water resources are presented for each of the 15 planning subareas. (These planning subareas are shown in Figure 6–7.) Figure 6–8 summarizes municipal, industrial, and rural water withdrawal requirements for the planning period.

Storage capacities and storage-yield relationships were obtained from Appendix 2, *Surface Water Hydrology*, and were used to estimate the theoretical yield from existing reservoirs and watersheds that have the potential to be developed to provide on-stream surface water storage.

In Appendix 3, *Geology and Ground Water*, estimates of ground-water discharge are presented. The base flow of unregulated surface-water streams represents the outflow of the ground-water aquifer in the area. The sustained yield of the ground-water resources was estimated by the 70 percent flow duration of the surface-water streams in each planning subarea.

The information presented in each planning subarea report can be used to indicate the rel-

TABLE 6–13 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use in the Great Lakes Basin (mgd)

Use	1970				1980			
	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
Superior	48.5	126	12.5	187	54.3	104	12.8	171.1
Michigan	2,043.0	5,654	234.0	7,931	2,468.0	3,707	265.0	6,440.0
Huron	133.0	540	39.0	712	168.0	491	48.0	707.0
Erie	1,769.0	3,867	133.0	5,769	2,104.0	3,272	148.0	5,524.0
Ontario	362.0	388	52.0	802	423.0	332	62.0	817.0
Total	4,355.5	10,575	4,470.5	15,401	5,217.3	7,906	535.8	13,559.1
Consumption								
Superior	4.8	11	3.3	19.1	4.7	15	3.3	23
Michigan	191.0	486	75.0	752.0	244.0	683	91.0	1,018
Huron	11.0	34	11.0	56.0	15.0	61	16.0	92
Erie	161.0	338	39.0	539.0	222.0	466	48.0	736
Ontario	34.0	31	22.0	86.0	39.0	44	27.0	110
Total	401.8	900	150.3	1,452.1	524.7	1,269	185.3	1,979
1970 Capacity-Future Needs								
Superior	98	126	13	237	3.3	2	0.3	5.6
Michigan	3,588	5,654	234	9,477	479.0	585	31.0	1,095.0
Huron	199	540	39	778	34.0	107	8.3	149.3
Erie	3,028	3,867	133	7,028	307.0	356	15.0	678.0
Ontario	496	388	52	936	47.0	59	9.0	115.0
Total	7,409	10,575	471	18,456	870.3	1,109	63.6	2,042.9

Use	2000				2020			
	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
Superior	66.5	117	14.9	198.4	80.8	198	17	295.8
Michigan	3,227.0	3,725	323.0	7,275.0	4,218.0	6,351	362	10,931.0
Huron	251.0	428	60.0	739.0	365.0	929	72	1,366.0
Erie	2,825.0	2,695	182.0	5,702.0	3,762.0	4,642	209	8,613.0
Ontario	581.0	294	70.0	945.0	770.0	648	78	1,496.0
Total	6,950.5	7,259	649.9	14,859.4	9,195.8	12,768	738	22,701.8
Consumption								
Superior	7.9	33	4	44.9	10	61	4.2	75.2
Michigan	372.0	1,449	117	1,938.0	528	2,964	141.0	3,633.0
Huron	28.0	242	22	292.0	45	663	29.0	737.0
Erie	328.0	1,082	60	1,471.0	469	2,312	74.0	2,855.0
Ontario	63.0	102	33	198.0	90	248	39.0	377.0
Total	798.9	2,908	236	3,943.9	1,142	6,248	287.2	7,777.2
1970 Capacity-Future Needs								
Superior	13	15	3	31	25	73	4.6	102.6
Michigan	1,401	2,188	89	3,678	2,594	4,772	128.0	7,494.0
Huron	121	354	21	497	245	861	33.0	1,139.0
Erie	1,055	1,929	49	3,033	2,110	4,025	76.0	6,211.0
Ontario	220	180	18	418	424	519	26.0	969.0
Total	2,810	4,666	180	7,657	5,398	10,250	267.6	15,915.6

TABLE 6-14 Base Municipal Water Supply in the Great Lakes Basin

Planning Subarea	1970 Population Served (thousands) From Great Lakes	From Inland Lakes & Streams	From Ground-water	Total	1970 Municipal Water Use (mgd) From Great Lakes	From Inland Lakes & Streams	From Ground-water	Total	Per Capita (gpcd)
1.1	154.6	6.0	100.6	261.2	19.9	0.5	12.7	33.1	127
1.2	69.4	8.5	43.8	121.7	8.7	1.1	5.5	15.3	126
2.1	154.8	140.5	264.0	559.3	30.9	25.0	36.9	92.8	166
2.2	6,705.6	8.2	1,408.1	8,121.9	1,487.7	0.9	156.2	1,644.8	203
2.3	523.7	--	1,026.3	1,550.0	92.7	-	173.2	265.9	172
2.4	169.8	25.9	92.1	287.8	23.1	3.5	12.5	39.1	136
3.1	27.8	-	30.1	57.9	3.4	-	3.6	7.0	121
3.2	510.5	7.8	189.7	708.0	90.6	1.4	33.6	125.6	177
4.1	4,018.3	118.7	259.4	4,396.4	675.4	19.9	43.6	738.9	168
4.2	527.5	519.5	179.1	1,226.1	94.2	67.6	24.1	185.9	152
4.3	2,127.8	445.4	135.0	2,708.2	442.9	59.6	14.4	516.9	191
4.4	1,478.0	82.0	140.4	1,700.4	300.3	11.3	15.6	327.2	192
5.1	638.7	89.3	66.7	794.7	110.4	13.4	7.2	131.0	165
5.2	124.3	810.8	118.4	1,053.5	22.5	147.8	16.4	186.7	177
5.3	46.8	75.0	24.4	146.2	6.7	35.0	2.7	44.4	303
Total	17,277.6	2,337.6	4,078.1	23,693.3	3,409.4	387.0	558.3	4,354.6	184

TABLE 6-15 Base and Projected Municipal Water Supply in the Great Lakes Basin

Planning Subarea	1970 Population Served (thousands)	1970 Total Water Use (mgd)	1980 Population Served (thousands)	1980 Total Water Use (mgd)	2000 Population Served (thousands)	2000 Total Water Use (mgd)	2020 Population Served (thousands)	2020 Total Water Use (mgd)
1.1	261.2	33.1	277.8	40.0	326.1	50.8	382.7	62.9
1.2	121.7	15.3	111.4	14.3	115.3	15.7	125.9	17.9
2.1	559.3	92.8	692.4	128.9	967.8	192.9	1,336.1	280.7
2.2	8,121.9	1,644.8	9,741.0	1,946.8	12,586.8	2,440.2	16,128.0	3,065.9
2.3	1,550.0	265.9	1,922.9	344.3	2,780.7	525.9	3,885.3	773.8
2.4	287.8	39.1	342.5	47.7	467.1	68.5	637.4	97.9
3.1	57.9	7.0	70.0	8.8	97.0	12.7	137.0	19.0
3.2	708.0	125.6	851.6	159.6	1,205.3	238.2	1,662.2	345.6
4.1	4,396.4	738.9	5,162.6	891.7	6,789.8	1,236.4	8,933.0	1,710.1
4.2	1,226.1	185.9	1,502.9	236.6	2,013.2	335.4	2,655.6	454.5
4.3	2,708.2	516.9	3,155.0	610.2	4,067.9	800.3	5,205.2	1,036.8
4.4	1,700.4	327.2	1,862.0	365.9	2,275.2	453.6	2,782.6	560.9
5.1	794.7	131.0	858.6	150.2	1,138.1	209.4	1,454.3	280.6
5.2	1,053.5	186.7	1,242.3	225.7	1,686.9	319.0	2,245.4	429.4
5.3	146.2	44.4	157.3	47.3	188.8	53.1	230.6	60.4
Total	23,693.3	4,354.6	27,950.3	5,218.0	36,706.0	6,952.1	47,801.3	9,196.4

TABLE 6-16 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Great Lakes Basin (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
Great Lakes	Capital	211.692	456.064	535.658	667.756	1203.415
	Annual OMR	10.549	43.825	93.245	54.374	147.620
	Total OMR	105.492	876.507	1864.913	981.999	2846.913
Inland Lakes and Streams	Capital	10.644	40.036	72.866	50.680	123.546
	Annual OMR	.530	3.055	8.682	3.586	12.268
	Total OMR	5.304	61.119	173.644	66.424	240.068
Ground Water*	Capital	20.566	45.525	59.872	66.091	125.963
	Annual OMR	2.270	9.568	21.206	11.839	33.045
	Total OMR	22.709	191.372	424.127	214.081	638.208
Long Distance Transport of Great Lakes	Capital	175.350	123.950	192.500	299.300	491.800
	Annual OMR	5.800	4.380	6.490	10.180	16.670
	Total OMR	58.000	87.600	129.800	145.600	328.000
Total	Capital	418.652	666.489	916.136	1085.090	2001.023
	Annual OMR	19.224	61.170	133.044	80.391	213.441
	Total OMR	191.995	1223.362	2660.894	1415.615	4229.116

*Ground water unit cost assumptions are as follows:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells & pumping (See Figure 6-4)	40,320	27,818
total	160,320	35,418

ative quantities of water resources available and development potential in the planning subarea. The water resource figures presented are an aggregate quantity and are generally distributed over a wide portion of a planning subarea. Because the water resource quantities are distributed over such a large area, the quantities shown may not be available for use in urban areas that might have a water supply need. Potential capacities and yield used in this section relate to the total resource. No attempt has been made to identify the portion of the resource that may not be suitable for use.

2.1.2 Lake Superior Basin

In the base year of this study, 1970, the Lake Superior basin accounted for a mere 1.9 percent of the Great Lakes Basin resident population. It is estimated that municipal water supplies served 48.5 mgd to 382,900 people (79 percent of the basin population). This represents an average per capita usage of 127 gpcd, the lowest in the Great Lakes Basin.

In 1970 Lake Superior was the source for more than half the total withdrawal requirements of the basin by providing 28.6 mgd, or 59 percent of the withdrawals. Ground water resources provided 18.2 mgd, 38 percent of the total withdrawals. Inland lakes and streams of the basin are largely undeveloped, and provided 1.6 mgd, 3 percent of the total requirements. The presently developed, rated capacity of municipal water supplies of the basin is estimated to be 98 mgd.

By the year 2020 the Lake Superior basin, with a projected population of 668,804 persons, will account for only 1.3 percent of the total population of the Great Lakes Basin. It is expected that municipal water supply facilities will meet the needs of 80.8 mgd to 508,600 people (76 percent of the population), an average per capita usage of 159 gpcd.

The water resources of Lake Superior are expected to provide 71 percent, or 57.6 mgd, of the total projected withdrawal requirements.

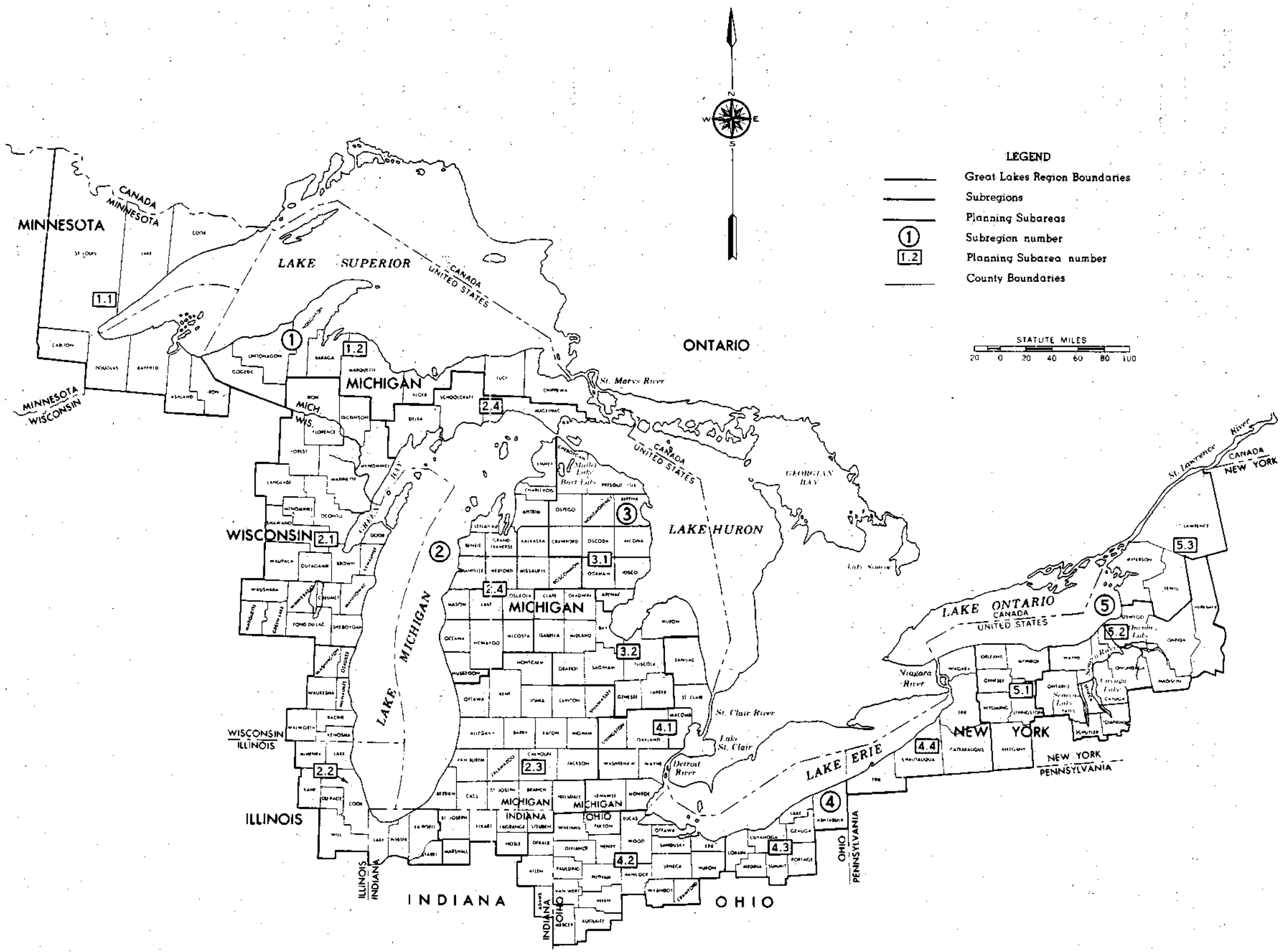


FIGURE 6-7 Great Lakes Region Planning Subareas

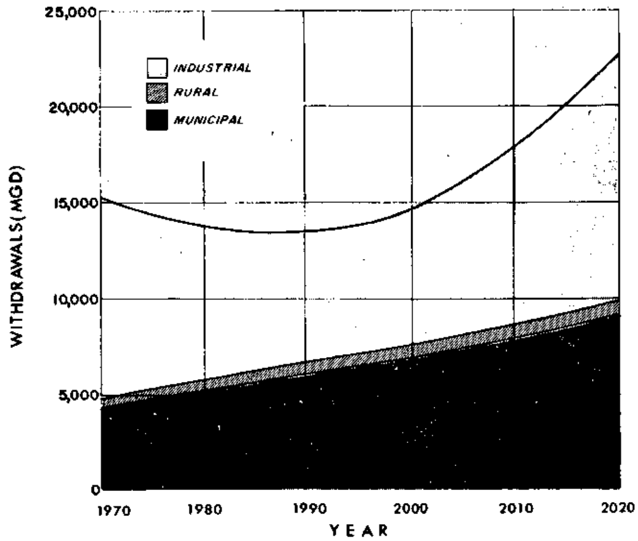


FIGURE 6–8 Municipal, Industrial, and Rural Water Withdrawal Requirements—Great Lakes Basin

Although physically occupying only 4 percent of the nation's area, the population of the Great Lakes Basin, at 29.3 million in 1970, accounts for 15 percent of the total U.S. population. Municipal water supplies served 80 percent or 23.6 million people in the Basin in 1970. This is expected to increase to 47.8 million people by 2020.

The agricultural economy in 1964 sold crops, livestock, and livestock products valued at $2.4 billion, which represented 7 percent of the national total.

The Great Lakes Basin is highly industrialized with a diversified manufacturing economy concentrated in the central section of the Basin, while the lakeshores are centers for heavy industry, with emphasis on iron, steel, petroleum, and chemical production.

Ground-water development will provide 26 percent, or 21 mgd, and inland lakes and streams are expected to provide 3 percent, or 2 mgd.

By the year 2020 projected needs resulting from the additional water-use demands of new growth are estimated to be 25.3 mgd in the Lake Superior basin. No needs are projected for Planning Subarea 1.2 because no population growth beyond past levels is projected. To provide the municipal water supply facilities to meet the projected needs, it is estimated that capital expenditures of $6.9 million and total OMR expenditures of $18.6 million will be required during the 50-year period 1970 to 2020.

Because Lake Superior is the largest freshwater lake in the world, it should be an adequate water resource. The necessary development of surface-water supplies will occur as the need arises. Ground-water resources provide low yield and are poor in quality in some areas of the basin, but this is not considered a grave problem. Development will occur in areas where the ground-water resource is of adequate quantity and quality.

2.1.3 Lake Michigan Basin

In the base year of this study, 1970, the Lake Michigan basin, with a population of 13.4 million, accounted for 46 percent that municipal water supplies served 2,043 mgd to 10.4 million people, or an average per capita usage of 196 lion, accounted for 46 percent of the Great Lakes Basin resident population. It is estimated that municipal water supplies served 2,043 mgd to 10.4 million people, or an average per capita usage of 196 gpcd, the greatest in the Great Lakes Basin. Seventy-eight percent of the population was served by municipal water supplies.

In 1970 the waters of Lake Michigan served as a source for more than three-fourths (80 percent) of the total withdrawal requirements for the basin by providing 1,634 mgd. Inland lakes and streams provided 1.5 percent, or 29 mgd, of the total withdrawals. Ground water resources provided 18.5 percent, or 379 mgd, of the total withdrawals to municipal water users. The presently developed and rated capacity of municipal water supplies of the basin is estimated to be 3,588 mgd.

By the year 2020 the Lake Michigan basin, with a projected population of 24.8 million, will account for 46 percent of the Great Lakes Basin population. It is expected that municipal water supplies will serve 4,218 mgd to 22.0 million people (89 percent of the population) to meet the projected withdrawal requirements, an average per capita use of 192 gpcd.

The water resources of Lake Michigan are expected to provide 73 percent, or 3,090 mgd, of all projected withdrawal requirements. If facilities that use inland lakes and streams as their raw water source are developed, they would provide 2 percent, or 88 mgd, of total projected withdrawals. Ground-water development is expected to provide 25 percent, or 1,044 mgd, of the projected requirements in the Lake Michigan basin.

By the year 2020 projected needs resulting from the additional water use demands of new growth in the Lake Michigan basin are estimated to be 2,594 mgd. To provide the municipal water supply facilities required to meet projected needs, it is estimated that capital expenditures of $790 million and total OMR expenditures of $2,051 million will be required during the 50-year period 1970 to 2020.

No problems are expected in terms of quality and quantity of water resources of Lake Michigan, assuming that adequate water pollution abatement programs are in effect. As needs arise, surface-water supplies will be developed. Ground-water resources are generally adequate in Planning Subareas 2.3 and 2.4, but in Planning Subareas 2.1 and 2.2 serious depletion of ground-water aquifers has occurred near major urban centers, notably Chicago. Pollution and contamination of aquifers have occurred and are a constant potential threat to ground-water resources.

2.1.4 Lake Huron Basin

In 1970 the Lake Huron Basin, with a population of 1.2 million, accounted for 4.2 percent of the Great Lakes Basin resident population. It is estimated that municipal water supplies served 133 mgd to 0.8 million people (62 percent of the population) to meet the water demands of the domestic, commercial, and municipally supplied industrial water users. This represents an average per capita usage of 173 gpcd.

In 1970 Lake Huron was the source for 71 percent of the total withdrawal requirements for the basin, or 94 mgd. Inland lakes and streams provided 1 percent, or 1.4 mgd, of the total withdrawals. Ground-water resources provided 28 percent, or 37 mgd, of the total withdrawals to municipal water users. The presently developed rated capacity of municipal water supplies of the basin is estimated to be 199 mgd.

In 1970 the water from Lake Huron provided part of the public water supply for municipalities in Planning Subarea 4.1. The bulk of this supply was provided by the connecting channels (the St. Clair River, Lake St. Clair, and the Detroit River) and Lake Erie.

By the year 2020 the Lake Huron basin, with a projected population of 2.3 million, will account for 4.3 percent of the total population of the Great Lakes Basin. It is expected that municipal water supplies will serve 365 mgd to 1.8 million people (78 percent of the population) to meet the projected withdrawal requirements, an average per capita use of 203 gpcd.

The water resources of Lake Huron are expected to provide 79 percent, or 288 mgd, of the total projected withdrawal requirements for the basin. Development of facilities using inland lakes and streams as their raw water source is expected to provide 0.5 percent, or 1.7 mgd, of the total projected withdrawals. Ground-water development is expected to provide 20 percent, or 75 mgd, of the projected requirements in the Lake Huron basin.

Rapidly growing demand in the Detroit metropolitan area has resulted in the planned development of an additional water supply from Lake Huron to meet future needs. An intake tunnel near Port Huron, Michigan, has a capacity of 1,200 mgd.

The water resources of Lake Huron and its connecting channels will provide the major portion of the water supply requirements of the Detroit metropolitan area and its service area in Planning Subarea 4.1. By the year 2000 the Detroit Metropolitan Water Department expects to serve 1,273 mgd to 8 million people in southeastern Michigan with the development of a large intake in Lake Huron.[13]

By the year 2020 projected needs resulting from the additional water use demands of new growth are estimated to be 245 mgd in the Lake Huron basin. To provide the municipal water supply facilities required to meet projected needs, it is estimated that capital expenditures of $107 million and total OMR expenditures of $210 million will be required during the 50-year period 1970 to 2020.

No problems are expected in the quality and quantity of water resources of Lake Huron, assuming that adequate water pollution abatement programs are in effect. As needs arise surface-water supplies will be developed. Ground-water supplies are generally sparse in the basin. Water quality is considered poor in Planning Subarea 3.2 and highly mineralized in Planning Subarea 3.1.

2.1.5 Lake Erie Basin

In 1970 the Lake Erie basin, with a population of 11.6 million, accounted for 39.7 percent of the Great Lakes Basin resident population. It is estimated that municipal water supplies served 1,769 mgd to 10.0 million people (86 percent of the population), an average per capita usage of 177 gpcd.

In 1970 the water of Lake Erie and the connecting channels and withdrawals from Lake Huron served as a source for more than three-quarters of the total withdrawals. Inland lakes and streams provided 9 percent, or 159 mgd, of the total withdrawals. Ground-water resources provided 6 percent, or 98 mgd, of the total withdrawals to municipal water users. The presently developed rated capacity of municipal water supplies of the basin is estimated to be 3,028 mgd.

By the year 2020 the Lake Erie basin, with a projected population of 21.3 million people, will account for 39.7 percent of the total population of the Great Lakes Basin. It is expected that municipal water supplies will serve 3,762 mgd to 19.6 million people (92 percent of the population) to meet the projected withdrawal requirements, an average per capita use of 192 gpcd.

The water resources of Lake Huron, the connecting channels (the St. Clair River, Lake St. Clair, and the Detroit River), and Lake Erie are expected to provide 85 percent, or 3,197 mgd, of the total projected withdrawal requirements, the bulk of the water supply required. Approximately one-third of this amount will come from Lake Huron. Facilities that use inland lakes and streams for raw water are expected to provide 20 percent, or 416 mgd, of the total projected withdrawals. Ground-water development is expected to provide 7 percent, or 148 mgd, of the projected requirements in the Lake Erie basin.

By the year 2020 projected needs resulting from the additional water use demands of new growth are estimated to be 2,110 mgd in the Lake Erie basin. To provide the municipal water supply facilities required to meet projected needs, it is estimated that capital expenditures of $973 million and total OMR expenditures of $1,572 million will be required during the 50-year period from 1970 to 2020.

At present there are no problems foreseen with the quantity of water resources of Lake Erie. Poor water quality may be corrected with pollution abatement programs. The necessary development of surface-water supplies will occur as the need arises. Ground-water supplies are generally poor in water quality, with high dissolved solids, iron, and hydrogen sulfide common. In some areas the ground-water aquifers have declined in recent years, creating a problem for resource management.

2.1.6 Lake Ontario Basin

In 1970 the Lake Ontario basin, with a population of 2.5 million, accounted for 8.4 percent of the Great Lakes Basin resident population. It is estimated that municipal water supplies served 362 mgd to 2.0 million people (80 percent of the population), an average per capita use of 181 gpcd.

In 1970 the waters of Lake Ontario were the source for 39 percent of the total withdrawal requirements for the basin (140 mgd). Inland lakes and streams provided 54 percent, or 196 mgd, of the total withdrawals. Ground-water resources delivered 7 percent, or 26 mgd, of the total withdrawals to municipal water users. The presently developed rated capacity of municipal water supplies of the basin is estimated to be 496 mgd.

By the year 2020 the Lake Ontario basin, with a projected population of 4.4 million, will account for 8.3 percent of the total population of the Great Lakes Basin. It is expected that municipal water supplies will serve 770 mgd to 3.9 million people (89 percent of the population) to meet the projected withdrawal requirements, an average per capita use of 197 gpcd.

The water resources of Lake Ontario are expected to provide 52 percent, or 397 mgd, of the total projected withdrawal requirements. Development of facilities using inland lakes and streams as their raw water source is expected to provide 41 percent, or 315 mgd, of the total projected withdrawals. Ground-water development is expected to provide 7 percent, or 58 mgd, of the projected requirements in the Lake Ontario basin.

By the year 2020 projected needs resulting from the additional water-use demands of new growth are estimated to be 424 mgd in the Lake Ontario basin. To provide the municipal water supply facilities required to meet the projected needs, it is estimated that capital expenditures of $124.5 million and total OMR expenditures of $277.5 million will be required during the 50-year period 1970 to 2020.

There are no problems foreseen with the quality or quantity of the water resources of Lake Ontario, assuming that adequate water pollution abatement programs are in effect. The necessary development of surface-water supplies will occur as the need arises. Ground-water resources are considered limited in availability, and water quality is generally poor with high dissolved solids, hydrogen sulfide gas, and contamination from septic tanks.

2.2 Public Health Aspects of Municipal Water Supplies

2.2.1 Surface-Water Quality

It is estimated that 17.3 million people (58 percent of the total Basin population) used municipally processed water from the surface waters of the Great Lakes in 1970, the base year of this study. To meet the domestic, commercial, and industrial water demands of these people and commercial and industrial establishments in the Basin, municipal water supplies withdrew an estimated 3,409 mgd from the waters of the Great Lakes in 1970. The major consideration associated with public water supply in the Great Lakes is the quality of raw water obtained from the Lakes related to the ability to provide adequate treatment in water treatment plants and the cost of withdrawal and treatment.

Inhabitants of the Basin served by the waters of the Great Lakes generally assume that the water from their faucets is healthful and free of bacterial or chemical contaminants that can inflict disease. Usually, this assumption is correct. The drinking water supplies in the cities and towns of the United States, including the Great Lakes Basin, rank in quality, on the average, among the best in the world.[9] In this appendix it has been assumed that water pollution abatement programs will successfully maintain water quality of the Great Lakes for the 50-year period of this study. The water quality standards program of the U.S. Environmental Protection Agency calls for making the waters of the Great Lakes suitable as a source of municipal water supply and includes plans of implementation and timetables for its accomplishment.

However, water quality fluctuates, and its changing parameters require the water technologist to be in constant touch with many other segments of the scientific world. Chemists, bacteriologists, toxicologists, and biologists are making advances in the assessment and quantification of water quality parameters. These advances generally demonstrate that there is cause for concern over the future water quality of the Great Lakes and its use as a source of public water supply. A prominent water resources authority recently stated that:

> Great Lakes water quality is indeed threatened for many uses, including public water supply uses. On the other hand it is rather clear that the situation is not so bad that we must throw up our hands in despair.[52]

Water treatment plants were designed principally to remove filterable material and to disinfect in order to kill coliform bacteria from sources of relatively unpolluted waters. The objective of the water treatment plant is to provide a safe water supply to the public, free from typhoid, dysentery, cholera, and other waterborne communicable diseases. This objective has generally been achieved in the Basin.

Public health considerations such as contamination of raw water by bacteria, viruses, pathogens, and toxic or harmful substances are of primary concern in water supply. The majority of water intakes within the Great Lakes are presently located to yield relatively high quality waters. As population increases and economic growth continues around the shores of the Basin, it will be necessary to insure that the influence of wastewaters discharged from municipal and industrial treatment plants and urban and other runoff do not contaminate water intakes.[28]

However, all drinking water supplies in the Basin are safe. Although the communicable water-borne diseases of the past such as typhoid fever, amoebic dysentery, and bacillary dysentery were brought under control by the 1930s, there are still outbreaks of communicable disease from sewage contamination of water supply systems in the United States.[9] These disease outbreaks are not necessarily due to poor bacterial quality of the raw source water, because some outbreaks involve a failure in the distribution system, but they are indicative of potential problems with public water supply that must be confronted in planning the future management of the Great Lakes water resource.

Most municipal water supply systems in the Great Lakes Basin were constructed more than 20 years ago. Each year they become increasingly obsolete because the populations they were designed to serve have increased rapidly, thus placing a greater strain on treatment plant and distribution system capacity. Over the years many municipalities in the Basin have expanded and improved existing public water supply systems to meet the withdrawal requirements of an increasing population.

Conventional water treatment plants are not capable of coping with the large variety of chemical contaminants introduced into the surface waters of the Great Lakes by the multitude of urban and industrial developments in the Basin. The potential public health hazards associated with chemical pollutants have been a matter of increasing concern to authorities in the water supply field. In 1960 Hopkins and Gullans, two outstanding authorities, stated that:

> Today the new challenge facing the water supply profession is the control and removal of the hazardous non-living contaminants—the chemicals and isotopes which are being produced in a bewildering array of new compounds. It is to be expected that some of these chemicals, as well as the wastes from their production, enter public water supplies. Unfortunately, very little is known about the extent of the pollution of the nation's water supplies by these new chemicals which include many commercial poisons.[56]

A decade later the U.S. Environmental Protection Agency released a study of 969 community water supplies in the United States in an attempt to determine, on a nationwide basis, the efficacy of current practices in water treatment and to assess future prospects for maintaining safe, high-quality drinking water.[9] In this study serious concern was expressed over the possible health hazards due to the increasing concentration of chemical pollutants:

> Chemical contaminants in our environment have been on the increase for about 25 years, due to the dramatic expansion in the use of chemical compounds for agricultural, industrial, institutional and domestic purposes. There are about 12,000 different toxic chemical compounds in industrial use today, and more than 500 new chemicals are developed each year. Wastes from these chemicals—synthetics, adhesives, surface coatings, solvents and pesticides—already are entering our ground and surface waters, and this trend will increase. We know very little about the environmental and health impacts of these chemicals. For example, we know very little about possible genetic effects. We have difficulty in sampling and analyzing them—we have much greater difficulties in determining their contribution to the total permissible body burden from all environmental insults.[9]

Substances that have been measured in at least detectable amounts in the waters of the lower Great Lakes are arsenic, cadmium, chromium, cobalt, copper, lead, mercury, vanadium, and zinc. These materials reach the waters by both natural processes and man's activities.[32] Table 23–9 in Appendix 23, *Health Aspects*, presents a tabulation of concentrations of selected minor elements measured at various locations in the Basin.[26] In general, the concentrations in the Lakes are well below the levels considered hazardous for public water supply.

Organic contaminants such as pesticides and polychlorinated biphenyls (PCBs) are persistent in the aquatic environment and biochemically resistant to degradation, resulting in a serious health threat to aquatic life and possibly to man.

Many organic chemical pollutants have not been adequately evaluated in terms of their toxicity and possible effects on human health. Because of their persistent nature and because many of them are toxic at very low concentrations, they pose a serious threat to the health of man and to marine life. Also, due to their persistency, these chemicals can have a synergistic effect with one another, i.e., organic compounds that might be only slightly toxic as a sole contaminant, may increase their toxicity many times in the presence of other compounds.[32]

The physiologic effects of long-term exposure to organic contaminants are not well understood. It is possible that there might be parallels between the health effects of the accumulation and concentration of toxic materials on predator fishes, shore birds, and people consuming dissolved materials of unknown toxicity over a long period of time. The fact that current epidemiological techniques are inadequate to identify and define these problems is no basis for concluding that they have no detrimental effects on human health.[32]

The International Joint Commission (IJC) has recognized the complex interrelationship between chemical pollutants in the Great Lakes and their potential hazard to human health via public water supplies. In its 1970 report, the IJC states that:

> One of the major problems relating to public water supplies is the false sense of security based on past experience in a far less polluted environment. The infrequency of waterborne disease outbreaks does not justify complacency. Conventional water treatment does not remove all dissolved organics and inorganics . . . .[32]

Other serious potential public health hazards are the viruses that have been recently isolated in drinking water supplies.[49] Conventional sewage treatment plants do not adequately treat viruses. Viable viruses have been isolated in effluents from sewage treatment plants, urban and rural runoff, and discharges from watercraft. Until recently it was thought that disinfection techniques in conventional water treatment plants inactivated viruses, thus protecting the health of the public. Studies recently conducted by researchers from the U.S. Environmental Protection Agency in two of the most modern water purification systems in the country showed that disease-producing viruses remained viable after conventional disinfection.[49]

Information is not available about the extent of the presence of viruses in the Great Lakes, but it is clear that conventional bacteriological analyses can no longer be considered as an adequate indicator of viral pollution. There is as yet no suitable agent available that can be used as an indicator of the presence of viruses in natural waters.[32] The IJC, in its 1970 report, discussed the matter of viruses in the Great Lakes and stated that:

> . . . viral survival is longest in slightly or moderately polluted water. Such conditions of pollution prevail in many areas of both Lake Erie and Lake Ontario. The situation is critical because the areas where there is the highest possibility of viral survival, that is, areas near large urban centers, are often the same areas used for recreation and public water supplies. . . .[32]

The Advisory Board to the IJC considered the matter of viral pollution serious enough to recommend that:

> . . . viral research be intensified so as to determine the significance of viruses in water, the epidemiologic relationship of the various types and amounts of viruses in waters used for recreation and human consumption, and morbidity caused by exposure to viruses.[39]

A potential long-range water supply problem is associated with a possible build-up of total dissolved solids, chlorides, calcium and magnesium salts, hazardous chemicals, and other dissolved chemicals in the Lakes. These water supply problems are not significant at present, but future population and economic growth could accelerate the accumulation of these materials. The present level of total dissolved solids in Lakes Erie and Ontario is 180 to 200 mg/l.[32] Dissolved solids become dangerous to domestic and industrial water supplies at a concentration of approximately 500 mg/l, the limit established in the U.S. Public Health Service Drinking Water Standards.[14] The IJC recognized the public health significance of the 500 mg/l total dissolved solids concentration recommended by the USPHS, but adopted a more stringent objective of 200 mg/l for the lower Great Lakes. This value was also adopted in the Great Lakes Water Quality Agreement between the United States and Canada.[22]

Therefore, there are some basic questions to be answered:

(1) Will total dissolved solids surpass recommended concentration levels?

(2) If so, when might this undesirable concentration be reached?

(3) What alternative control measures should be adopted if the level of total dissolved solids exceeds the recommended limit at some point in the future?[28]

In its 1970 summary report, the IJC reported on the accumulation of total dissolved solids in the Great Lakes:

> . . . Notwithstanding the fact that these levels in themselves do not inhibit use of these waters, the data indicate the changes which are occurring through man's use of the Great Lakes as receiving waters for his wastes.[32]

A somewhat different area of concern in water supply is the quality of finished water and the cost of operating water treatment plants. Specific problems have been experienced with Great Lakes water supplies in terms of taste, odor, color, clogging of intake screens, reduced filter runs, and increased chemical costs. Municipal water supplies in Milwaukee, Chicago, Cleveland, Green Bay, and Toledo have been affected by excessive *Cladophora* growths, phytoplankton blooms, and possibly the residual effects of chemicals discharged in municipal and industrial wastes.[28]

These water supply problems have resulted in increased operating costs in many locations and reduced quality of treated water in Chicago. Many of the taste, odor, color, and clogging problems are encountered in the summer period when water supply demands approach a maximum.[28]

The following list summarizes the various problems influencing present and future usage of the Great Lakes as a source of public water supply:[28]

(1) bacterial and viral contamination

(2) presence of toxic or harmful substances such as heavy metals and pesticides

(3) taste, odor, and color

(4) intake and filter clogging from aquatic plant growth and fish such as alewife

(5) build-up of total dissolved solids and hardness

(6) quality control of treated water

Future industrial growth and a projected 84-percent increase in the Basin population by the year 2020 could result in a deterioration of water quality in previously unaffected areas of the Lakes. This increased growth will place substantial demands on the capabilities of water treatment plants. The probability of mistakes in the treatment of hazardous substances and the spilling of toxic materials into water supplies may increase along with the other problems mentioned in this section. Adequate planning should be undertaken to minimize these health risks in the Great Lakes Basin.

Water supply problems associated with bacteria, viruses, and potentially harmful or toxic chemical substances could probably be controlled by the proper location of water intakes, the design of unit processes of water treatment, and the selection of appropriate waste treatment facilities for municipal and industrial sewage. Reverse osmosis, electrodialysis, ion exchange, adsorption, freezing, distillation, and increased dosages and contact time of chlorination and activated carbon are all unit processes of water treatment that are technologically feasible for the removal of harmful substances in drinking water. Water quality surveillance programs should be established to monitor raw water at critical locations and treated water quality for bacteria, viruses, toxic chemicals, and other harmful substances.

2.2.2 Ground-Water Quality

The following discussion about ground-water quality and pollution of ground-water resources is based on a preliminary draft of a regional water supply plan prepared by the Northeastern Illinois Planning Commission.[72]

In general the raw quality of ground-water is superior to that of most surface streams in the Basin. This has been a major contributing factor to its widespread use as a water supply. However, because ground water is in contact with rocks and soil longer than surface water, it tends to absorb certain natural materials. These materials may or may not cause water supply problems depending upon their concentrations.

For example, excessive amounts of dissolved minerals can affect the palatability of water. Water that contains more than 500 ppm of dissolved solids normally should not be used for domestic supply if other supplies are available.

Water that contains high concentrations of calcium and magnesium salts is said to be hard. Very hard water is a problem for domestic supply because it reduces the cleansing power of soaps and detergents and can cause the formation of scale on the inside of pipes, boilers, and tanks. Exceptionally high concentrations of salts may also indicate water pollution. There are no recommended standards for hardness, and a criterion for objectionable hardness must be developed for each community. As a general rule, however, hardness greater than 300 to 500 ppm is excessive for public water supply. The hardness can be reduced to acceptable levels either by centralized softening at municipal treatment plants or by individual home softening units, although this adds to the total cost of water.

Iron can also be a problem in ground-water supplies. Excessive concentrations can cause reddish stains on plumbing fixtures and laundered clothing and can impart a bitter taste to the water. The U.S. Public Health Service standards recommend a limit of 0.3 ppm for iron in treated water.

With the exception of these problems ground water is relatively free of chemical or bacterial pollution and is normally acceptable for domestic use without extensive treatment. However, due to certain physical characteristics of aquifers, the encroachment of human-related activity can create pollution problems if adequate safeguards are not taken. In extreme cases, actual contamination of the water supply can occur, creating a threat to public health and severely restricting the use of water for domestic purposes. Because ground water is in a continual state of flow, a pollutant introduced into one segment of the water-bearing strata has the potential of spreading throughout the system. Although the natural filtering capability of the soil provides some protection against bacterial pollution, the degree of protection may not always be complete. Furthermore, there is virtually no attenuation of dissolved chemical constituents that may inadvertently be introduced. Fractured dolomite provides no protection whatsoever, and polluted water can rapidly move great distances through the interconnected cracks and joints in the rock. High-capacity pumping wells draw in degraded water and influence the spread of pollution. Eventually the wells may become permanently damaged. When compared with surface-water flow, ground-water movement is extremely slow. Therefore, once a pollutant has been introduced and distributed within an aquifer, it may take a long time for it to be detected and flushed out. The problem is further accentuated by the delays incurred in attempting to find the source of the pollutant, evaluating the problem, and making remedial corrections. Even if the source is discovered and checked promptly, deleterious effects may persist for considerable lengths of time. Artificial flushing is impractical, heavy induced pumping is expensive, and treatment may be both impractical and expensive. In some cases, abandonment of the affected wells may be the only possible alternative. In addition, certain toxic or chemical materials are naturally resistant to rapid attenuation. This is particularly true of gasoline, oils, petrochemicals, and pesticide compounds which are not readily soluble in water. In Aurora, Illinois, for instance, fuel oil was spilled and later entered the dolomite aquifer. Wells in the area had to be abandoned. Seven years later, when one well was temporarily reactivated, a strong hydrocarbon taste and odor was still present in the water.

Potential pollution sources may exist either above or below the ground. Typical sources include poorly located, constructed, or maintained septic tanks, leaky sewers, barnyards and other livestock areas, and improper methods of liquid or solid waste disposal. However, the ground-water pollution potential of sanitary landfills appears to have been exaggerated. There are very few recorded cases of actual water supply contamination from solid waste disposal sites. Modern engineering and operational techniques further serve to minimize the threat of pollution from these sources. Strict enforcement of the plumbing codes governing septic tank installation (usually requiring distances of 50 to 100 feet between on-site disposal facilities and wells) greatly reduces the risk of pollution from these sources.

Poorly cased or uncased wells are a potential problem source, but dangers can be minimized through proper construction procedures. Abandoned wells should be sealed off to prevent the entrance of contaminants from the surface, or admixture of water from one aquifer with that of another. Other water quality degradation can result from the upward migration of mineralized waters from the St. Simon aquifer into the heavily pumped Cambrian-Ordovician system due to the differences in head between the two aquifers.

The shallow dolomite aquifer is particularly susceptible to bacterial contamination resulting from surface runoff (during and after rainstorms) entering the aquifer in recharge areas. In the course of its flow, overland runoff may pass over various areas where pollutants have been deposited. These materials can become dissolved in or carried in suspension by surface runoff. Subsequent percolation into the ground may afford insufficient filtration or attenuation prior to entering the aquifer. Marked increases in the turbidity of water pumped from dolomite wells after a rainstorm are cause to suspect possible contamination. Intrusion of heavily polluted flood waters into private wells is a recognized problem in developed flood plains.

Perhaps no other aspect of ground-water pollution has attracted so much attention as nitrate contamination of shallow wells. Although this is not a significant problem for public systems, recent studies have indicated that several thousand private, domestic, and farm wells in Illinois may be producing waters that exceed the safe limit (45 ppm as nitrate-nitrogen). The primary sources of nitrate pollution are livestock feedlots and septic systems, in which nitrates contained in excrement are leached through the soil into shallow wells. When this water is subsequently consumed, the nitrates are reduced to nitrite in the intestinal tract. Excessive amounts of nitrite can cause methemoglobinemia, a disease in which the oxygen-transportability of the blood is impaired. Methemoglobinemia can be fatal, and infants are particularly vulnerable.

In summary, there are a large number of potential sources and types of ground-water pollution or contamination. Once pollution has occurred, eradication is slow and difficult. Prevention is the best solution.

2.3 Review of Public Water Supply Research Needs and Recommendations

To fully evaluate the effect of various contaminants in sources of public drinking water, water treatment technology should be developed and health aspects of new contaminants in the Basin's lakes and streams should be studied.

One objective of this appendix is to define and recommend needed research and development in order to improve water treatment technology. The potential problems of public water supply should be identified within the 50-year time period of this study.

The American Water Works Association has compiled a list of research needs in "Public Water Supply Treatment Technology,"[38] a report prepared for the Office of Water Resources Research, U.S. Department of the Interior. These research needs are listed in the following seven subsections.

2.3.1 Summary: Research Studies Urgently Needed

Needs include the following:

(1) Extensive research is needed to develop epidemiologic information on the effects of

bacteria, viruses, and the organic and inorganic constituents of water on human health. It is necessary to develop epidemiologic tools as well as conclusions. Without these, intelligent action cannot be taken.

(2) Development of improved analytical techniques is required to meet the need for more sensitive, more precise, and more rapid methods.

(3) Modifications in institution and management policies for total management of water resources must be studied. The need is to provide water supplies of improved quality and quantity, with interlinkages of human behavior with ecology to the improvement and enhancement of the quality of life for all the population of an area.

(4) Studies are needed on the regionalization of water systems to develop institutional aspects and provide means of meeting community reactions. For small water systems, the many improvements required include aspects of personnel, training, management, financing, and water use.

(5) Reuse, or successive use, of water requires a systems approach to include studies of treatment requirements, new practices for distributing reused water, legal and economic studies, socio-political aspects, and consumer perceptions of reuse of water.

(6) The practicability of dual water systems requires more detailed study, as a means to distribute high quality potable water for its necessary uses, and water of lesser quality for all other purposes. In areas having adequate water resources, this study would involve determination of an economic balance between the cost of dual distribution systems compared with treatment of the total supply and a single system.

(7) Studies are needed of legal and institutional analyses to ascertain legal rights with respect to reuse.

(8) Training programs are needed to provide higher levels of competence in managerial and operational personnel.

(9) Research is needed to identify each substance, or group of substances, which commonly cause taste and odor in water. The intensity of odor (or concentration of the substance causing it) must be correlated with the removal treatment required.

(10) Research is needed to identify causes of development of taste and odor in water distribution systems, and means of preventing such development.

(11) There is a substantial need for developing monitoring systems which are sensitive, precise, reliable, and practical. These should be applied to monitoring water at sources, throughout treatment, and in distribution systems, in order to promote the delivery of quality water.

(12) Advanced methods of water treatment for removal of organic compounds from water must be developed. These are needed for removing hazardous trace materials, organic pesticide chemicals, exotic chemicals, and inorganic compounds.

(13) There is a need to develop small-size, economical facilities for in-plant regeneration of adsorbents, particularly granular activated carbon.

(14) There is a need to determine institutional arrangements best adapted to enabling State agencies to fulfill their rightful role of monitoring the State's waterways, and to advise water utilities of major or impending changes in water quality.[38]

In addition, there is a need to evaluate various technological advances that would significantly reduce withdrawal requirements for industrial and domestic water users. Such advances might include process development modifications in industry and development of dry, chemical sanitary facilities for residential use.

2.3.2 General Areas

The American Water Works Association report further states that research and developmental studies have been proposed in several broad areas. These studies relate to operations affecting the efficiency and economy of public water supply management.

(1) Closed-Loop Control of Water Quality

Monitoring will have increasing applications in the control of water quality and treatment. These applications include research to:

(a) develop optimization of quality and treatment costs through suitable monitoring; "automatic" interpretation from developed models; and feed control without human attention, for closed-loop control of the basic treatments such as coagulation, taste and odor control, virus control, bacterial control, and the control of trace organics and heavy metals

(b) develop guidelines for the application of closed-loop control systems

(c) develop a full "line" variety of sensing elements, or sensors, having satisfactory sensitivity, selectivity and maintenance requirements for monitoring.

(2) Regional Management Organization

Research is needed to develop a regional management organization for public water supplies. Such an organization could harmonize the existing conflicting and competing institutional arrangements and organizations. It could, at the same time, equitably distribute the costs involved, in relationship to the benefits obtained.

It seems clear that one form of organization will not be appropriate for all communities. Institutions may be required at several levels: regional, State, interstate and national. The institutional arrangements must include:

(a) The relationships between water resource institutions at various levels

(b) The relationships of a water resource institution to other institutions having an interest in water, and

(c) The relationship of the water resource institution to the usual governmental entities.[38]

2.3.3 Water Resources

The AWWA has stated that the technical literature identifies many water resources research needs relating to water quality and drinking water supply. The following is a representative list of these:

(1) Determine the economic benefits from incremental improvement of intake water quality for municipal and industrial water uses.

(2) Develop instruments for monitoring source water, and waters in distribution systems, to provide accurate and current recordings of quality characteristics.

(3) Correlate analytical methods with water treatment requirements to handle specific problems.

(4) Identify the causes of taste and odor problems and develop effective low-cost treatment processes. Continuing research on this problem is required, especially where the water supply contains industrial wastes and may be subject to the introduction of new and unknown contaminants.

(5) Establish the dynamics of trace elements within water supplies so that control may be instituted to monitor and alleviate hazards associated with these elements.

(6) Routinely identify the important trace elements having significant toxicity potential. (Molybdenum and beryllium may have potential toxicity of significant magnitude.)

(7) Conduct research and studies to interrelate requirements for advanced treatment with various applications of reused water for municipal supplies. Four important factors should be considered:

(a) the degree of advanced treatment required

(b) the cost of advanced treatment

(c) methods and costs of delivery of the treated water

(d) consumer acceptance of this source of supply

(8) Develop information as to the utility of aeration, copper sulfate treatment, or other means of improving raw water quality.

(9) Conduct research on the design of wells as it affects water quality. For example, is there a design available for a gravel packed well that could operate safely under 15 feet of floodwater?

(10) Evaluate the impact of Federal water quality standards on availability of water resources.

(11) Determine the relationship between urea from sewage treatment plant effluents and the production of NCl_3 in water treatment when free residual chlorination is employed.

(12) Establish a suitable basis for prescribing the limits of pollution that various water treatment processes can remove. (Uncertainty about the significance of viruses and organic chemical contaminants in water, rather than bacterial loadings, renders uncertain the degree of pollution that treatment plants can dependably remove.)

(13) Evaluate the quality effects of recreational uses of public water supply watersheds.

(14) Make studies of how man can alter nature, when needed, to improve his source of supply; i.e., by weather modification.

(15) Determine the nature of specific organic compounds present in raw waters and how they can be quantified. (Carbon adsorption and elution is now the only method.)

(16) Research is needed to determine the toxic byproducts of algae growths.

(17) Research is needed to determine the toxicity of each of the myriad of new organic chemicals wasted to the streams and lakes.

(18) Investigate the effect of minimized nitrate concentrations on various algal populations.

(19) Determine the nitrate sources which are of significant importance to public water supplies.

(20) Evaluate the economics of wastewater denitrification.

(21) Further studies are needed to develop more adequate information on the distribution by types and concentrations of pesticides in various waters used for public water supply.

(22) Determine the persistence of various organics and their products of decomposition in water.

(23) Study the influence of reservoir management on the production or reduction of tastes and odors.

(24) Evaluate techniques for the control of runoff from farms and forests in relation to taste and odor production.[38]

(25) Determine natural ground water recharge areas in the Basin. Evaluate establishment of zoning controls to prevent adverse development over recharge areas and determine areas amenable to artificial recharge of aquifer.

2.3.4 Water Treatment

The technical literature identifies many water treatment research needs relating to water quality, and the following is a representative list of these:

(1) Develop a practical method for determining floc strength, to evaluate the effectiveness of the coagulation process prior to filtration.

(2) Develop standard methods for the selection and application of coagulant aids to achieve optimum coagulation and improved filtrability.

(3) Conduct research on the rate of oxidation of iron by chlorine at different temperatures and pH values.

(4) Develop new and improved treatment methods to remove water impurities which are unaffected by currently available treatment technology.

(5) Conduct research to identify the organics in water containing sewage treatment plant effluent.

(6) Develop and evaluate processes that will continuously treat directly recycled municipal wastewaters to produce "safe and satisfactory" drinking water.

(7) Develop economically feasible water treatment processes to reduce specific toxic chemicals to acceptable levels.

(8) Develop methods of supplementary treatment that could be used by conventional water treatment plants to remove abnormal concentrations of specific pollutants due to accidental upstream spills.

(9) Conduct research on the deliberate employment of both demineralization and addition of specific minerals to provide water of any desired mineral quality.

(10) Evaluate the utility of polyelectrolytes for removal of insecticides in water treatment.

(11) Study the application of catalysts to facilitate rapid oxidation of insecticides.

(12) Develop more extensive information on the effects of minerals in water on taste, odor, and public acceptance.

(13) Establish the threshold odor values of various organic chemicals in water, singly or in combination, and the relationship of these chemicals to algae control.

(14) Develop new, and possibly more economical, methods of clarifying water as alternates to coagulation and filtration. (The anticipated change of the turbidity limit in drinking water standards from 5 to 1 J.t.u. will create a demand for producing water of greater clarity. Water presently put into distribution systems in many instances becomes cloudy, develops objectionable tastes, or supports the growth of worms.)

(15) Determine the physical and chemical properties of specific odorants as a basis for the development of processes specifically designed for the removal of these compounds. "The objective of odor research is to provide specific information about the identity of each odor substance, its composition, chemical reactivity, and odor characteristics. This is to enable physical, chemical, and biological odor treatment methods to be tailored exactly to the individual compound to be removed."

(16) Research studies are needed to isolate and identify geosmin and mucidone from natural water, since current research is based on laboratory cultures. The two metabolites are representative of a larger group of odorous metabolites produced by aquatic microorganisms. There is need to investigate others in this group, as current research has given evidence of more than one additional metabolite similar in odor to geosmin and mucidone.

(17) Evaluate the economic effects of raw water quality against economics of investment, for the production and distribution of high-quality potable water.

(18) Evaluate the effect of organic substances such as ammonia, other nitrogen forms, or COD, as nutrients for the growth of

bacteria within water distribution systems, and develop criteria for water quality to avoid such growths.

(19) Develop treatment capabilities that can effectively control a broad spectrum of taste and odor problems by one treatment process.

(20) Compile an inventory of procedures for the removal of each of the common pesticides and for each of the heavy metals, which can be utilized at each water utility.

(21) Reevaluate sterilizing agents as alternates to chlorine, including iodine, bromine, ozone, and permanganate. Conduct research on methods of evaluating the effectiveness of disinfection other than the measurement of coliform organisms.

(22) Evaluate granular carbon filter beds as replacement of anthracite or sand beds. (The supply of anthracite is rapidly dwindling, and has fallen far behind the demand for this material as a filter medium.)

(23) Identify each substance or group of substances causing taste and odor in water. Correlate the intensity of odor (or concentration of the substance causing it) and the removal treatment required.

(24) Study the application of demineralization for treatment of brackish waters to conform to drinking water standards. This application will make possible the use of more water resources not now meeting these standards, waters particularly in the West and Midwest.

(25) Conduct research on water treatment processes to assure the effective control of viruses.[38]

2.3.5 Water Distribution

The technical literature identifies many water distribution research needs relating to water quality, and the following is a representative list of these:

(1) Conduct research on the relation of velocities of water flow in the distribution system to the protection, or degradation, of the water quality.

(2) Develop effective standards for free residual chlorine levels and contact periods in relation to disinfection programs.

(3) Conduct research to develop alternate procedures for main flushing and disinfection programs when potable water is not available to waste. These procedures are needed in the disinfection of large diameter and/or long transmission lines.

(4) Develop complete programs for disinfecting water mains and storage facilities, including sampling and analysis.

(5) Research is needed to understand the nature of the micro-environment at the interface between the water and the interior face of the pipe, where little information is available concerning the physical, chemical and biological phenomena that take place.

(7) Conduct studies of stabilizing water by chemical treatment, in order to reduce corrosion and incrustation.

(8) Develop improved techniques to provide representative samples of water in distribution systems.

(9) Investigate the interrelationships between the quality aspects of water supplies at the source, the treatment, and the distribution systems.

(10) Evaluate the effectiveness of automatic control systems to maintain water quality in distribution systems.

(11) Evaluate the chemical treatment methods available to reduce corrosion rates in distribution systems, and develop improved methods of corrosion control.

(12) Conduct more extensive studies of the economic and technical feasibility of dual water distribution systems.

(13) Develop improved methods to monitor quality in distribution systems, for surveillance of water quality.

(14) Study the design of back-flow prevention devices to eliminate service problems due to substantial pressure loss through the unit.

(15) Conduct research to develop a chemical inhibitor of slime growths which will maintain a residual throughout the distribution system and not affect potability of the water.

(16) Develop and evaluate new materials of construction and pipe linings which will be resistant to corrosion by public water supplies.

(17) Conduct research to determine the benefits and cost of maintaining free chlorine residuals in distribution systems.

(18) Evaluate the substitution of chlorine residual for coliform examinations or determine conditions under which it may be a sufficient indication of bacterial safety.

(19) Collect survey data to determine the effect of water quality on household piping and fixtures.

(20) Determine the optimum characteristics of water for domestic use, and prepare an index of water quality for use by water utility managers and planners.[38]

2.3.6 Public Health

It should be emphasized that the physiological significance of many substances in water is not well understood. The technical literature identifies extensive needs for research to determine the public health effects of chemical and biological constituents in water. Following is a representative list of these:

(1) Supplement current knowledge relating to the hazardous or beneficial effects of various trace substances in water by both toxicologic and epidemiologic studies.

(2) Improve epidemiological and toxicological water supply surveillance techniques.

(3) Study the possible occurrence and public health effects of trace residues of the many powerful drugs now used almost universally—drugs such as the steroids and hormones.

(4) Evaluate need to put all standards of drinking water quality on a scientific basis, and to include in such standards the simultaneous influence of all sources of a given element.

(5) Enlarge analytical capability to adequately evaluate water quality with regard to the body accumulation of specific substances.

(6) Expand biologic research on viruses, bacterial indicators, and nematodes in water.

(7) Determine if there are constituents in water other than nitrates and nitrites involved in methemoglobinemia, and if the present USPHS Drinking Water Standard limit for nitrate is too conservative.

(8) Conduct research on the chronic physiological effects of boron in water.

(9) Evaluate the physiological significance of minerals and organic constituents in water, such as pesticides and herbicides, individually or in combination.

(10) Continue studies of the relationship (if any) between total dissolved solids or water hardness and heart disease.

(11) Establish drinking water quality standards for emergency use, especially safe limits to be used for short periods of time in emergencies.

(12) Conduct research on the relation between copper in water and arthritis.

(13) Study arsenic limits and methods for removal, in light of its occurrence in water used in Lane County, Oregon, and other communities. Determine if the present limit established for arsenic is realistic. (The body is not known to be dependent upon an intake of arsenic, nor is it an element of nutrition [Browing 1961] though normal blood contains 0.2 to 1.0 mg/l of arsenic. Evidence supports the view that arsenic may be carcinogenic [Hill 1948], [Doll 1959], [Mereweather 1956], [Drill 1958]. Drinking water standards give a recommended limit of 0.01 for arsenic, and a rejection limit of 0.05 mg/l.)

(14) Evaluate the adequacy of coliform tests to reflect absence of pathogenic virus or bacteria, or to develop a more rapid indicator test for microbial forms applicable to quality control in water treatment.

(15) Explore the impact on man of viruses of nonhuman sources. (Viruses of cattle, wildlife, and many lower forms abound in rivers and streams.)

(16) Evaluate the risk of tumor induction in man brought about by the action of chemicals and potential carcinogens in streams.

(17) Conduct extensive epidemiological studies to determine the extent of water transmission of viruses, and to assess the risk of virus transmission by renovated wastewaters. (Precise studies must be done to determine the infectivity for man of a variety of viruses representing the picornaviruses, reoviruses, adenoviruses, and the infectious hepatitis agent, when these viruses are present in water.)

(18) Investigate whether products toxic to man result from the application of water disinfectant procedures. (Toxicity may be a major determinant in the choice of disinfectants.)

(19) Evaluate the hazards to consumers of high cadmium content zinc for galvanizing of water service pipes. (This type of pipe can result in appreciable concentrations of cadmium in the water delivered to consumer taps.)

(20) Determine if the present drinking water standard for selenium is realistic.

(21) Undertake studies to collect accurate and comprehensive data on the engineering, medical, and public health aspects of the sodium content of domestic water supplies.

(22) Determine the need to establish concentration limits for vanadium in water.

(23) Determine the need to establish concentration limits for molybdenum in water.

(24) Determine the limit that should be established for mercury in water.

(25) Evaluate the relation of polluting substances in water to incidence of goiter.

(26) Evaluate the physiological effects of heavy concentrations of minerals in water.

(27) Evaluate the physiological effects of organic contaminants in water.

(28) Determine the actual need for removal of specific organic substances from public

water supplies, and the treatment costs for removal.

(29) Conduct research on the physiological significance of polychlorinated biphenyls (PCBs) in drinking water and collect data on the incidence of PCBs in surface water and bottom sediments. (The National Academy of Science estimated global production of PCBs to be about 100,000 tons per year. Sales in the U.S. in 1970 were estimated at 34,000 tons.)[38]

2.3.7 Laboratory Procedures

The technical literature identifies laboratory procedures relating to water quality in need of research. Following is a representative list of these:

(1) Develop improvements in sampling techniques to provide truly representative water samples.

(2) Develop accurate and rapid techniques to measure taste and odor producing substances in water.

(3) Conduct research and development to provide methodology for the enumeration and isolation of bacteria and viruses.

(4) Develop analytical procedures which enable identification and quantification of organic contaminants of water in the milligram-per-liter, microgram-per-liter, or lower concentration range. (The instrumental procedures which are most promising at present involve spectrographic and chromatographic techniques. However, these instruments lack the sensitivity to analyze organic constituents directly at the levels found in waters and wastewaters.) Development of concentration techniques that will not alter the constituent or its distribution in complex mixtures are essential (Baker 1967) (Rosen 1969).

(5) Evaluate and improve the application of carbon-chloroform-extract and carbon-alcohol-extract (CCE and CAE) techniques for determination of organic contaminants.

(6) Develop standard methods for biodegradability, to indicate undesirable concentrations of resistant organic pollutants in surface runoff and in discharges from sewage and industrial wastes.

(7) Develop a suitable indicator for organic substances in water, and relate their presence to water treatment plant operating problems.

(8) Expand research to develop improved analytical methods for determining hazardous inorganic and organic trace materials, exotic substances, etc. (These may require utilizing membrane filters, electron microscopes, flame spectrophotometers, autoanalyzers, and atomic absorption analyzers.)

(9) Conduct research on biological assay methods for rapid determination of water safety. There is a need to develop simple test methods for various toxic substances, and to refine aquarium tests methods for continuous flow-through monitoring. (More than 300 organic pesticidal chemicals are in use in the United States. Many factors affect the fate of pesticides in different aquatic systems. At present, the determination of chlorinated hydrocarbons in water may be made only by instruments not found in most water plant laboratories, or even in some State laboratories. Water systems therefore are generally quite unprotected so far as control tests are concerned. Toxicity to fish may be used as a safety test of water for human consumption, but there is no other practical method available.)[38]

2.4 Present and Projected Industrial Water Use

Manufacturers in the Great Lakes Basin took into their plants more than 11.8 billion gallons of water per day in 1970. Approximately 1.1 billion gallons per day, 10 percent of their total requirement, was obtained from nearby public water supply systems, but most of the water was obtained through intake and delivery systems owned and operated by the manufacturers.

Of the nearly 11 billion gallons of water self-supplied by manufacturing for an average day, more than 95 percent was taken from surface-water supplies of the Region. The remaining 320 million gallons per day were obtained from company-owned wells. It may be presumed that the Great Lakes themselves or their connecting waterways were the source of most surface water withdrawn for manufacturing, because many of the industries with very large water requirements (steel mills, petroleum refineries, and chemical plants) are located in the shoreline counties of the Region. Paper manufacturers, particularly those which process the pulpwood into chemical pulp, paper, and cardboard, are most commonly located inland near the forests which supply their raw material, and on the shores of inland streams and lakes which provide generally ample quantities of good quality water.

Approximately 90 percent of the total water withdrawals by all Great Lakes Basin manufacturers are made by the industries in five major industry groups: Standard Industrial Classification (SIC) 20, Food and Kindred Products; SIC 26, Paper and Allied Products; SIC 28, Chemicals and Allied Products; SIC 29, Petroleum and Coal Products; and SIC 33, Primary Metals industries. Within each of the industry groups there is broad diversity in raw materials, processes, products, and degree of vertical integration between raw materials and finished products. To illustrate the characteristics of manufacturing water use, examples are presented of the hypothetical uses of water by representative establishments in each SIC two-digit group.

The water needs of a manufacturing plant are related directly to its products, the quantities produced, the processes employed, the starting materials, the need for electric energy and its availability from exterior sources, health, safety, environmental concerns, the number of employees and employee amenities, aesthetic considerations, and other factors. A manufacturer may meet its water needs by choosing options ranging from single use (no recycling) to closed systems with multiple recycling. Many changing factors influence the manufacturer's decision:

(1) the availability of water, including water rights of the user and subsequent users

(2) the quality of water at source

(3) the quality of water required at each point of use

(4) pretreatment cost of water prior to use and the feasibility of cost minimization through recycling, counter-current use, or secondary use

(5) the value of recoverable products, byproducts, and heat energy in the waste streams

(6) secondary water use characteristics

(7) the degree of treatment required for plant effluents and cost reductions that may be acquired by recycling

(8) the consumptive losses of water that occur through its use

(9) the availability of dry methods in place of water-dependent manufacturing methods

(10) maintenance of attractive plant grounds

(11) the competitive advantages or disadvantages of water recycling and reuse

(12) company policy

Although many advocate that manufacturers adopt a closed system, at present few manufacturers can institute such practices for all plant uses and still remain competitive in existing markets. Nevertheless, manufacturers are increasing the quantities of water that are recycled in their plants because of stricter application of Federal and State powers to abate water pollution from industrial waste discharges. Frequently treatment of plant effluents produces water of equal or better quality for a particular use than that of the original source. In order to further offset the costs of pollution abatement, materials, products and byproducts are also recovered and recycled. Several examples of this trend have been reported. A steel mill recovers mill scale for recycling into the furnaces by treating effluent from its rolling mills, and in so doing has reduced its water intake from 140 mgd to 8.6 mgd. A chemical plant is installing cooling towers for recycling of its cooling water with a potential reduction of 100 mgd in total plant intake.

The truly closed system cannot be achieved for manufacturing water use because of consumptive losses of water that occur by incorporation of water in products, evaporation, employee use, and leaks. Currently the U.S. manufacturing sector has a gross water use of approximately 114 bgd (billion gallons per day) and consumes approximately 4 bgd. Water consumption imposes a minimum withdrawal requirement at least equal to the losses and thus places an upper limit on the number of times that water can be recirculated.

In 1970 the manufacturers of the Great Lakes Basin withdrew 11.8 bgd to meet their estimated gross water requirements of 24.8 bgd. Approximately 900 mgd was consumed. Of the 11.8 bgd of water withdrawn, more than 7.5 bgd was used as cooling water. It is believed that evaporation accounted for most of the consumptive water losses in the Region. Approximately 3.4 bgd was applied to process use. With the exception of a few industries, such as food and beverage manufacture, consumptive losses by incorporation of water into the product are minor. In process use evaporation constitutes the largest element of consumptive loss. The remaining 600 mgd of withdrawal was used for boiler feedwater, the domestic needs of employees, and plant and ground maintenance.

Because evaporation adds to the vapor phase of the hydrologic cycle, the addition of large quantities of water vapor to the atmosphere from areas of concentrated industrial activity, along with similar additions from thermal electric power plants and other users, may increase the occurrence of weather anomalies. This phenomenon has already been observed downwind from metropolitan Chicago and other areas. Consumptive losses can be expected to increase as the economy grows. The effects of these losses on resource availability, weather, and climate may warrant separate study.

In the following sections discussions and estimates of manufacturing water use in the 15 planning subareas are presented. The estimated value added by manufacture for the five major water-using SIC two-digit industry groups and the remainder of the manufacturing sector are given (Figures 6–9 through 6–13). Estimates of gross water use, recirculation rates, withdrawal needs, and consumptive losses for 1970, 1980, 2000, and 2020 have also been included (Table 6–17).

Table 6–17 shows a decline in the rates of manufacturing withdrawals of water in the Great Lakes Basin for the near future. Gradually the rate will increase and eventually it will approach the rate of increase in manufacturing production. In this appendix the reasons for the decline and subsequent rise are discussed in the methodology section and in the chapters dealing with planning subarea requirements. Although manufacturing withdrawals may initially decrease and then increase by the year 2020 to only 40 percent more than the 1970 quantities withdrawn in the Basin, there are likely to be large requirements for new water supplies at new locations in the period 1985 to 2020. In most of the planning subareas the total quantities of water to be supplied at new locations by the year 2020 may be greater than the quantities presently supplied to existing manufacturing plants. These impending situations present legal, institutional, and structural problems.

Water-use forecasts invite interpolation for interim years. Interpolation should be used to project only for target years because it is highly unlikely that the withdrawal trends will occur with the smoothness that the curves imply. On the contrary, the trends probably will be uneven because of decisions made by individual companies in response to economic and social factors that are uncertain now. If one or several large water-using plants in a planning subarea decide to institute water recycling, the projections can be distorted.

The forecasts should be used to indicate changes that are expected to occur in manufacturing water use based upon the existing industries and forecasts of industrial growth. The forecasts are warnings of directions and magnitudes of the demand/supply relationships of industry and resources. Planning water resources may be reallocated in order to accommodate future growth.

2.5 Present and Projected Rural Water Use

The relative importance of the various rural water uses is projected to remain the same as in 1970. Rural nonfarm use is by far the heaviest. Rural nonfarm use accounts for 61 to 66 percent of the total rural water requirements for 1970 and the projection periods. On rural farms, water use for livestock is the greatest, followed by domestic consumption and spray water (Table 6–18). Although total rural water requirements are projected to increase for both rural farm and rural nonfarm purposes, within the rural farm category there is a relative decline in rural domestic requirements. Changes between 1970 and 2020 in each component of rural farm water requirements for planning subareas were grouped into three general categories: relatively stable, relatively increasing, and relatively decreasing (Table 6–19). Tables 6–20 through 6–25 contain additional information on rural water requirements and use.

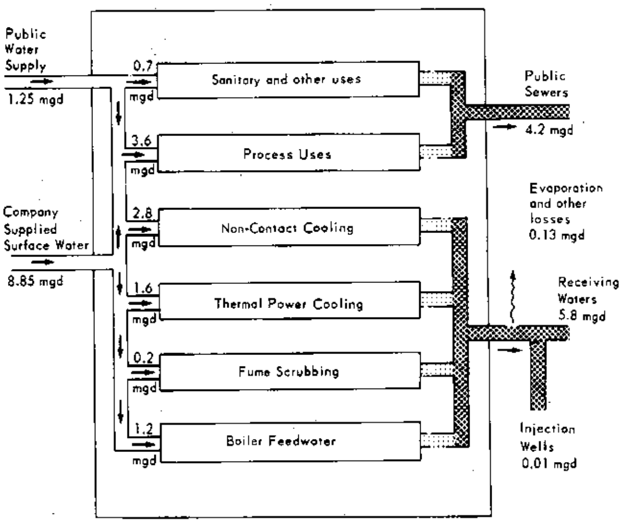


FIGURE 6–9 Characteristics of Water Use in Medium-Sized Wet Corn Milling Plant

SIC 2046—Wet Corn Milling—establishments primarily engaged in milling corn or sorghum grain (milo) by the wet process, and producing starch, syrup, oil, sugar, and by-products such as gluten feed and meal. Establishments primarily engaged in manufacturing starch from other vegetable sources (potato, wheat, etc.) are also included.

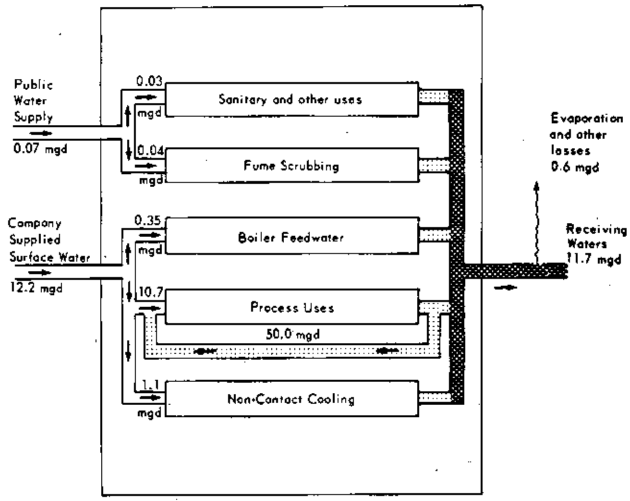


FIGURE 6–10 Characteristics of Water Use in Medium-Sized Plant with Own Pulp Mill

SIC 2621—Paper Mills, except Building Paper Mills—establishments primarily engaged in manufacturing paper from wood pulp and other fibers. They also may manufacture converted paper products. Pulp mills combined with paper mills, and not separately reported, are also included in this industry. Where separately reported, they are classified in Industry 2611.

TABLE 6–17 Total Manufacturing Withdrawal From All Sources, Great Lakes Basin (mgd)[1]

Planning Subarea	1970 With-drawals	1970 Con-sumption	1980 With-drawals	1980 Con-sumption	2000 With-drawals	2000 Con-sumption	2020 With-drawals	2020 Con-sumption
1.1	100	8	77	11	79	21	123	35
1.2	33	4	35	5	48	15	86	30
2.1	359	40	378	59	351	97	601	176
2.2	5174	423	3461	587	3543	1202	5867	2415
2.3	554	53	538	88	624	250	1059	509
2.4	96	8	89	14	98	39	183	92
3.1	25	3	23	4	31	10	63	16
3.2	567	34	535	62	497	245	1011	648
4.1	1562	148	1219	196	1031	430	1704	842
4.2	371	42	414	69	429	158	724	342
4.3	1449	100	1341	151	1319	381	2131	847
4.4	1051	89	976	126	818	251	1189	496
5.1	100	8	109	10	146	18	248	39
5.2	313	22	303	35	299	94	604	230
5.3	105	10	70	10	47	14	53	18
TOTAL BASIN	11,859	992	9568	1427	9360	3225	15,646	6735

[1] self-supplied + municipally supplied water

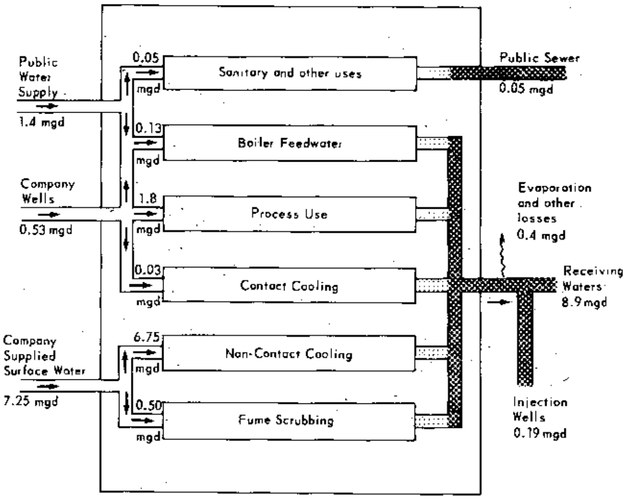


FIGURE 6–11 Characteristics of Water Use in Medium-Sized Industrial Inorganic Chemicals Plant

SIC 2819—Industrial Inorganic Chemicals, Not Elsewhere Classified—establishments primarily engaged in manufacturing inorganic chemicals, and not elsewhere classified. Important products of this industry include inorganic salts of sodium, potassium, aluminum, calcium, magnesium, mercury, nickel, silver, and tin; inorganic compounds such as alums, calcium carbide, hydrogen peroxide, phosphates, sodium silicate, ammonia compounds and anhydrous ammonia; rare earth metal salts and elemental bromine, fluorine, iodine, phosphorus, and alkali metals.

TABLE 6–18 Shares of Rural Water Requirements by Specific Components, Great Lakes Basin (percent of total requirements)

	1970	1980	2000	2020
Rural farm				
Domestic	12.6	12.1	8.7	7.8
Livestock	20.9	24.5	26.8	30.7
Spray	0.2	0.2	0.2	0.2
Subtotal	33.8	36.8	35.7	38.7
Rural Nonfarm	66.2	63.2	64.3	61.3
Total	100.0	100.0	100.0	100.0

TABLE 6–19 Relative Direction of Change Projected for Rural Water Requirements, 1970 to 2020, Great Lakes Basin

	Planning Subareas		
Use	Increase	Decrease	Stable
Rural Nonfarm	All planning subareas	---	---
Rural Farm			
Domestic	2.4, 4.4, 5.1	1.1, 1.2, 2.2, 3.1, 3.2, 4.1, 4.3, 5.3	2.1, 2.3, 4.2 5.1
Livestock	All others	---	1.1, 1.2, 2.2
Spray	3.2, 5.3	All others	1.1, 2.3, 3.1

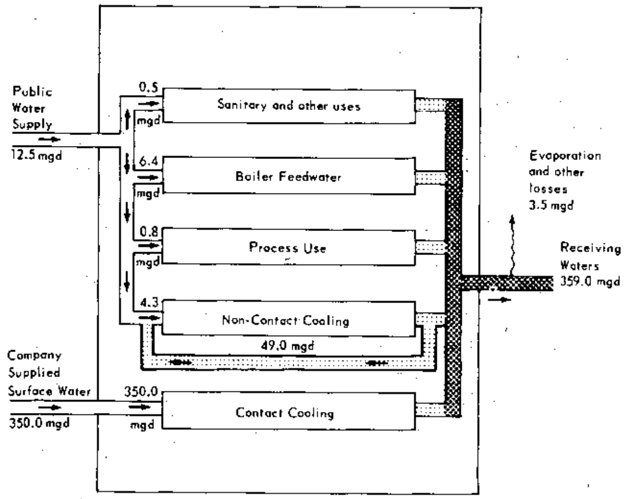


FIGURE 6–12 Characteristics of Water Use in Large Refinery

SIC 2911—Petroleum Refining—establishments primarily engaged in producing gasoline, kerosene, distillate fuel oils, residual fuel oils, lubricants, and other products from crude petroleum and its fractionation products, through straight distillation of crude oil, redistillation of unfinished petroleum derivatives, cracking, or other processes.

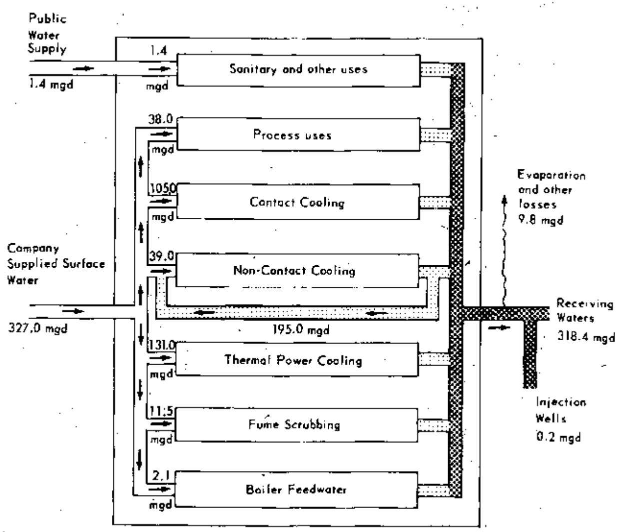


FIGURE 6–13 Characteristics of Water Use in Large Integrated Steel Mill

SIC 3312—Blast Furnaces, Steel Works, and Rolling Mills—establishments primarily engaged in manufacturing hot metal, pig iron, silvery pig iron, and ferroalloys from iron ore and iron and steel scrap; converting pig iron, scrap iron, and scrap steel into steel; and hot rolling iron and steel into basic shapes such as plates, sheets, strips, rods, bars, and tubing. Merchant blast furnaces and by-products or beehive coke ovens are also included in this industry.

TABLE 6-20 Rural Water Use Requirements and Consumption, Great Lakes Basin (mgd)

	1970	1980	2000	2020
REQUIREMENTS				
Rural Farm				
Domestic	59.4	64.7	56.4	57.6
Livestock	98.9	130.9	174.4	226.9
Spray Water	1.1	1.1	1.0	1.0
Subtotal	159.4	196.7	321.8	285.5
Rural Nonfarm	312.0	338.4	417.8	452.5
Total	471.3	535.0	649.6	738.0
CONSUMPTION				
Rural Farm				
Domestic	14.8	16.2	14.1	14.0
Livestock	89.0	117.8	157.5	204.1
Spray Water	1.1	1.1	1.0	1.0
Subtotal	104.9	135.1	172.7	219.0
Rural Nonfarm	46.8	50.8	62.7	67.9
Total	151.8	185.8	235.3	286.9

TABLE 6-21 Summary of Rural Water Use in the Great Lakes Basin (mgd)

	1970		1980		2000		2020	
Planning Subarea	Require-ments	Con-sumption	Require-ments	Con-sumption	Require-ments	Con-sumption	Require-ments	Con-sumption
1.1	7.5	2.1	7.7	2.1	9.3	2.5	10.0	2.5
1.2	5.0	1.2	5.0	1.2	5.5	1.5	7.0	1.7
2.1	47.5	23.4	57.4	30.5	70.6	38.6	82.7	47.8
2.2	87.6	22.9	94.2	23.9	109.2	26.6	114.9	27.5
2.3	82.3	24.1	93.8	30.2	118.1	42.5	134.4	53.2
2.4	16.8	4.8	19.6	6.7	24.8	9.6	29.7	12.8
3.1	6.8	2.0	9.3	3.3	12.4	3.9	16.8	6.3
3.2	32.5	9.4	38.3	13.0	47.8	17.7	55.0	23.0
4.1	49.2	11.9	54.1	13.4	63.3	15.6	67.7	17.3
4.2	42.4	15.3	51.0	20.9	64.1	28.3	76.3	37.3
4.3	24.6	5.8	26.2	5.9	30.9	6.9	33.4	7.9
4.4	16.5	6.4	16.4	7.1	23.5	8.8	31.6	10.9
5.1	10.8	5.2	14.9	6.9	14.4	8.0	17.6	10.2
5.2	32.1	12.3	36.4	14.8	43.4	17.9	47.0	21.0
5.3	9.2	4.9	10.2	5.6	12.0	6.5	13.4	7.5
Total Basin[1]	471.0	151.7	535.0	185.5	650.0	234.9	738.0	286.9

[1]Total may not add due to rounding.

TABLE 6–22 Rural Nonfarm, Rural Domestic, Livestock, Spray Water, and Total Rural Water Requirements, Great Lakes Basin, 1970 (mgd)

Planning Subarea	Rural Non-Farm	Rural Domestic	Livestock	Spray Water	Total
1.1	5.6	0.8	1.2	0.00	7.6
1.2	4.1	0.4	0.5	0.00	5.0
2.1	18.7	8.1	20.5	0.14	47.5
2.2	70.7	5.0	11.7	0.15	87.6
2.3	56.4	11.8	14.0	0.20	82.4
2.4	11.6	2.4	2.7	0.04	16.7
3.1	4.7	0.9	1.2	0.01	6.8
3.2	22.1	5.1	5.3	0.08	32.6
4.1	39.6	4.1	5.4	0.08	49.2
4.2	22.9	8.8	10.6	0.20	42.5
4.3	20.3	1.8	2.6	0.02	24.7
4.4	9.1	2.6	4.8	0.04	16.5
5.1	4.3	2.0	4.5	0.05	10.9
5.2	18.6	4.1	9.3	0.07	32.2
5.3	3.3	1.4	4.5	0.01	9.3
Total Basin	312.0	59.4	99.0	1.09	471.5
Lake Basin					
1.0	9.7	1.2	1.7	0.00	12.6
2.0	157.4	27.3	48.9	0.53	234.2
3.0	26.8	6.0	6.5	0.09	39.4
4.0	91.9	17.3	23.4	0.34	132.9
5.0	26.2	7.6	18.4	0.13	52.4

Source: ERS computation using 1970 Basic Water Use Budget.

TABLE 6–23 Rural Nonfarm, Rural Domestic, Livestock, Spray Water, and Total Rural Water Requirements, Great Lakes Basin, 1980 (mgd)

Planning Subarea	Rural Non-Farm	Rural Domestic	Livestock	Spray Water	Total
1.1	6.1	0.4	1.2	0.01	7.7
1.2	4.2	0.2	0.6	0.00	5.0
2.1	19.8	9.7	27.8	0.13	57.4
2.2	78.6	3.0	12.5	0.14	94.2
2.3	60.6	13.5	19.5	0.20	93.8
2.4	12.3	2.8	4.6	0.04	19.7
3.1	6.1	0.8	2.4	0.01	9.3
3.2	23.0	6.6	8.7	0.10	38.4
4.1	44.2	3.3	6.6	0.08	54.2
4.2	24.8	9.8	16.2	0.22	51.0
4.3	22.9	0.9	2.4	0.02	26.2
4.4	7.4	3.2	5.8	0.03	16.4
5.1	5.9	3.1	5.8	0.04	14.8
5.2	19.1	5.7	11.7	0.06	36.6
5.3	3.4	1.5	5.2	0.01	10.1
Total Basin	338.4	64.7	131.0	1.09	534.8
Lake Basin					
1.0	10.3	0.6	1.8	0.01	12.7
2.0	171.3	29.0	64.4	0.51	265.1
3.0	29.1	7.4	11.1	0.11	47.7
4.0	99.3	17.3	31.0	0.35	148.0
5.0	28.4	10.4	22.7	0.11	61.6

Source: ERS computation using 1980 Basic Water Use Budget

TABLE 6–24 Rural Nonfarm, Rural Domestic, Livestock, Spray Water, and Total Rural Water Requirements, Great Lakes Basin, 2000 (mgd)

Planning Subarea	Rural Non-Farm	Rural Domestic	Livestock	Spray Water	Total
1.1	7.6	0.3	1.5	0.01	9.4
1.2	5.3	0.1	0.1	0.00	5.5
2.1	26.8	7.5	36.2	0.12	70.6
2.2	93.2	2.8	13.2	0.12	109.3
2.3	74.7	12.0	31.3	0.20	118.2
2.4	13.5	3.9	7.3	0.03	24.7
3.1	9.0	0.7	2.7	0.01	12.4
3.2	28.3	6.2	13.2	0.08	47.8
4.1	53.0	2.4	7.8	0.06	63.3
4.2	31.6	8.8	23.5	0.24	64.1
4.3	27.3	0.7	2.9	0.02	30.9
4.4	14.1	2.8	6.6	0.03	23.5
5.1	4.3	2.6	7.4	0.03	14.3
5.2	24.2	4.6	14.5	0.05	43.4
5.3	4.9	1.0	6.2	0.01	12.1
Total Basin	417.8	56.4	174.4	1.01	649.5
Lake Basin					
1.0	12.9	0.4	1.6	0.01	24.9
2.0	208.2	26.1	87.9	0.47	322.8
3.0	37.3	6.9	15.9	0.09	60.2
4.0	126.0	14.7	40.9	0.35	181.8
5.0	33.4	8.3	28.1	0.09	69.8

Source: ERS computation using 2000 Basic Water Use Budget.

TABLE 6–25 Rural Nonfarm, Rural Domestic, Livestock, Spray Water, and Total Rural Water Requirements, Great Lakes Basin, 2020 (mgd)

Planning Subarea	Rural Non-Farm	Rural Domestic	Livestock	Spray Water	Total
1.1	8.3	0.2	1.5	0.01	10.0
1.2	6.1	0.1	0.8	0.00	7.0
2.1	29.5	6.9	46.2	0.12	82.7
2.2	99.1	2.3	13.4	0.11	114.9
2.3	79.6	12.5	42.2	0.20	134.5
2.4	14.3	4.3	11.1	0.03	29.7
3.1	11.2	0.7	4.9	0.01	16.8
3.2	30.0	6.8	18.1	0.09	55.0
4.1	56.1	2.5	9.1	0.06	67.8
4.2	33.6	9.4	33.1	0.23	76.3
4.3	28.9	0.8	3.8	0.02	33.5
4.4	20.9	2.9	7.9	0.02	31.7
5.1	5.2	2.7	9.7	0.03	17.6
5.2	24.5	4.5	18.0	0.04	47.0
5.3	5.2	1.0	7.2	0.01	13.4
Total Basin	452.5	57.6	227.0	0.98	737.9
Lake Basin					
1.0	14.4	0.3	2.3	0.01	17.0
2.0	222.5	25.9	112.9	0.45	361.8
3.0	41.2	7.5	23.0	0.10	71.8
4.0	139.5	15.6	53.8	0.34	209.3
5.0	34.9	8.2	34.9	0.08	78.0

Source: ERS computation using 2020 Basic Water Use Budget.

Section 3

LAKE SUPERIOR BASIN

3.1 Summary

3.1.1 The Study Area

The Lake Superior basin drains 14 percent of the U.S. portion of the Great Lakes Basin and encompasses portions of Minnesota, Wisconsin, and Michigan. Figure 6–14 is an area map of the basin. Major streams and tributaries draining the 16,986 square-mile hydrologic area include the St. Louis, Bad, Montreal, Ontonagon, Sturgeon, and Tahquamenon Rivers. The basin is divided into two planning subareas, Lake Superior West, Planning Subarea 1.1, and Lake Superior East, Planning Subarea 1.2. The basin is a long narrow watershed extending 350 miles from east to west and 150 miles from its northernmost reach to its southernmost boundary. Its boundary extends inland as much as 100 miles and as little as 20 miles from the shoreline.

3.1.2 Economic and Demographic Characteristics

In 1970 the resident population of the Lake Superior region was approximately 524,400, nearly 4 percent less than the 1960 total. The basin contains 2 percent of the Great Lakes Basin population. The most heavily populated areas are St. Louis, Douglas, and Marquette Counties. With the exception of St. Louis and Marquette Counties, all Lake Superior basin counties have populations of less than 50,000. The only SMSA located within the basin is Duluth-Superior, which in 1960 contained 52 percent of the basin's population. During the summer and hunting seasons, significant numbers of visitors are attracted to the area. In 2020 the resident population of the Lake Superior basin is expected to be 669,000.

In 1962 total personal income in the region was a little more than $1 billion. Average per capita income in the basin in 1970 was approximately $3,500, almost 20 percent lower than the national level.

In 1960 nearly 265,000 people were employed in the region. Ample raw materials (timber and minerals), the short growing season, and infertile soils are factors that greatly affect employment.

Although dairy farming is the principal activity, many farmers produce potatoes, hay, beef cattle, sheep, and poultry as well. Many farm owners cut timber during the winter and operate their farms during the summer. The farms in this basin are less prosperous than those farther south. In 1960, 6,500 agricultural employees in the basin produced crops, livestock, and livestock products valued at $25.4 million.

Manufacturing and mining of copper and iron account for most of the employed population at present. In 1960 there were 27,500 manufacturing employees and 21,000 mining employees.

Throughout this region the rate of economic growth has been low in recent years. Many forest and mining industries have declined. New activities are little more than replacements. However, mining will continue to be a most significant economic factor for the basin. The change from standard ores to the use of concentrated, pelletized ore has stimulated iron ore mining. In 1965 the Lake Superior basin produced approximately half of the iron ore in the United States.

3.1.3 Water Resources

Runoff averages 8 to 10 inches per year. The basin contains thousands of short and fast-moving streams that, depending on the season, flow erratically. Their average annual discharge does not generally exceed 1,000 cfs.

The basin contains approximately 58,000 acres of inland lakes larger than 40 acres in size. Many smaller lakes also dot the region. Lake Gogebic, the largest inland lake, has an area of 8,700 acres. There are 14 reservoirs,

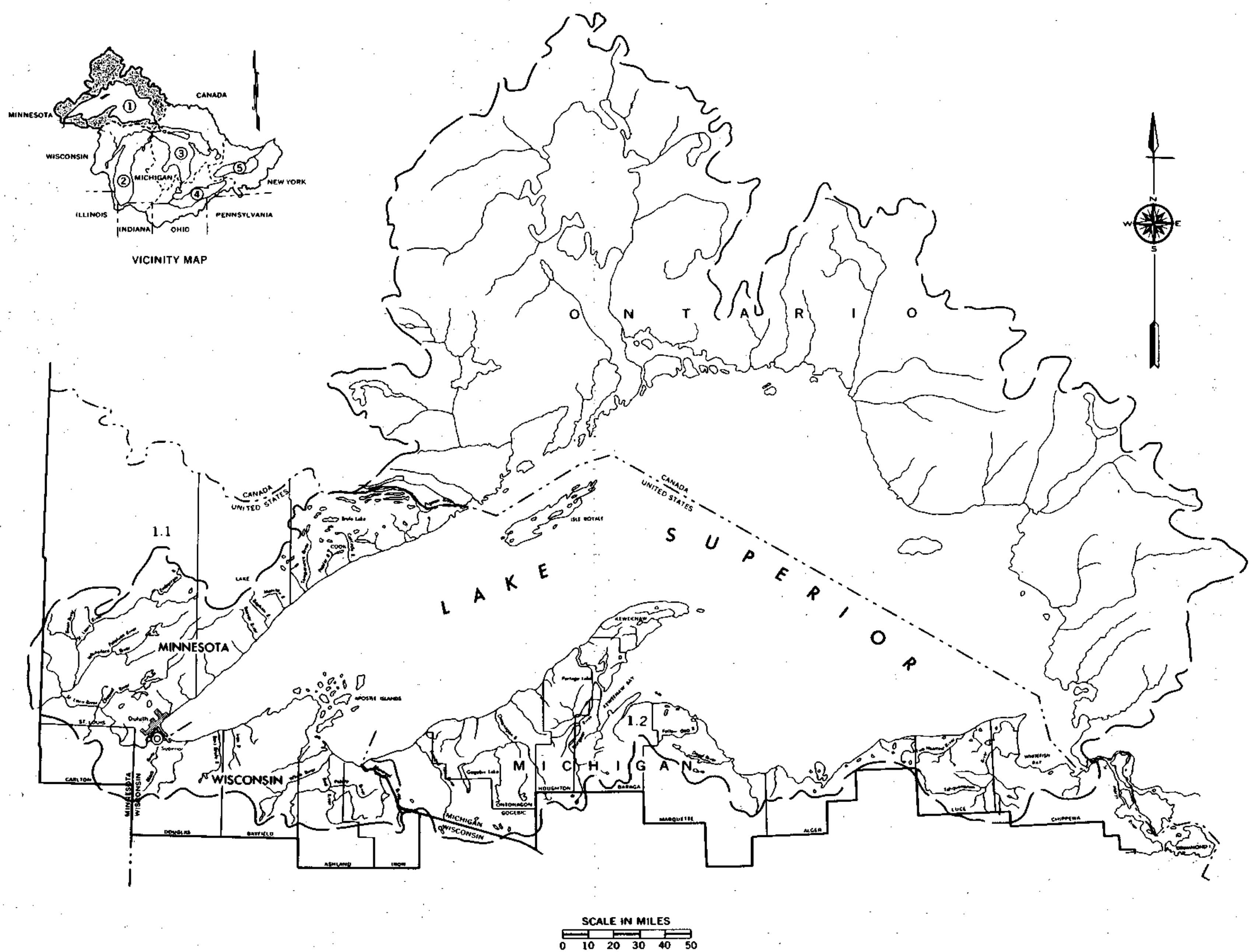


FIGURE 6-14 Lake Superior Basin

several of which are located near Duluth, Minnesota. Lake Superior has the largest surface area of any freshwater lake in the world, with a volume of 2,935 cubic miles and a total surface area of 31,700 square miles.

Quality of surface waters in the basin is generally high. Some areas receive substantial amounts of domestic and industrial wastes. Except for a few nearshore areas, the biological, chemical, and physical characteristics of Lake Superior are generally indicative of an oligotrophic lake.

The Lake Superior basin has a poor to fair potential for ground-water supplies, but locally there are good aquifers. The best aquifers are in sand and gravel deposits, especially east of the Upper Peninsula of Michigan and in the headwaters of the St. Louis River system of Minnesota. Sedimentary rocks in the eastern part also have good aquifers. Elsewhere the bedrock is dominantly Precambrian igneous, metamorphic, and sedimentary rock covered by a 25- to 400-foot thick glacial drift.

The major ground-water problem is that well yields are generally low. Highly mineralized water is found in a few areas, particularly in the Superior Slope, the Apostle Islands, the Keweenaw Peninsula area, and in the headwaters of the Tahquamenon Complex.

3.1.4 Present and Projected Water Withdrawal Requirements

In 1970 the Lake Superior basin total water withdrawals, 187 mgd, accounted for a mere 1 percent of the total water withdrawals for the Great Lakes Basin. A summary of present and projected water withdrawal requirements and needs for the municipal, industrial, and rural water-using sectors is presented in Table 6–26 and Figure 6–15.

The waters of Lake Superior are expected to provide 75 percent of the municipal water supply requirements by the year 2020. This water resource is more than adequate to meet the water-use requirements projected for the municipal sector. Development and proper management of the water resources of Lake Superior are needed.

Estimated costs for developing, operating, and maintaining municipal water supply facilities are shown in Table 6–27. During the 50-year period of this study it is estimated that $6.9 million will be required for capital investment in municipal water supply facilities. Total OMR expenditures will be $18.6 million.

Lake Superior can be classified as suitable for domestic water supply in all periods to the year 2020. Although some problems may be experienced, the water quality standards program for these interstate waters unequivocally calls for making them a suitable source of municipal water supply. The program also includes schedules and implementation plans.

3.1.5 Acknowledgements

Figures for average municipal water supply demands and population served by municipal water supplies are based on 1965 data from the Michigan Department of Public Health and on

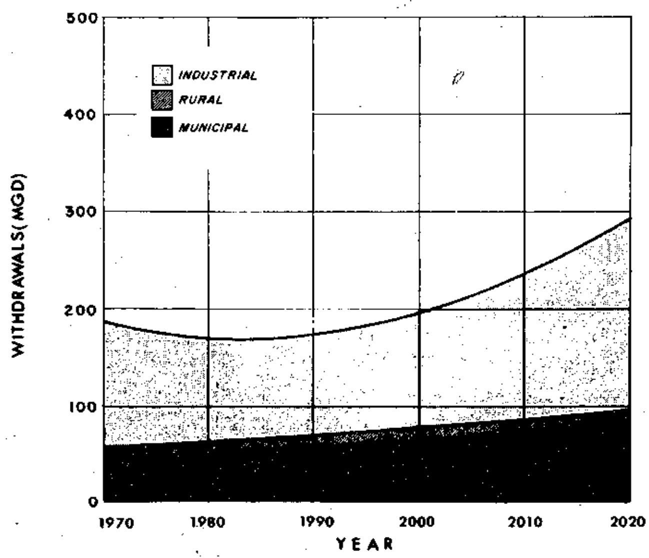


FIGURE 6–15 Municipal, Industrial, and Rural Water Withdrawal Requirements—Lake Superior Basin

In 1970 the resident population of the Lake Superior basin was 524,400, 2 percent of the Great Lakes Basin population. Municipal water supplies served 382,900 people or 71 percent of the basin population. This is expected to increase to 508,600 by 2000.

Dairying is the principal farming activity, but many farmers produce potatoes, hay, beef cattle, sheep, and poultry.

Manufacturing and mining (copper and iron) are predominant industrial activities in the basin. Duluth-Superior is the basin's major ore transshipping port. In 1960 the manufacturing sector of the economy employed 27,500 people while the mining sector employed 21,000 people.

TABLE 6-26 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Lake Superior Basin (mgd)

Use	1970				1980			
	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
1.1	33.2	94	7.5	135	40.0	70	7.8	118
1.2	15.3	31.5	5.0	51.8	14.3	33.6	5.0	52.9
Total	48.5	125	12.5	187	54.3	104	12.8	171
Consumption								
1.1	3.2	7.6	2.1	12	3.7	10	2.1	16
1.2	1.6	3.8	1.2	6.6	1.0	4.8	1.2	7.0
Total	4.8	11	3.3	19	4.7	15	3.3	23
1970 Capacity-Future Needs								
1.1	75.1	94	7.5	177	3.3	--	0.3	3.6
1.2	23.0	31.5	5.0	59.5	--	2.1	--	2.1
Total	98.1	126	12.5	237	3.3	2.1	0.3	5.7

Use	2000				2020			
	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
1.1	50.8	71	9.4	131	62.9	114	10.0	187
1.2	15.7	46.4	5.5	67.6	17.9	84.3	7.1	109.3
Total	66.5	117	14.9	199	80.8	198	17.1	296
Consumption								
1.1	5.8	19	2.5	27	7.9	31.5	2.5	42
1.2	2.1	14.3	1.5	17.9	2.4	29.2	1.7	33.3
Total	7.9	33	4.0	45	10.3	61	4.2	75
1970 Capacity-Future Needs								
1.1	13.2	--	1.9	15	25.3	20	2.5	48
1.2	--	14.9	1.1	16.0	--	52.8	2.1	54.9
Total	13.2	14.9	3.0	31	25.3	72.8	4.6	103

TABLE 6-27 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Lake Superior Basin (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
Great Lakes	Capital	.777	2.242	2.691	3.019	5.710
	Annual OMR	.038	.189	.435	.227	.663
	Total OMR	.387	3.784	8.701	4.172	12.873
Inland Lakes and Streams	Capital	.000	.029	.059	.029	.089
	Annual OMR	.000	.001	.005	.001	.007
	Total OMR	.000	.029	.119	.029	.149
Ground Water*	Capital	.129	.426	.538	.556	1.095
	Annual OMR	.014	.079	.190	.094	.284
	Total OMR	.149	1.583	3.809	1.733	5.542
Long Distance Transport of Great Lakes	Capital	.000	.000	.000	.000	.000
	Annual OMR	-	-	-	-	-
	Total OMR	-	-	-	-	-
Total	Capital	0.907	2.700	3.289	3.607	6.896
	Annual OMR	0.054	0.269	0.631	0.323	0.955
	Total OMR	0.537	5.394	12.630	5.935	18.565

*Ground water unit cost assumptions are as follows:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells & pumping (See Figure 6-4)	65,600	35,200
Total	185,600	42,800

1968 data from the Wisconsin Department of Natural Resources. The U.S. Department of Commerce, Bureau of Domestic Commerce, furnished data and the analysis on industrial water-use requirements for the Lake Superior basin.

3.2 Lake Superior West, Planning Subarea 1.1

3.2.1 Description of Planning Subarea

3.2.1.1 Location

Planning Subarea 1.1 is located to the west of Lake Superior. Four northeastern Minnesota counties and four northern Wisconsin counties form this planning subarea (Figure 6-16).

The region is 250 miles long around the western end of Lake Superior. Its width varies from 18 miles in Lake County to 65 miles in St. Louis County, Minnesota.

3.2.1.2 Topography and Geography

Planning Subarea 1.1, a region of great natural beauty, contains numerous lakes and streams. A large portion of the area is wilderness characterized by forested hills, cascading streams, and rocky cliffs. Elevation ranges from 602 feet to 2,301 feet above sea level at Eagle Mountain, the highest point in the region.

One of the most striking features of the Lake Superior shoreline is its steeply rising walls. These escarpments vary from 800 to 1,000 feet above Lake Superior in the Bayfield Peninsula and the Douglas Copper Range to as much as 1,400 feet above Lake Superior at Keweenaw Point in Michigan.

Dominant land forms of the Superior Slope were created by glacial erosion. Rocky ridges

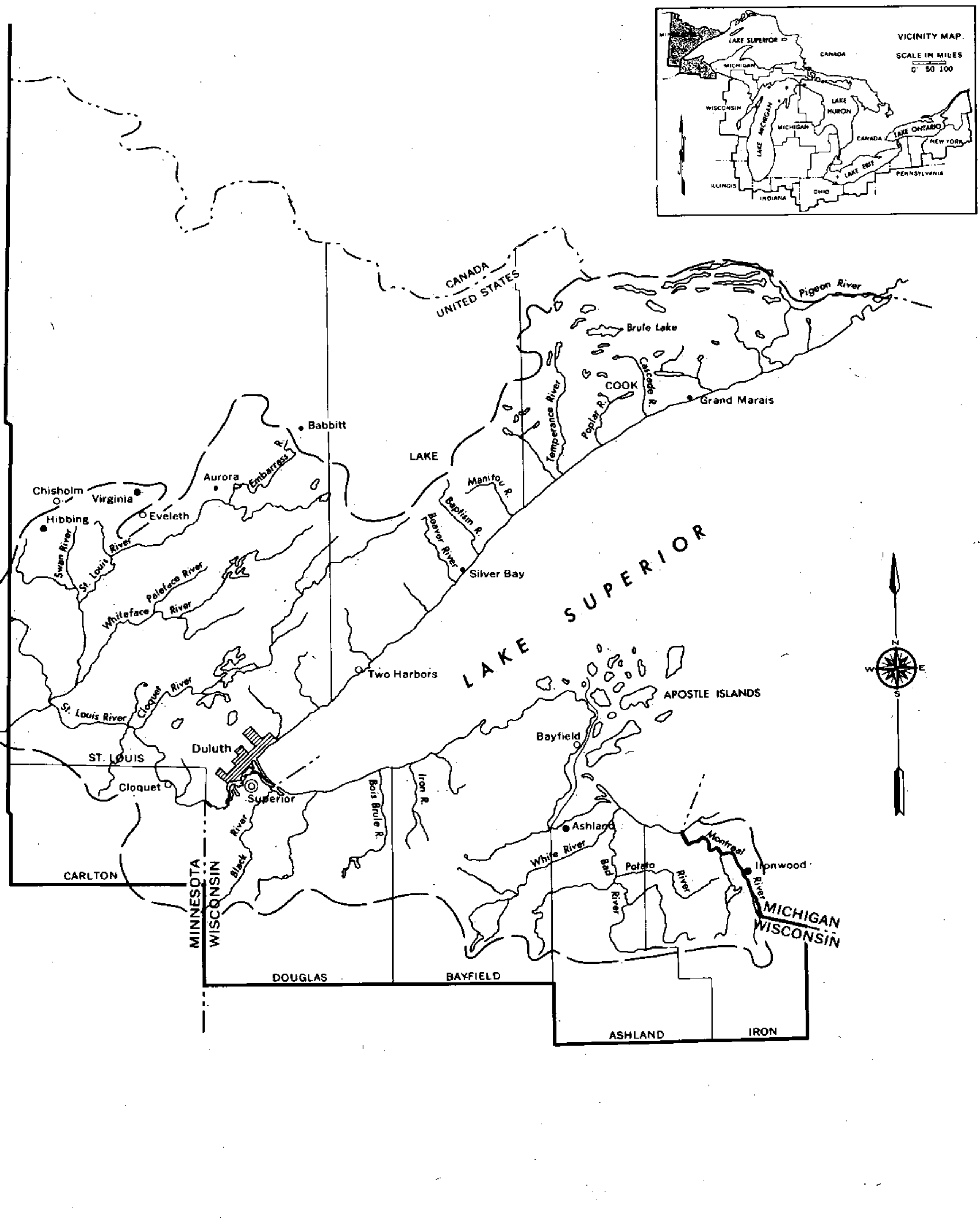


FIGURE 6–16 Planning Subarea 1.1

and knobs extend north from Duluth. The Sawtooth Mountains near Grand Marais are the most conspicuous bedrock relief. Inland from the shoreline most of the rocky hills are covered with glacial sediments which may be as deep as 200 feet, but probably average less than 50 feet. The thickest occur near Duluth. Most of the Nemadji River basin in Minnesota is covered with glacial lake sediments. In a few places the old beach ridges can be observed.

Five major drainage basins combine to form a total drainage area of 8,738 square miles (6,142 square miles in Minnesota, 2,956 square miles in Wisconsin, and 131 square miles in Michigan). The five basins are the Superior Shore complex, the St. Louis River basin, the Apostle Islands complex, the Bad River basin, and the Montreal River basin.

3.2.1.3 Climate

Planning Subarea 1.1 has a climate typified by very cold winters and rather warm summers. The tempering influence of Lake Superior is evident along the shoreline. Mean annual snowfall ranges from 107 inches at Pigeon River to 42.4 inches at Meadowlands. Precipitation averages 27.06 inches in the Minnesota portion, and average annual precipitation varies from 27 to 33 inches across the Wisconsin portion. Approximately half the total rainfall occurs during May, June, July, and August.

Prevailing winds in the Minnesota portion are northwesterly, except for the extreme northern tip where winds are northeasterly. In the Wisconsin portion prevailing winds are westerly in the late fall through early spring and easterly the rest of the year. Recorded temperature extremes are −5°F and 108°F. The average annual growing season varies from 150 days along the shores of Lake Superior to 90 days inland.

3.2.2 Water Resources

3.2.2.1 Surface-Water Resources

Lake Superior is a water source, supports commercial and sport fishing, is important for shipping, and has significant scenic and recreational aspects.

Most of the streams in Planning Subarea 1.1, except for those comprising the St. Louis River basin, flow perpendicular to the lakeshore and have an average length of less than 30 miles. The St. Louis River drains the central two-fifths of the planning subarea and flows eastward into Lake Superior at Duluth, Minnesota. Average annual runoff is about 8 to 10 inches per year across the basin.

Inland lakes and streams have a water storage capacity of 337,870 acre-feet. If all inland lakes and streams considered to be suitable for development as surface-water impoundments were developed in Planning Subarea 1.1, the total potential storage capacity is estimated to increase to 904,870 acre-feet.[45]

Water storage areas can now produce a sustained water supply yield of 595 mgd. If all potential water storage areas were fully developed, impounded inland lakes and streams could produce a sustained water supply yield of 1,191 mgd.[45]

Potential capacities and yields, as used in this section, relate to the total water resource. No attempt has been made to identify that portion of the water resource not suitable or available for use.

3.2.2.2 Ground-Water Resources

In the St. Louis basin major aquifers are stratified deposits of sand and gravel located in glacial drift. The Biwabik iron formation, the most important bedrock aquifer, is a sedimentary deposit consisting of fine-grained quartz with variable amounts of hematite, magnetite, and limonite. Where these deposits have been subject to weathering and oxidation, porosity and permeability have been greatly increased. Ten communities in the Mesabi range obtain all or part of their water from this formation.

Ground water in the Superior Slope (Minnesota) is available from the unconsolidated alluvial sands and gravels along some of the stream valleys, from stratified glacial sediments, and from igneous, metamorphic, and sedimentary bedrock formations.

Regional ground-water movement through the glacial deposits and bedrock is southeastward toward Lake Superior. Local movement is toward the valleys where discharge aids in maintaining streamflow during periods of low precipitation. None of the water-bearing strata in the region produces large quantities of water. In some areas ground-water supplies are insufficient even for domestic purposes, except in the Nemadji basin, where ground-water supplies are available because of the thickness of the glacial overlay.

Wisconsin counties in Planning Subarea 1.1 do not generally have good ground-water aquifers. Sand and gravel units in the glacial drift, particularly adjacent to streams, offer the best potential for ground-water development, but seldom can wells in this area be developed to yield more than 10 gpm. However, deep wells in Washburn and Bayfield tapping the Lake Superior sandstone formation are known to have yields of greater than 100 gpm.

Appendix 3, *Geology and Ground Water*, has reported the estimated ground-water yield from 70 percent flow duration data in the river basin group to be 2,240 mgd.[21]

3.2.3 Water-User Profile

3.2.3.1 Municipal Water Users

In 1970 Planning Subarea 1.1 supported a population of 354,200. It has one of the lowest average densities in the Basin with 38 people per square mile. Population is concentrated in the northwestern and central parts, and Duluth is populated by more than 100,000 people. The population in 2020 is projected to be 475,500 people, of which 74 percent (382,700) will be served by municipal water supplies. In 1970, 261,200 people were served by municipal water facilities. Average annual per capita personal income was $3,700 in 1970. Major manufacturing activity consists of forestry, pulp and paper industries, and iron ore mining.

3.2.3.2 Industrial Water Users

During the ice-free months the ports of Duluth, Minnesota, and Superior, Wisconsin, handle large shipments of minerals, basic metals, and forest products. Most of the manufacturing activity is in the Duluth-Superior SMSA. There are more than 300 plants in the Minnesota portion and approximately 60 plants in the Wisconsin portion. There are approximately 200 manufacturing plants in the other counties of the planning subarea. Most are in Carlton County, Minnesota, and Ashland County, Wisconsin.

3.2.3.3 Rural Water Users

In 1964 Planning Subarea 1.1 contained 901,000 acres of land in farm. Crop production is highly limited by the weather. Oats, hay, and meadow grass are the major crops. Potatoes, which require a great deal of water, were grown on 1,300 acres. Approximately two-thirds of livestock and livestock products came from dairies, which use great amounts of water. Crop sales returned only $3 million, but livestock and livestock product sales returned approximately $14 million in 1964. In 1960 the rural farm population was 19,000, and rural farms employed 4,000 people.

3.2.4 Present and Projected Water Withdrawal Requirements

A summary of municipal, industrial, and rural water withdrawal requirements for Planning Subarea 1.1 is contained in Figure 6–17 and Table 6–28.

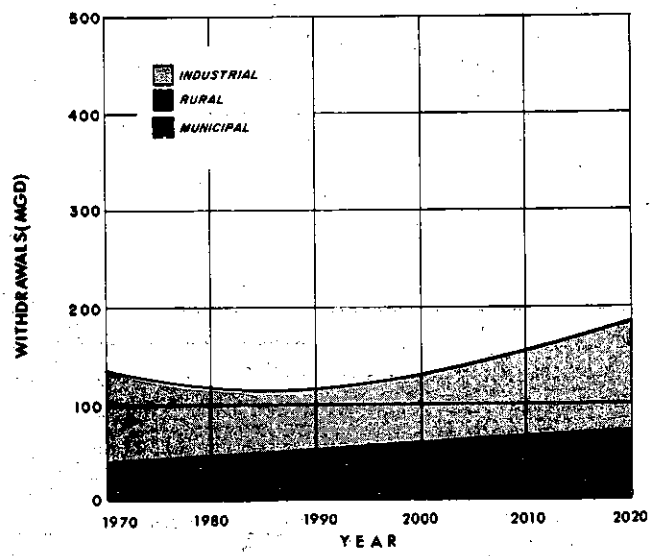


FIGURE 6–17 Municipal, Industrial, and Rural Water Withdrawal Requirements—Planning Subarea 1.1

Planning Subarea 1.1, located in the Duluth-Superior area of Minnesota and Wisconsin, is sparsely populated, with 354,200 people living in the region in 1970. Seventy-four percent of the population (261,200) was served by municipal water supplies in 1970, and this is expected to increase to 382,700 by 2020.

Agriculture is limited due to the short growing season and the scarcity of suitable land. Dairy farming constitutes the major agricultural activity in the region.

Major manufacturing activities consist of forestry, pulp and paper industries, and iron ore mining.

TABLE 6–28 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Planning Subarea 1.1 (mgd)

Use	1970 mun.	1970 ind.	1970 rural	1970 total	1980 mun.	1980 ind.	1980 rural	1980 total
Withdrawal Requirements								
Michigan	1.0	-	-	1	0.9	-	-	1
Minnesota	25.8	68	5.2	99	31.8	51	5.4	88
Wisconsin	6.4	26	2.3	35	7.3	19	2.4	29
Total	33.2	94	7.5	135	40.0	70	7.8	118
Consumption								
Michigan	0.1	-	-	-	0.1	-	-	-
Minnesota	2.6	5	1.5	9	3.0	7	1.5	12
Wisconsin	0.5	2	0.6	3	0.6	3	0.6	4
Total	3.2	7	2.1	12	3.7	10	2.1	16
1970 Capacity-Future Needs								
Michigan	1.5	-	-	2	-	-	-	-
Minnesota	49.6	68	5.2	123	3.0	-	0.2	3
Wisconsin	24.0	26	2.3	52	0.3	-	0.1	1
Total	75.1	94	7.5	177	3.3	-	0.3	4

Use	2000 mun.	2000 ind.	2000 rural	2000 total	2020 mun.	2020 ind.	2020 rural	2020 total
Withdrawal Requirements								
Michigan	0.7	-	-	1	0.6	-	-	1
Minnesota	41.8	52	6.5	100	52.5	83	7.0	143
Wisconsin	8.3	19	2.9	30	9.8	31	3.0	44
Total	50.8	71	9.4	131	62.9	114	10.0	187
Consumption								
Michigan	0.1	-	-	-	0.1	-	-	-
Minnesota	4.8	14	1.7	21	6.7	23	1.7	31
Wisconsin	0.9	5	0.8	7	1.1	9	0.8	11
Total	5.8	19	2.5	28	7.9	31.5	2.5	42
1970 Capacity-Future Needs								
Michigan	-	-	-	-	-	-	-	-
Minnesota	12.1	-	1.3	13	23.0	15	1.8	40
Wisconsin	1.1	-	0.6	2	2.3	5	0.7	8
Total	13.2	-	1.9	15	25.3	20	2.5	48

3.2.4.1 Municipal Water Use

Most of the 30 public water supplies in Planning Subarea 1.1 serve less than 5,000 people, with the exception of Chisholm, Duluth, Hibbing, Virginia, and Cloquet, Minnesota; and Superior-Ashland, Wisconsin. Nine systems use Lake Superior water, two use inland surface waters, and 19 use ground-water resources as the source of raw water for public supply.

Water withdrawal for municipal systems is approximately 25 percent of the total withdrawals required for water supply in the region. Lake Superior supplies approximately 60 percent of the municipal water. Thirty-eight percent comes from ground water, and less than 2 percent comes from inland lake and stream sources. The Duluth municipal system provides treated water for approximately 32 percent of the total planning subarea population. The remaining municipal systems provide water to 42 percent of the population.

Appendix 19, *Economic and Demographic Studies*, projects a 34 percent population increase for the planning subarea by 2020. In 1970 population was 354,200, and by 2020 population should increase to 475,500. Average daily municipal water demand is projected to increase from 33 to 63 mgd by 2020, a 90 percent increase. Approximately 75 percent of this projected demand will be supplied by the waters of Lake Superior.

There is virtually no possibility that this source will be inadequate. If ground-water needs in a small community increased, a local problem could arise because large capacity wells are usually difficult to develop.

Average water usage in Duluth, Minnesota, is 15.9 mgd. The supply serves 112,000 people and is the largest in the planning subarea. Water for the Duluth supply is withdrawn from Lake Superior through a rotary fine screen, chlorinated, and pumped to storage where it is held for approximately 1½ hours. Ammonia is added to the chlorinated water to form chloramines as it is discharged from the detention basin to the distribution system. Basically no treatment other than disinfection is provided for the surface-water supply of Duluth.

Because of the influence of seasonal changes, weather, and other natural occurrences, surface-water quality is subject to temporary deterioration. Effects include increased levels of turbidity, algal growths, and miscellaneous contaminants that will hinder disinfection treatment and may alter the taste of water.

To insure that water will be safe and clear, the Duluth water supply (as well as all other surface-water supplies) should receive intermediate treatment such as coagulation, sedimentation, filtration, and disinfection.

The City of Superior, the largest consumer of water in the Wisconsin portion of the basin, converted its source from a well field to Lake Superior in 1969. The well field, which consists of 70 to 80 shallow wells, is located on a point of land extending into the harbor. Superior obtains its lakewater from the intake and facilities constructed by the City of Cloquet, Minnesota. A treatment plant serving both these cities is in the planning stage. At present the treatment process in Superior consists of disinfection and slow sand filtration. Ashland, the only other city that uses Lake Superior, will continue with that source of supply and retain its slow sand filters.

The chemical and bacterial quality of water from Lake Superior is uniformly very good except at limited inshore areas near centers of population. Ground-water supplies in the small communities receive only chlorination, although iron removal would be desirable in some instances. Tables 6–29, 6–30, and 6–31 contain information on municipal water supply for Planning Subarea 1.1.

3.2.4.2 Industrial Water Use

The manufacturing sector expanded slowly between 1963 and 1970 with an increase in value added by manufacture of only 11 percent. During the same period approximately 30 plants closed down, but total employment climbed from approximately 17,500 to 18,500 because other establishments expanded. Among the larger users of water are the minerals beneficiation plants, pulp and paper mills, and primary metals product factories whose self-supplied water needs are obtained primarily from inland surface-water sources. These sources appear to be adequate for the 50-year study period.

Table 6–32 presents the base year estimates and projections of five water-use parameters and the value added by manufacture for four major water-using SIC four-digit industries and another manufacturing category that includes the residual industries of the sector. Although as much as 95 percent of the water needs result from the activities of fewer than 30 establishments, the estimates represent

TABLE 6-29 Municipal Water Supply, Planning Subarea 1.1, Wisconsin and Minnesota (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Consumption
1970	GL	354.2	154.6	19.9	23.8	30.3	2.0
	IS		6.0	0.5	0.6	0.8	
	GW		100.6	12.7	14.9	17.2	1.2
1980	GL	370.7	204.7	29.7	35.7	44.6	2.7
	IS		5.2	0.6	0.7	0.9	
	GW		67.9	9.7	11.6	14.7	0.9
2000	GL	419.1	243.1	38.3	46.0	57.5	4.4
	IS		5.7	0.7	0.8	1.1	
	GW		77.3	11.8	14.0	17.9	1.4
2020	GL	475.5	286.5	47.4	56.9	71.1	6.0
	IS		6.7	0.8	0.9	1.2	
	GW		89.5	14.7	17.8	22.2	1.9

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Consumption	Municipally Supplied Industrial Water: Average Demand	Consumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
1970	GL	93	14.2	1.4	5.7	0.6	43.8
	IS		0.5				1.4
	GW		9.6	0.9	3.1	0.3	30.0
1980	GL	105	21.3	2.1	8.4	0.7	2.6
	IS		0.6				
	GW		7.2	0.7	2.5	0.2	0.7
2000	GL	112	27.4	2.8	10.9	1.6	10.1
	IS		0.7				0.1
	GW		8.6	0.9	3.2	0.5	3.0
2020	GL	118	33.8	3.3	13.6	2.7	19.1
	IS		0.8				0.3
	GW		10.7	1.1	4.0	0.8	5.9

TABLE 6-30 Municipal Water Supply, Planning Subarea 1.1, Minnesota (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Con-sumption
	GL		142.6	18.6	22.4	28.7	1.9
1970	IS	270.5	3.2	0.3	0.36	0.45	
	GW		51.0	6.86	8.3	10.3	0.7
	GL		156.0	23.0	27.6	34.6	2.2
1980	IS	288.2	3.5	0.4	0.5	0.6	
	GW		55.1	8.4	10.1	12.6	0.8
	GL		189.3	30.6	36.7	45.9	3.5
2000	IS	334.3	4.2	0.5	0.6	0.8	
	GW		66.6	10.7	12.8	16.1	1.3
	GL		227.6	38.4	46.1	57.6	4.9
2020	IS	386.1	5.1	0.6	0.7	0.9	
	GW		79.8	13.5	16.2	20.3	1.8

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Con-sumption	Municipally Supplied Industrial Water: Average Demand	Con-sumption	Source capacity (1970) & Needs (1980, 2000, 2020)
	GL		13.0	1.3	5.6	0.6	38.3
1970	IS	92	0.3				0.22
	GW		4.8	0.5	2.04	0.2	11.1
	GL		16.0	1.6	7.0	0.6	2.3
1980	IS	103.4	0.4				
	GW		5.9	0.6	2.5	0.2	0.7
	GL		21.3	2.1	9.3	1.4	9.0
2000	IS	112	0.5				0.1
	GW		7.5	0.8	3.2	0.5	3.0
	GL		26.7	2.6	11.7	2.3	16.9
2020	IS	117	0.6				0.3
	GW		9.5	1.0	4.0	0.8	5.8

Needs: Maximum month demand for all additions in population served.

TABLE 6-31 Municipal Water Supply, Planning Subarea 1.1, Wisconsin (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Con-sumption
1970	GL	72.7	12.05	1.29	1.40	1.61	0.1
	IS		2.76	0.22	0.25	0.32	--
	GW		38.60	4.86	5.41	6.38	0.4
1980	GL	73.8	48.7	6.7	8.1	10.1	0.6
	IS		1.7	0.2	0.2	0.3	--
	GW		4.1	0.4	0.4	0.7	--
2000	GL	78.3	53.3	7.7	9.3	11.6	0.9
	IS		1.5	0.2	0.2	0.3	--
	GW		4.2	0.4	0.4	0.7	--
2020	GL	84.2	58.9	9.0	10.8	13.5	1.1
	IS		1.6	0.2	0.2	0.3	--
	GW		4.5	0.6	0.7	1.0	--

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Con-sumption	Municipally Supplied Industrial Water: Average Demand	Con-sumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
1970	GL	97	1.17	0.1	0.12	--	5.50
	IS		0.22	--	--	--	1.15
	GW		3.77	0.3	1.09	0.1	17.38
1980	GL	108	5.3	0.5	1.4	0.1	0.3
	IS		0.2	--	--	--	--
	GW		0.4	--	--	--	--
2000	GL	114	6.1	0.7	1.6	0.2	1.1
	IS		0.2	--	--	--	--
	GW		0.4	--	--	--	--
2020	GL	121	7.1	0.7	1.9	0.4	2.2
	IS		0.2	--	--	--	--
	GW		0.6	--	--	--	0.1

**Superior source to Lake Superior in 1969 - Projections made using lake water.

TABLE 6–32 Estimated Manufacturing Water Use, Planning Subarea 1.1 (mgd)

	SIC 20	SIC 26	SIC 28	SIC 33	Other Mfg.	Total
1970						
Value Added (Millions 1958$)	42	72	13	56	112	295
Gross Water Required	10	134	11	87	6	248
Recirculation Ratio	2.00	3.14	1.77	2.03	2.12	--
Total Water Withdrawal	5	43	6	43	3	100
Water Consumed	0.3	4.8	0.6	1.6	0.3	7.6
1980						
Value Added (Millions 1958$)	57	113	18	77	162	427
Gross Water Required	13	201	17	107	10	348
Recirculation Ratio	2.77	6.03	3.32	3.63	2.80	--
Total Water Withdrawal	5	33	5	30	4	77
Self Supplied	--	--	--	--	--	70
Water Consumed	0.6	7.4	1.0	1.9	0.3	11.2
2000						
Value Added (Millions 1958$)	97	247	38	119	334	835
Gross Water Required	21	390	41	148	20	620
Recirculation Ratio	3.15	8.00	11.70	9.63	4.80	--
Total Water Withdrawal	7	49	4	15	4	79
Self Supplied	--	--	--	--	--	71
Water Consumed	1.0	14.4	1.9	2.9	0.6	21
2020						
Value Added (Millions 1958$)	165	497	69	191	731	1653
Gross Water Required	34	672	72	204	47	1029
Recirculation Ratio	3.50	8.00	15.00	12.00	5.86	--
Total Water Withdrawal	10	84	5	17	8	123
Self Supplied	--	--	--	--	--	114
Water Consumed	1.2	24.7	3.5	3.8	1.6	35

the requirements for all manufacturing plants, large and small.

Water withdrawals by manufacturers are projected to decrease during the period 1970 to 2000 even though manufacturing production will grow at a more rapid rate than that of the recent past. The decrease in withdrawals is expected to occur through the introduction of improved efficiencies in reuse and recycling of water in mills and factories.

3.2.4.3 Rural Water Use

Rural water requirements and consumption were estimated for each planning subarea according to the methodology outlined in Subsection 1.4. In Table 6–33 total requirements and consumption are divided according to rural nonfarm and rural farm use. The rural farm category is further subdivided into domestic, livestock, and spray water requirements.

3.2.5 Needs, Problems, and Solutions

3.2.5.1 Municipal

The water resource available in Planning Subarea 1.1 is more than adequate to meet all projected requirements. Needs, which are defined as the water supply demands resulting from new growth, pertain only to the development and proper management of the water resource.

By 2020 the accumulated need for municipal water supply, as shown in Table 6–26, is expected to be 25.3 mgd. Lake Superior is expected to provide 19.1 mgd of this need. Ground water should supply 5.9 mgd. It has been projected that inland lakes and streams will supply only 0.3 mgd.

Table 6–34 gives an estimate of costs to develop municipal water supply facilities to meet projected needs. Considerable investment in public water supply systems is needed to pro-

TABLE 6–33 Rural Water Use Requirements and Consumption, Planning Subarea 1.1 (mgd)

	1970	1980	2000	2020
REQUIREMENTS				
Rural Farm				
Domestic	0.8	0.4	0.2	0.2
Livestock	1.2	1.2	1.5	1.5
Spray Water	0.0	0.0	0.0	0.0
Subtotal	2.0	1.7	1.7	1.7
Rural Nonfarm	5.6	6.1	7.6	8.3
Total	7.6	7.7	9.4	10.0
CONSUMPTION				
Rural Farm				
Domestic	0.2	0.1	0.1	0.1
Livestock	1.1	1.1	1.3	1.2
Spray Water	0.0	0.0	0.0	0.0
Subtotal	1.3	1.2	1.4	1.3
Rural Nonfarm	0.8	0.9	1.1	1.2
Total	2.1	2.1	2.5	2.5

vide for a growing population. Other costs will also be incurred to provide facilities where inadequacies now exist and to replace facilities that will wear out or become obsolete.

The Wisconsin counties in Planning Subarea 1.1 do not generally have good groundwater aquifers. Future growth away from Lake Superior may be limited by a need for water.

Because of projected demand and existing capabilities, no extensive alternative schemes should be needed. The municipal systems served by Lake Superior do anticipate the greatest increase in usage, but this source is unquestionably adequate. Minor changes in the demand upon municipal systems could occur. Excessive waste and leakage from the distribution system could be reduced when they become a problem. Domestic customers could conserve water. Industries could modify processes and increase circulation. However, it is not possible to address such alternatives in a quantitative manner. There are problems with high iron and manganese concentrations in ground water and a need for an adequate supply of water in the small communities in the Hurley-Montreal, Wisconsin, vicinity. Hurley uses water from a small lake that has been a marginal source in dry years, and the other three communities use ground water that is also not in abundant supply. Engineering firms and planning agencies are studying several sources of water including a portion of Michigan for a regional supply. The Wisconsin communities involved are small, economically depressed, and have declining populations. Expenditures for additional water could be a hardship and may not be necessary if the pro-

TABLE 6–34 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Planning Subarea 1.1 (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
Great Lakes	Capital	.777	2.242	2.691	3.019	5.710
	Annual OMR	.038	.189	.435	.227	.663
	Total OMR	.387	3.784	8.701	4.172	12.873
Inland Lakes and Streams	Capital	.000	.029	.059	.029	.089
	Annual OMR	.000	.001	.005	.001	.007
	Total OMR	.000	.029	.119	.029	.149
Ground Water*	Capital	.129	.426	.538	.556	1.095
	Annual OMR	.014	.079	.190	.094	.284
	Total OMR	.149	1.583	3.809	1.733	5.542
Total	Capital	.907	2.700	3.289	3.607	6.896
	Annual OMR	.054	.269	.631	.323	.955
	Total OMR	.537	5.394	12.630	5.935	18.565

*Ground water unit cost assumptions are as follors:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells & pumping (see Figure 6-4)	65,600	35,200
total	185,600	42,800

jected water demand remains the same or declines.

The Northwestern Wisconsin Regional Planning Commission includes the four Wisconsin counties in Planning Subarea 1.1. A portion of their planning responsibility includes water resource and community assistance planning. This Commission should be consulted before any recommendations in this study are carried out.

3.2.5.2 Industrial

Industrial water sources appear to be adequate for the time period of this study. No industrial water-use problems are foreseen for this planning subarea.

3.2.5.3 Rural

Future rural water requirements are assumed to draw primarily from ground-water sources, although in some areas streams will become increasingly important. The location and quality of ground water will be important for channeling additional development, particularly for rural nonfarm dwellings. In areas where ground water is in short supply development should proceed only after water supplies are located. Some areas cannot develop until a central supply is available.

Rural water requirements are projected to increase 32 percent and consumption is expected to increase 20 percent between 1970 and 2020.

Generally, low well yields and poor water quality are the principal problems in this area. The chemical quality of ground water varies considerably and thus influences location of rural development.

3.3 Planning Subarea 1.2, Lake Superior East

3.3.1 Description of Planning Subarea

3.3.1.1 Location

Planning Subarea 1.2, located in the northwestern portion of the Great Lakes Basin along the southern shore of Lake Superior, contains nine northern Michigan counties (Figure 6–18). This planning subarea extends the entire length of Michigan's Upper Peninsula (approximately 350 miles) and varies in width from less than 10 miles in Alger County to nearly 80 miles in the western portions of the region.

3.3.1.2 Topography and Geography

The topography is characterized as hilly with rock escarpments bordering on the lakeshore. The elevation of Lake Superior is 600 feet above mean sea level, but elevations of 1,800 to 2,000 feet above mean sea level are common in the area. Although a large part of the area is covered by glacial moraine, most of the area consists of bedrock covered by lake deposits. The uppermost bedrock layers are Ordovician in the west, Cambrian sandstone along the southern lakeshore to the Keweenaw Bay area, and Precambrian in the southwest. Four ground-water aquifers, Quaternary, Silurian, Ordovician, and Cambrian, are in use in Planning Subarea 1.2.

Eight major drainage systems combine to drain more than 7,750 square miles, including 7,665 square miles in Michigan and 92 square miles in Wisconsin. These drainage systems, which flow generally north into Lake Superior are the Porcupine Mountains complex, the Ontonagon River, the Keweenaw complex, the Sturgeon River, the Huron Mountains complex, the Grand Marais complex, the Tahquamenon complex, and the Sault complex. Major drainage areas to the south and west of the region include the Les Cheneaux complex, the Manistique River basin, the Sturgeon-Whitefish River basins, the Escanaba River basin, and the Montreal River basin.

3.3.1.3 Climate

Planning Subarea 1.2 has a continental climate and is significantly affected by Lake Superior. The region is subject to great extremes of weather conditions and temperatures caused by storms from the west and southwest. The Keweenaw Peninsula serves to deflect storms originating from a westerly direction.

Temperatures are generally mild, although the region is subject to extreme variation. Mean annual temperatures do not exceed 43°F in the region but extremes of −46°F at Kenton in Houghton County and 108°F at Marquette have been recorded. Mean temperatures for

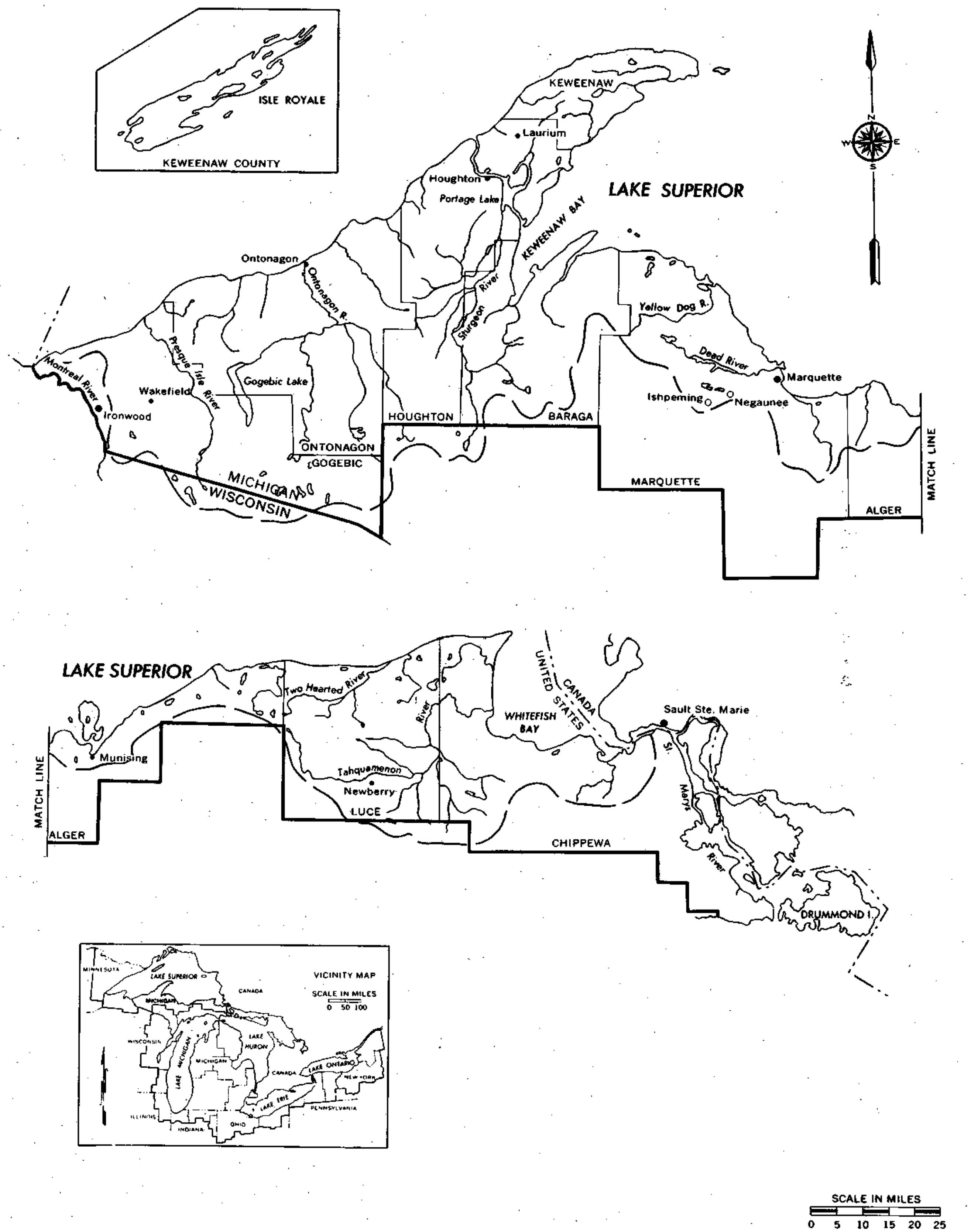


FIGURE 6–18 Planning Subarea 1.2

the month of July are in the range of a mean maximum of 80°F to a mean minimum of 50°F. Winters tend to be severe. Temperatures of −30°F are not uncommon. Mean annual precipitation varies from 36 inches in the western highlands and the Keweenaw Peninsula to approximately 28 inches in the eastern lowlands in Chippewa County. Average annual precipitation is 32 inches.

Average snow accumulation may be as much as 170 inches in the western highlands, in the Keweenaw Peninsula, and along the lakeshore. Average depths decrease to nearly 80 inches in Chippewa County.

Annual growing season ranges from 150 days on Lake Superior to 90 days inland.

3.3.2 Water Resources

3.3.2.1 Surface-Water Resources

The complex and varied hydrologic characteristics encountered in Planning Subarea 1.2 watersheds account for the variation of streamflow. Topographic features control to a large degree the direction and intensity of streamflow. Streams in the region are short and maintain stable flows. Low infiltration rates are common in the western highlands. High rates of infiltration generally occur in the eastern region. Streams in the western highlands often flood during the spring. Seasonal variations in streamflow tend to be less in areas with sandy soils, but where clay soils predominate streamflow is more varied. Average annual surface-water runoff for the region is 8 inches.

Planning Subarea 1.2 has an abundance of inland lakes. Marquette, Gogebic, and Houghton Counties contain most of the surface water acreage. Most of the lakes are undeveloped and despite widespread public ownership accessibility is limited. Public use is low through the region. Overenrichment and pollution are seldom a problem.

Inland lakes and streams of the planning subarea provide an existing water storage capacity of 246,700 acre-feet. If all inland lakes and streams suitable for development as surface-water impoundments were developed, the total potential storage capacity would increase to 338,700 acre-feet.[45]

Presently developed water storage areas can produce a sustained water supply yield of 1,356 mgd. If all potential water storage areas were fully developed in Planning Subarea 1.2, impounded inland lakes and streams could produce a sustained water supply yield of 1,525 mgd.[45]

Potential capacities and yields used in this section relate to the total water resource. No attempt has been made to identify that portion of the water resource not suitable or available for use.

3.3.2.2 Ground-Water Resources

Water available from bedrock and glacial deposits varies from low in the western highlands to moderate in some eastern counties. Most of the bedrock deposits in the western portion of the region are impervious and very few wells are completed in those formations. Sandstone formations located in the eastern portion yield as much as 100 gpm in some wells. Limestone formations produce as much as 500 gpm, although the water is sometimes very hard. Water from surficial deposits generally follow a similar availability pattern. In general, wells completed in the western portions of the region produce significantly larger quantities of water. Thicker glacial deposits in the eastern region generally produce as much as 100 gpm, and even higher quantities are obtained from streambed deposits. Water in surficial deposits is generally of good quality although it is usually hard. Bedrock that exists underneath glacial deposits usually contains highly mineralized water of poor quality.

Ground-water resources within the region are not extensive, especially along the shore of Lake Superior, yielding less than 10 gpm to wells. The Tahquamenon complex has potential yields of 100 to 500 gpm from bedrock and glacial drift aquifers. The Sturgeon and Ontonagon River basins have good potential. Chemical quality of ground water is variable although typically hard with an appreciable iron content. Major aquifer systems and their corresponding yields are the Quaternary (15 to 200 gpm), Silurian (50 to 100 gpm), Ordovician (50 to 500 gpm), and Cambrian (50 to 500 gpm).

Ground-water yield based on 70 percent flow-duration data is estimated to be 2,000 mgd in River Basin Group 1.2.[21]

3.3.3 Water-User Profile

3.3.3.1 Municipal Water Users

In 1970 the population of Planning Subarea 1.2 was 187,300, less than 1 percent of the Great Lakes Basin population. Population has declined in this planning subarea during the last decade. Approximately 47 percent of the 1960 population was classified as urban. The population in the year 2020 is projected to be 193,800. Major urban settlements are Sault Ste. Marie, Marquette, Negaunee, and Ironwood, none of which has a resident population of more than 20,000. Average population density in 1970 was approximately four people per square mile.

Municipal water supplies served 121,700 persons in 1970. In the year 2020 municipal water supplies are expected to serve 125,900 people. The total population served by municipal water supplies both in the present and future is a constant 65 percent. Average annual per capita income in 1970 was $3,300.

Forestry is the predominant land use feature. Wood production provides significant income and employment opportunity. Climate and soil conditions limit agriculture.

Manufacturing, transportation, mining, trades, and services account for most of the employment and income generated by the region. Manufacturing activity in Planning Subarea 1.2 centers around natural resources. In 1963 the region contributed approximately 3 percent of Michigan's total value added in manufacture. The nine counties constituting the planning subarea contain some of the highest quality recreational resources in the Great Lakes Basin, such as Tahquamenon Falls, Pictured Rocks, and the Huron and Porcupine Mountains, as well as the only national park in the Basin, Isle Royale. The area contains more than two million acres that can be used for recreation. Good game populations attract hunters from the Lower Peninsula of Michigan and from other States. Tourism now provides a base for economic development.

3.3.3.2 Industrial Water Users

Planning Subarea 1.2 is the least industrialized planning subarea in the Great Lakes Basin. In 1963 there were 471 manufacturing plants operating, employing 8,400 people. By 1967, although total manufacturing production had increased, the number of mills and factories had decreased to 355 and employment had fallen to 7,500. Lumber and wood products, ferrous and nonferrous metals, and pulp and paper are the leading activities. Output of such products will continue to grow, as well as the production of food products, fabricated metals, and light machinery.

3.3.3.3 Rural Water Users

In 1964 Planning Subarea 1.2 contained 411,000 acres of land in farm. Although climatic factors and soil conditions severely limit cropping, hay and meadow crops are produced. Approximately 2,000 acres of potatoes, which require a great deal of water, were grown in the area. Approximately two-thirds of livestock and livestock products came from dairies, which use large amounts of water. Crop sales amounted to only a little more than $2 million, and livestock and livestock product sales amounted to nearly $6 million. According to the 1960 census only 10,000 people lived on farms and 2,000 people were employed on farms.

3.3.4 Present and Projected Water Withdrawal Requirements

3.3.4.1 Municipal Water Use

Municipal water systems in the region now provide residents with 15.3 mgd. Approximately 64 percent is withdrawn from Lake Superior and other surface-water sources and the remainder from ground-water sources. Shoreline communities and major urban centers depend largely upon surface-water resources, but communities with lower demands rely upon ground-water sources. Of the 74 central water systems operating in this planning subarea in 1965, 27 obtained water from Lake Superior and the St. Marys River, three drew from inland surface sources, and 44 relied upon ground water. Sault Ste. Marie is the only community that withdraws water only from the St. Marys River. Withdrawals reach 2.7 mgd. Most of the water withdrawn by municipal systems is used for residential, commercial, and institutional uses. However, industrial water supply from municipal systems is also important. Table 6–36 shows 1970 withdrawals from each source.

According to recent data, water supply systems will not require expansion. It is reason-

TABLE 6–35 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Planning Subarea 1.2 (mgd)

	1970				1980			
Use	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
Michigan	15.3	31.5	5.0	51.8	14.3	33.6	5.0	52.9
Total	15.3	31.5	5.0	51.8	14.3	33.6	5.0	52.9
Consumption								
Michigan	1.6	3.8	1.2	6.6	0.9	4.8	1.2	6.9
Total	1.6	3.8	1.2	6.6	0.9	4.8	1.2	6.9
1970 Capacity-Future Needs								
Michigan	23.0	31.5	5.0	59.5	-	2.1	-	2.1
Total	23.0	31.5	5.0	59.5	-	2.1	-	2.1

	2000				2020			
Use	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
Michigan	15.7	46.4	5.5	67.6	17.9	84.3	7.1	109.3
Total	15.7	46.4	5.5	67.6	17.9	84.3	7.1	109.3
Consumption								
Michigan	2.1	14.3	1.5	17.9	2.4	29.2	1.7	33.3
Total	2.1	14.3	1.5	17.9	2.4	29.2	1.7	33.3
1970 Capacity-Future Needs								
Michigan	-	14.9	1.1	16.0	-	52.8	2.1	54.9
Total	-	14.9	1.1	16.0	-	52.8	2.1	54.9

able to assume that the distribution of people requiring water from the Great Lakes, inland surfaces, and well sources will remain the same.

Municipal, self-supplied industry, and rural water withdrawal requirements in 1970 and needs in 1980, 2000, and 2020 are shown in **Table 6–35 and Figure 6–19.**

3.3.4.2 Industrial Water Use

Water withdrawals by manufacturers in Planning Subarea 1.2 are estimated to have averaged approximately 33 mgd in 1970, and by the year 2020 these withdrawals are projected to be 86 mgd. These totals were derived from estimates of annual production requirements of four major SIC two-digit industry groups and from a separate grouping of all other industries in the area.

Only a few establishments in this region require large amounts of water. The estimates of water requirements have been reported only as total manufacturing needs in order to avoid distortion (Table 6–37).

3.3.4.3 Rural Water Use

Rural water requirements and consumption were estimated for each planning subarea by using the method described in Subsection 1.4. Table 6–38 divides total requirements and consumption into categories of rural nonfarm and rural farm. Rural farm is further divided into domestic, livestock, and spray water requirements.

TABLE 6-36 Municipal Water Supply, Planning Subarea 1.2, Michigan (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Con-sumption
1970	GL	187.3 (interp.)	69.4	8.7	10.5	13.1	0.9
	IS		8.5	1.1	1.3	1.6	0.1
	GW		43.8	5.5	6.6	8.3	0.6
1980	GL	171.4	63.5	8.2	9.8	12.3	0.2
	IS		7.8	1.0	1.2	1.5	0.1
	GW		40.1	5.1	6.2	7.7	0.6
2000	GL	177.3	65.7	8.9	10.7	13.5	1.2
	IS		8.1	1.1	1.3	1.6	0.1
	GW		41.5	5.7	6.8	8.5	0.8
2020	GL	193.8	71.8	10.2	12.3	15.3	1.4
	IS		8.8	1.3	1.5	1.9	0.1
	GW		45.3	6.4	7.7	9.7	0.9

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Con-sumption	Municipally Supplied Industrial Water: Average Demand	Con-sumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
1970	GL	113.2	7.8	0.8	0.9	0.1	8.7
	IS		1.0	0.1	0.1	0.0	1.1
	GW		5.0	0.5	0.5	0.1	5.5
1980	GL	116.2	7.4	0.1	0.8	0.1	-
	IS		0.9	0.1	0.1	-	-
	GW		4.6	0.5	0.5	0.1	-
2000	GL	122.2	8.0	0.8	0.9	0.4	-
	IS		1.0	0.1	0.1	-	-
	GW		5.1	0.5	0.6	0.3	-
2020	GL	128.2	9.2	0.9	1.0	0.5	-
	IS		1.2	0.1	0.1	-	-
	GW		5.8	0.6	0.6	0.3	-

Note: No needs resulting from demands of new growth.

TABLE 6–37 Estimated Manufacturing Water Use, Planning Subarea 1.2 (mgd)

	1970	1980	2000	2020
Value Added (millions 1958$)	87	140	272	490
Gross Water Required	104	158	357	707
Total Water Withdrawal	33	35	48	86
Estimated Self Supplied	31.5	33.6	46.4	84.3
Water Consumed	4	5	15	30

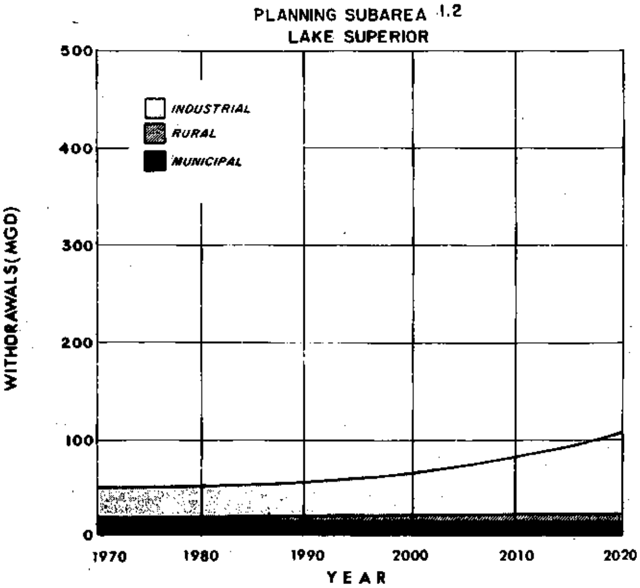


FIGURE 6–19 Municipal, Industrial, and Rural Water Withdrawal Requirements—Planning Subarea 1.2

Planning Subarea 1.2 is sparsely populated, with 187,300 people residing in the area in 1970. Of these, 65 percent or 121,700 people were served by municipal water supply systems in 1970. This is expected to increase to 125,900 by 2020.

Agriculture is locally important with 6 percent of the total land area in the planning subarea devoted to farming. Dairying is the most important agricultural activity, with potato production also important in certain counties.

The manufacturing economy is predominantly natural resource oriented, primarily along the shoreline and major cities. An important segment of the economy is based on wholesale and retail trade sales.

TABLE 6–38 Rural Water Use Requirements and Consumption, Planning Subarea 1.2 (mgd)

	1970	1980	2000	2020
REQUIREMENTS				
Rural Farm				
Domestic	0.4	0.2	0.1	0.1
Livestock	0.5	0.6	0.1	0.8
Spray Water	0.0	0.0	0.0	0.0
Subtotal	0.9	0.8	0.2	1.0
Rural Nonfarm	4.1	4.2	5.3	6.1
Total	5.0	5.0	5.5	7.1
CONSUMPTION				
Rural Farm				
Domestic	0.1	0.1	0.0	0.0
Livestock	0.5	0.5	0.7	0.8
Spray Water	0.0	0.0	0.0	0.0
Subtotal	0.6	0.6	0.8	0.9
Rural Nonfarm	0.6	0.6	0.8	0.9
Total	1.2	1.2	1.5	1.7

3.3.5 Needs, Problems, and Solutions

3.3.5.1 Municipal

At present in Planning Subarea 1.2 those supplies drawing upon the Great Lakes and connecting waters have a capacity of 8.7 mgd. The inland supplies have a total capacity of 1.1 mgd, and the developed ground-water capacity is 5.5 mgd. On the basis of the definition of needs presented in the section on methodology, no need for additional municipal water supply capacity was foreseen for the time period of this study.

3.3.5.2 Industrial

The water sources used by industry appear adequate for the 50-year time period of this study. No industrial water supply problems are foreseen in this region.

3.3.5.3 Rural

Future rural water requirements will be drawn primarily from ground-water sources, although in some areas streams will become more important. The location and quality of ground water will be important in planning development, and particularly in the location of rural nonfarm dwellings. In areas where ground water is in short supply, development should proceed only after water supplies have been located. Some areas cannot be developed until a central supply is available. Rural water requirements are projected to increase 40 percent and consumption is projected to increase 43 percent between 1970 and 2020.

The quality and quantity of ground water will influence the location of new rural development. Ground water varies from hard to very hard, and has an appreciable iron content. The high iron content is a basinwide problem. Mining and wood product wastes have polluted shallow aquifers in Michigan. Ground-water management is most important in the eastern portion of the planning subarea. Potentially important ground-water and saline-water zones require careful planning to prevent contamination.

Section 4

LAKE MICHIGAN BASIN

4.1 Summary

4.1.1 The Study Area

The Lake Michigan drainage area extends north of Chicago, through Wisconsin and the Upper Peninsula of Michigan to the Straits of Mackinac, the outlet of Lake Michigan, and south through Michigan and northeastern Indiana to a point close to Chicago. Figure 6–20 is an area map of the Lake Michigan basin. The study area extends over 45,330 square miles. Lake Michigan has a surface area of 22,300 square miles and a total basin area of 67,630 square miles. The basin extends 350 miles from north to south and approximately 270 miles from east to west. The basin of Lake Michigan is the only basin of the Great Lakes that lies entirely within the United States. Approximately 63 percent of the basin is in Michigan, 32 percent is in Wisconsin, and the remaining 5 percent is in Indiana and Illinois. The Illinois drainage area excludes the Chicago and Calumet Rivers, which are now diverted out of Lake Michigan to the Mississippi River basin. The basin is divided into four planning subareas: Lake Michigan Northwest, Planning Subarea 2.1; Lake Michigan Southwest, Planning Subarea 2.2; Lake Michigan Southeast, Planning Subarea 2.3; and Lake Michigan Northeast, Planning Subarea 2.4.

4.1.2 Economic and Demographic Characteristics

In 1970 the population of counties in the Lake Michigan basin was nearly 12.5 million, approximately 46 percent of the population in the Great Lakes Region. Cook County, Illinois, and Milwaukee County, Wisconsin, each contained more than 6.4 million people in 1970. Other major population centers include Green Bay and Racine, Wisconsin; Hammond-Gary and St. Joseph-Elkhart, Indiana; and Kalamazoo, Battle Creek, Lansing, Grand Rapids, Jackson, and Muskegon, Michigan. The northern and interior portions of the Lake Michigan basin have low population densities and small rural communities. Continued growth and urbanization around the southern shores of Lake Michigan and migration away from the north foreshadow the development of a megalopolis extending from Detroit to Milwaukee. The resident population of the Lake Michigan basin is expected to reach 23.2 million by 2020, an increase of 85 percent from 1970.

In 1960 total employment in the Lake Michigan region was 4,675,422, approximately 48 percent of those employed in the Great Lakes Region. Manufacturing activity is a major employment source. Total personal income generated in the region was $32.4 billion in 1962. Northeastern Illinois and Michigan counties in Planning Subareas 2.2 and 2.3 accounted for nearly 90 percent of the total. With the exception of Planning Subareas 2.1 and 2.4, per capita income levels equaled or exceeded the national level in 1962. Average per capita income in 1970 in the basin was $4,035, the second highest average per capita income in the Great Lakes Basin.

Forest and mineral resources, specialized agriculture along the lakeshores, and year-round recreation are vital aspects of the economy in the northern basin. In the southern basin widely diversified manufacturing trade and service and agriculture characterize the economy. The Lake Michigan basin is a major contributor to the national value added in manufacture.

Despite the basin's preeminence in industrial and manufacturing activity, agriculture and forest production are also important. In 1964 the value of all farm products sold in the region was more than $1 billion, approximately 44 percent of the entire Great Lakes agricultural crop value.

4.1.3 Water Resources

An abundant supply of generally high-

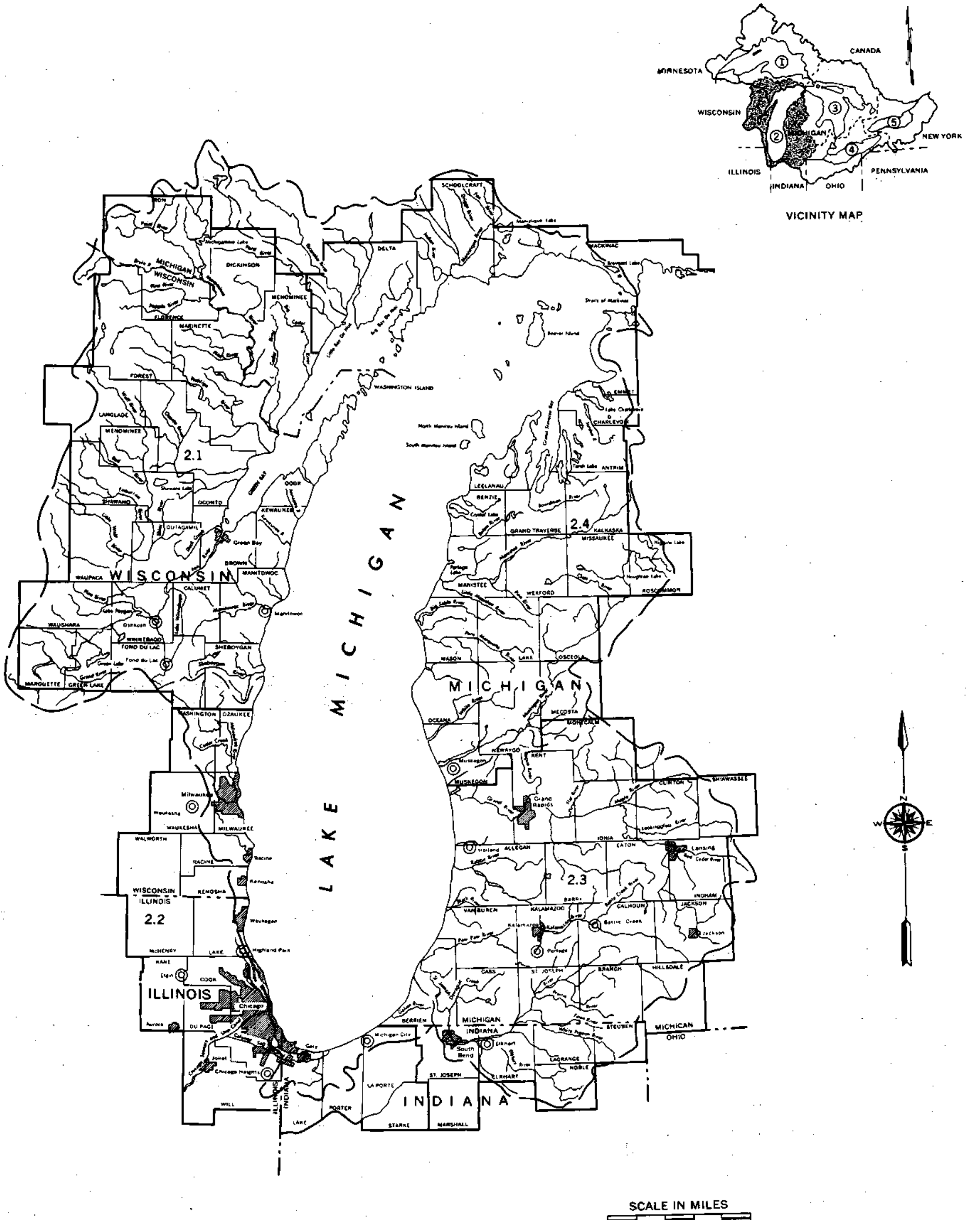


FIGURE 6–20 Lake Michigan Basin

quality water comes from surface and subsurface sources in the Lake Michigan basin. Average annual runoff in the basin is approximately 10 inches. The river systems of the basin are products of glacial moraines, are typically short, and have limited drainage basins. The Grand, Wolf, and St. Joseph drainage basins are among the largest in the basin. Many of the rivers of northern Wisconsin and Michigan flow through national or State forests. Southern streams generally originate or flow through agricultural and urban areas.

Rivers, lakes, and embayments in the basin cover approximately 1,010,700 acres. Wisconsin, Michigan, and Indiana contain more than 8,100 inland lakes, covering more than 680,000 acres. Lake Winnebago, in east-central Wisconsin, is the largest inland lake in the basin (215 square miles). Lake Michigan is the fifth largest freshwater lake in the world.

Subsurface water resources are contained in unconsolidated sediment as well as bedrock aquifers in the Lake Michigan basin. In fact, the Lake Michigan basin has the greatest ground-water potential of any of the individual Great Lakes basins. The glacial drift contains many high-producing aquifers, particularly in most of the Lower Peninsula of Michigan. In addition, high-producing bedrock aquifers lie underneath the western shore of Lake Michigan.

Areas of poor ground-water yield are relatively scarce and usually occur in the Precambrian areas of northern Wisconsin, in Michigan's Upper Peninsula, in the Ottawa River basin in the Lower Peninsula, and in northern Indiana. Overlying aquifers in the glacial drift provide good freshwater sources. The presence of saline water presents a potential for contamination source in the overlying aquifer.

4.1.4 Present and Projected Water Withdrawal Requirements

In 1970 Lake Michigan basin total water withdrawals, 7,931 mgd, accounted for 51.5 percent of the water withdrawals for the entire Great Lakes Basin. Approximately 71 percent of this withdrawal was due to tremendous industrial activity in the southern portion of the basin (Planning Subareas 2.2 and 2.3). A summary of present and projected withdrawal requirements and needs for the municipal, industrial, and rural water-using sectors is shown in Table 6–39 and Figure 6–21.

The waters of Lake Michigan are expected to provide 70 percent of the municipal water supply requirements by 2020. The remainder of the projected demands will be satisfied by ground-water and inland surface-water resources in the basin. This vast water resource is more than adequate to meet the projected water-use requirements for the municipal sector. Needs exist mainly in the development and proper management of the water resources of Lake Michigan.

Estimates of the costs for developing, operating, and maintaining municipal water supply facilities to meet the projected needs in

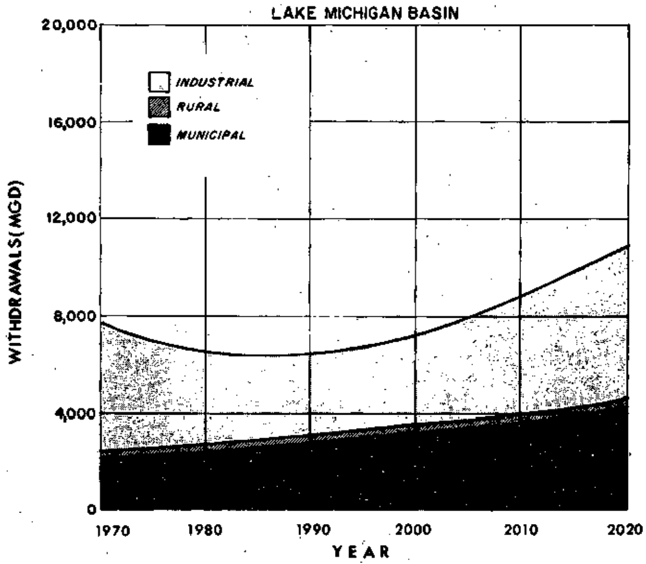


FIGURE 6–21 Municipal, Industrial, and Rural Water Withdrawal Requirements—Lake Michigan Basin

The Lake Michigan basin accounts for 46 percent of the total Great Lakes Basin population, with 13.3 million inhabitants in the region in 1970. Municipal water supplies served 10.4 million people or 78 percent of the basin population in 1970. This is expected to increase to 22.0 million by 2020.

Agricultural activity is specialized in the northern basin with dairy farming and fruit products the most important. In the southern basin, agriculture is widely diversified with corn, oats, soybeans, truck crops, and dairying the major enterprises.

The southwestern shoreline of Lake Michigan is one of the most heavily industrialized areas in the nation. Steel, petrochemical, transportation equipment, and heavy machinery production, and food processing are among the major industrial activities in the basin.

TABLE 6-39 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Lake Michigan Basin (mgd)

Use	1970				1980			
	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
2.1	92.8	320.0	47.5	460.3	128.9	222.0	57.4	408.3
2.2	1645.0	4790.0	87.6	6522.6	1947.0	3006.0	94.2	5047.2
2.3	265.9	454.0	82.3	802.2	344.3	398.0	93.8	836.1
2.4	39.1	89.6	16.8	145.5	47.7	81.2	19.7	148.6
Total	2042.8	5653.6	234.2	7930.6	2467.9	3707.2	265.1	6440.2
Consumption								
2.1	8.9	37.0	23.5	69.4	13.3	50.0	30.5	93.8
2.2	156.2	394.3	22.6	573.1	195.1	540.9	23.9	759.9
2.3	21.8	47.0	24.2	93.0	30.8	79.0	30.2	140.0
2.4	3.6	7.7	4.8	16.1	4.7	13.3	6.7	24.7
Total	190.5	486.0	75.1	751.1	243.9	683.2	91.3	1018.4
1970 Capacity-Future Needs								
2.1	292.0	320.0	47.5	659.5	34.2	105	9.9	149.1
2.2	2761.0	4790.0	87.6	7638.6	354.5	440	6.6	801.1
2.3	476.8	454.0	82.3	1013.1	81.0	40	11.5	132.5
2.4	58.7	89.6	16.8	165.1	8.9	--	2.9	11.8
Total	3587.5	5653.6	234.2	9476.3	478.6	585	30.9	1094.5

Use	2000				2020			
	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
2.1	193.0	269.0	70.5	532.5	280.7	481.0	82.7	844.4
2.2	2440.0	2944.0	109.3	5493.3	3066.0	4939.0	114.9	8,119.9
2.3	525.9	425.0	118.1	1069.0	773.8	764.0	134.5	1,672.3
2.4	68.5	86.8	24.8	180.1	97.9	167.1	29.8	294.8
Total	3226.4	3724.8	322.7	7274.9	4218.4	6351.1	361.9	10,931.4
Consumption								
2.1	26.1	82.0	38.6	146.7	42.7	149.0	47.8	239.5
2.2	280.5	1105.0	26.7	1412.2	378.2	2264.0	27.6	2669.8
2.3	58.7	224.0	42.5	325.2	95.2	462.0	53.2	610.4
2.4	7.2	37.5	9.6	54.3	10.9	89.4	12.8	113.1
Total	372.5	1448.5	117.4	1938.4	527.0	2964.4	141.4	3632.8
1970 Capacity-Future Needs								
2.1	102.7	159	23.0	284.7	202.4	346.0	35.2	583.6
2.2	986.1	1890	21.7	2897.8	1768.0	4020.0	27.3	5815.3
2.3	281.1	139	35.8	455.9	560.3	328.0	52.2	940.5
2.4	30.8	---	8.0	38.8	63.0	77.5	13.0	153.5
Total	1400.7	2188	88.5	3677.2	2593.7	4771.5	127.7	7492.9

TABLE 6–40 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Lake Michigan Basin (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
	Capital	106.085	195.605	252.714	301.691	554.405
Great Lakes	Annual OMR	5.286	20.320	42.661	25.607	68.268
	Total OMR	52.865	406.412	853.233	459.277	1312.511
Inland Lakes	Capital	2.990	6.458	9.418	9.448	18.866
and	Annual OMR	.149	.619	1.411	.768	2.179
Streams	Total OMR	1.490	12.396	28.220	13.886	42.107
	Capital	18.481	39.999	51.220	58.480	109.701
Ground Water*	Annual OMR	2.082	8.672	18.951	10.754	29.706
	Total OMR	20.825	173.447	379.029	194.272	573.302
Long Distance	Capital	5.850	21.450	78.000	27.300	105.300
Transport of	Annual OMR	0.200	0.720	2.630	0.920	3.55
Great Lakes	Total OMR	2.000	14.400	52.600	16.40	121.600
	Capital	133.692	264.211	392.572	397.851	790.224
Total	Annual OMR	7.723	30.361	65.705	38.085	103.794
	Total OMR	77.244	607.223	1314.096	684.465	2051.159

*Ground water unit cost assumptions are as follows:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells & pumping (see Figure 6-4)	42,400	28,975
total	162,400	36,575

the Lake Michigan basin are shown in Table 6–40. During the 50-year period of this study, $790 million will be required for capital investment in municipal water supply facilities and $2,051 million will be required for total OMR expenditures.

Lake Michigan water can be classified as suitable for domestic water supply for all periods to the year 2020. Although some problems may be experienced, the water quality standards program for these interstate waters demands that these waters be a suitable source of municipal water supply and includes plans of implementation and timetables for so doing.

Ground-water resources in Planning Subarea 2.2 have undergone heavy local withdrawals from certain aquifers, and consequently their water level has decreased significantly. Some western suburbs of Chicago in Du Page County have experienced shortages. In these areas greater dependence must be placed upon shallow aquifers. The future supply must be drawn from other sources, such as Lake Michigan.

4.1.5 Acknowledgements

The municipal water supply average demand for most of the water supply systems in the Wisconsin portion of Planning Subarea 2.1 and Planning Subarea 2.2 is the quantity submitted by the Wisconsin Department of Natural Resources for 1967 and 1968.

Figures for average municipal water supply demands and population served by municipal water supplies in Michigan were based on 1965 data from the Michigan Department of Public Health.

The U.S. Department of Commerce, Bureau of Domestic Commerce, furnished data and the analysis for industrial water-use requirements. Additional information about industrial water use was based on a special survey conducted in 1967 by the Indiana State Board

of Public Health. Information from technical reports of the Northeastern Illinois Metropolitan Area Planning Commission was also used to derive base year estimates and projections of municipal water use.

The U.S. Department of Agriculture, Economic Research Service, provided information on rural water-use requirements in the Lake Michigan basin.

4.2 Lake Michigan Northwest, Planning Subarea 2.1

4.2.1 Description of Planning Subarea

4.2.1.1 Location

Planning Subarea 2.1 is located along the northwestern shore of Lake Michigan. It consists of three counties in the Upper Peninsula of Michigan and 20 counties in northeastern Wisconsin (Figure 6–22). The region is approximately 200 miles from north to south and 100 miles from east to west.

4.2.1.2 Topography and Geography

Planning Subarea 2.1 may be divided into two geographical categories: the Northern Highlands, and the Central Plain and Eastern Lowlands in the southern region.

The Northern Highlands are composed of a combination of igneous and metamorphic rocks, the remains of ancient mountains. The region consists of slopes and hills. Its moderate relief averages approximately 200 feet. Exceptions to this are some isolated hilly to mountainous areas in Iron and Dickinson Counties. Elevation varies from 1,000 to 2,000 feet.

The southern region contains flat-lying sandstones, shales, and dolomites formed from sediments laid down in oceans millions of years ago. Topographically the Central Plain has a flat to gently rolling surface with low relief. The Eastern Lowlands is an area of ridges and lowlands of moderate relief. Elevation varies from 600 to 1,000 feet.

Drainage is generally from west to east. The Menominee, Peshtigo, Pensaukee, Suamico, and Fox Rivers rise in the Northern Highlands and flow into Green Bay. The Sheboygan and Manitowoc Rivers flow into Lake Michigan. These eight major river basins drain a total of 16,861 square miles (15,308 square miles in Wisconsin and 1,553 square miles in Michigan).

4.2.1.3 Climate

The climate of Planning Subarea 2.1 is classified as continental and is characterized by weather extremes common to the interior of large land masses. Pressure centers moving from west to east cause weather changes every few days. The climate and temperature of the region are moderated by Lake Michigan. The growing season varies from 80 to 160 days, increasing from northwest to southeast. Precipitation is adequate, and averages from 28 to 32 inches per year. Generally, higher average annual precipitation coincides with higher elevations. Droughts, although they do occur, are rarely widespread. Snow covers the ground in practically all winter months, and streams are ice-covered from late November to late March.

4.2.2 Water Resources

4.2.2.1 Surface-Water Resources

Of the approximately 10.4 million acres encompassed in Planning Subarea 2.1, 361,500 acres are water in the form of lakes, ponds, rivers, and streams. Runoff averages 10 to 15 inches annually, generally increasing from south to north. On the whole the rivers have a slightly higher concentration of dissolved solids than rivers to the west and north of the region, and their waters are moderately hard.

Fully developed water storage areas in the planning subarea's inland lakes and streams provide an existing storage capacity of 153,950 acre-feet. If all inland lakes and streams suitable for development as surface-water impoundments were developed, the total potential storage capacity would increase to 269,950 acre-feet. This does not include Lake Winnebago, which has an estimated capacity of 2.5 million acre-feet.[45]

Presently developed water storage areas can produce a sustained water yield of 888 mgd. If all potential water storage areas were fully developed in Planning Subarea 2.1, impounded inland lakes and streams could produce a sustained water supply yield of 1,333 mgd.[45]

Potential capacities and yields used in this

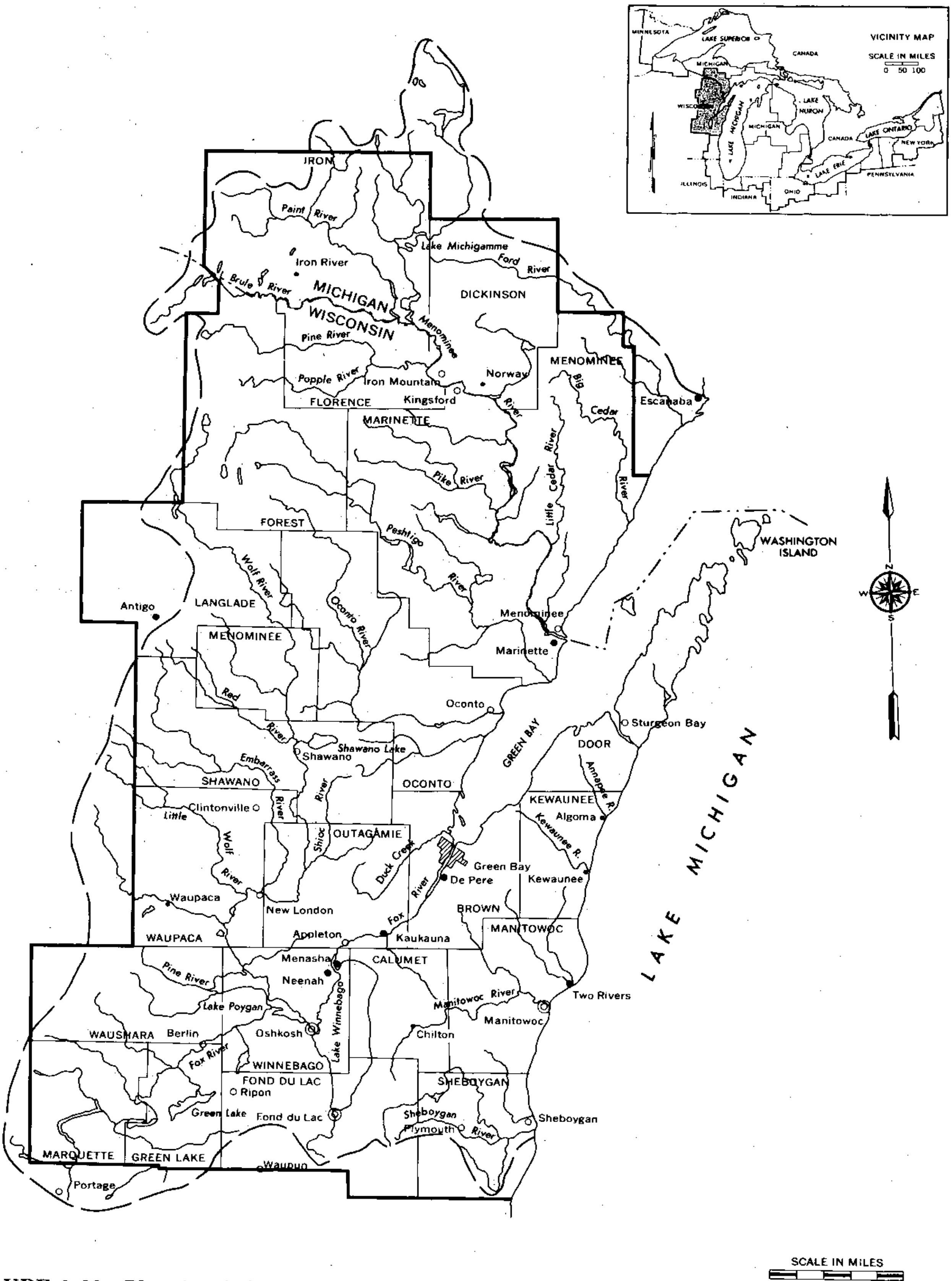


FIGURE 6-22 Planning Subarea 2.1

section relate to the total water resource. No attempt has been made to identify that portion of the water resource not suitable or available for use.

4.2.2.2 Ground-Water Resources

As in the case with surface water, ground-water reserves are abundant. In the Drift Province ground water is obtained from sands and gravels in glacial deposits. Where such deposits are thin, water supplies are scarce, because the rocks that underlie most of this province are poor aquifers. However in the Drift-Paleozoic Province the underlying sandstone is a good aquifer and has been heavily pumped. The mineral content and hardness of the ground water is related to geologic structure, and increases from northwest to southeast. In some cases it exceeds the 500 mg/l USPHS standard for total dissolved solids. Thus, in most of Forest County the ground water is soft, while in the counties along Lake Michigan it is very hard. Ground-water yield in River Basin Group 2.1 (based on 70 percent flow-duration data) is estimated to be 3,880 mgd.[21]

4.2.3 Water-User Profile

4.2.3.1 Municipal Water Users

The population of Planning Subarea 2.1 in 1970 was approximately 949,100, an increase of 7 percent since 1960. Forty-nine percent of the inhabitants were classified as urban and 51 percent as rural. Population concentration was primarily in the Green Bay-Lake Winnebago area, which includes the Cities of Appleton, Green Bay, Menasha, Neenah, Oshkosh, and Fond du Lac. The average population density is 56.3 people per square mile. Nine of the 12 counties that experienced a loss in population between 1950 and 1960 are the heavily forested, lightly populated counties north of Green Bay. The heavily populated counties in the Green Bay-Lake Winnebago area gained in population.

In 1970 municipal water supplies served 559,300 people, 59 percent of the total population of the planning subarea. The total population in 2020 is estimated to be 1.7 million, of which 1.4 million will be served by municipal water supplies. Average annual personal income in 1970 was $3,726. The majority of the people were employed in manufacturing (34 percent) and trades and services (34 percent). A small percentage (13 percent) were employed in agriculture. The remainder were employed in government, transportation, utilities, construction, mining, forestry, and the military.

4.2.3.2 Industrial Water Users

Planning Subarea 2.1 is the North Woods to many residents of the lower Great Lakes Basin and neighboring States. Its attractions for a growing influx of summer and winter vacationers have created the foundations for enterprises that provide much of the income and employment in the region. The woods, water, prosperous farms, and primitive areas that attract so many visitors also serve as the base for a vigorous and growing manufacturing sector. In 1967 there were 2,058 operating manufacturing plants in Planning Subarea 2.1, with approximately 1,860 in the 20 Wisconsin counties and the remainder in the three Michigan counties to the north. Total manufacturing employment was 120,300 in 1967, having grown from 105,600 in 1963. During the same period the value added by manufacture increased nearly 43 percent to $1.6 billion.

To a large extent, manufacturing is composed of industries related to agricultural and forest products, which account for approximately one-half of the value added by manufacture in this otherwise diverse sector. SIC 26, Paper and Allied Products, the largest industry group in terms of employment and value added, includes 19 pulp mills and 26 paper mills, the majority located in the Fox River and Menominee River basins. In 1967, 473 operating establishments, or approximately one of every four manufacturing plants, were engaged in the processing and preparation of food products from regional farms and dairies. Lumber and wood products industries are also significant in the manufacturing sector, but not all industries are farm or forest product related. There are producers of primary metals and fabricated metal products, manufacturers of machinery, and equipment plants that produce transportation equipment and parts.

4.2.3.3 Rural Water Users

In 1964 there were approximately 4.9 million acres of land in farm in Planning Subarea 2.1.

Principal crops consisted of silage, hay, pasture, and oats. Vegetables, including potatoes, peas, cabbage, and sweet corn, are grown in the area. Some of the vegetable crops consume large amounts of water. Dairying, which also requires a great deal of water, is very important in the area. Nearly three-fourths of the livestock and livestock product sales came from dairies. In 1964 crop sales amounted to approximately $52 million, and livestock and livestock product receipts were more than $233 million. Farm population included 154,000 people and farms employed 43,000, according to the 1960 Census of Population.

4.2.4 Present and Projected Water Withdrawal Requirements

A summary of present and projected water withdrawal requirements and needs for the municipal, industrial, and rural water-using sectors is presented in Figure 6–23 and Table 6–41.

4.2.4.1 Municipal Water Use

Municipal water withdrawal includes all water processed by municipalities even if used by industry. A few communities in Planning Subarea 2.1 are supplied from Lake Michigan. Neenah, Menasha, Appleton, and Oshkosh get their water from Lake Winnebago. All other municipalities rely on ground water as their source.

During 1970 in Planning Subarea 2.1, 132 public water supply systems provided water for 559,300 people in 22 counties. Lake Michigan was the source for six municipal water supplies. Inland lakes and streams were the source for seven public water supply systems, and the remaining 115 withdrew raw water from ground-water supplies.

The total resident population is expected to increase 82 percent to 1.7 million people by 2020. Municipal water supplies are expected to provide water to 82 percent, or 1.4 million people, by 2020.

The total population served by water from the Great Lakes is expected to increase from 155,000 in 1970 to 426,000 in 2020. The projected total municipal withdrawal from Lake Michigan in 2020 is 111 mgd, approximately four times the present withdrawal of 31 mgd. Of this daily average of 111 mgd, 62 mgd will be in cities near the Lake in the Sheboygan-Green Bay area. The 46 mgd projected to be used in the Fox River basin will require larger pipelines and conveyance facilities to meet the demand. Industrial use of municipal water comprises more than half of the total use and is anticipated to increase from 16 mgd to 60 mgd.

The population served by inland lakes and streams will increase from 141,000 to 369,000 by 2020, and the average daily water usage will increase from 25 mgd to 80 mgd. The industrial use of municipal water from these sources is also high and is projected to increase from 11.1 mgd to 35.9 mgd.

The population served by ground water is projected to increase from 264,000 to 541,000 by 2020, or from 37 mgd to 90 mgd. There are likely to be interference and declining water level problems in a number of areas when the

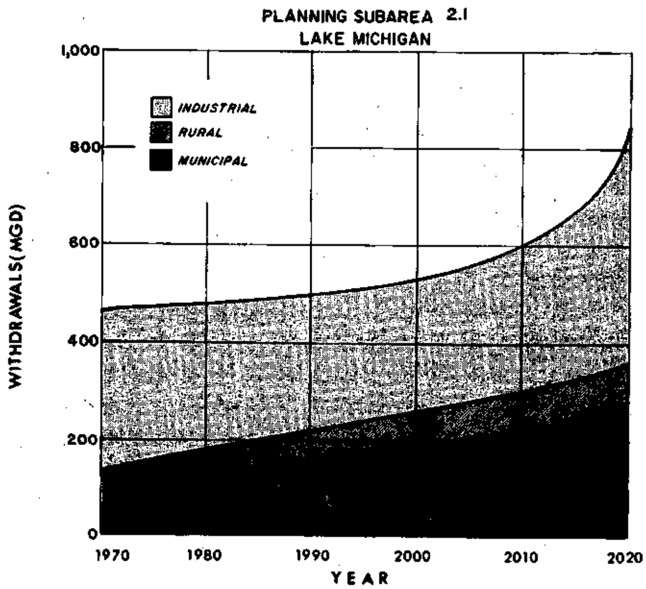


FIGURE 6–23 Municipal, Industrial, and Rural Water Withdrawal Requirements—Planning Subarea 2.1

Approximately half of the 949,100 people residing in Planning Subarea 2.1 are classified as living in urban areas, with municipal water supplies serving 559,300 people (59 percent) in 1970. This is expected to increase to 1.4 million by 2020.

Dairy farming and livestock and fruit and vegetable production are the prime agricultural activities. Livestock and livestock product sales are a major source of income.

Manufacturing activity accounts for 70 percent of total employment in the planning subarea. Paper products and food processing are major industries.

TABLE 6-41 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Planning Subarea 2.1 (mgd)

Use	1970 mun.	1970 ind.	1970 rural	1970 total	1980 mun.	1980 ind.	1980 rural	1980 total
Withdrawal Requirements								
Michigan	5.1	9	9	23	5.7	8	10.8	25
Wisconsin	87.7	311	38.5	437	123.2	214	46.6	384
Total	92.8	320	47.5	460	128.9	222	57.4	409
Consumption								
Michigan	.5	1	4.4	6	.6	1	5.8	7
Wisconsin	8.4	36	19.1	64	12.7	49	24.7	86
Total	8.9	37	23.5	70	13.3	50	30.5	94
1970 Capacity-Future Needs								
Michigan	7.7	9	9	26	.3	3	1.8	5
Wisconsin	284.3	311	38.5	634	33.9	102	8.1	144
Total	292.0	320	47.5	660	34.2	105	9.9	149

Use	2000 mun.	2000 ind.	2000 rural	2000 total	2020 mun.	2020 ind.	2020 rural	2020 total
Withdrawal Requirements								
Michigan	8.0	8	13.3	29	10	13	15.6	39
Wisconsin	184.9	261	57.2	503	270.7	468	67.1	806
Total	192.9	269	70.5	532	280.7	481	82.7	845
Consumption								
Michigan	1.0	2	7.3	10	1.2	4	9	14
Wisconsin	25.1	80	31.3	136	41.5	145	38.8	225
Total	26.1	82	38.6	147	42.7	149	47.8	239
1970 Capacity-Future Needs								
Michigan	1.6	4	4.3	10	3.6	10	6.6	20
Wisconsin	101.1	155	18.7	275	198.8	336	28.6	563
Total	102.7	159	23.0	285	202.4	346	35.2	583

ground-water withdrawals approach the projected figures. It seems apparent that the location of most of the population growth will coincide with the location of these problems, and cooperative planning of well spacing or an alternative source will have to be developed.

With one exception all the communities with a present population of 1,000 or more are served by public water supply systems. It is anticipated that a number of small communities will install water systems in conjunction with sewer projects as emphasis on water pollutant abatement continues. The number of new water systems could be 10 or 20, but the quantity of water required to serve them would be insignificant compared to the projected figures.

The City of Green Bay is located in the Fox River basin. The city discharges its wastewater into Green Bay, but draws water from Lake Michigan. The suburbs of Green Bay use ground water and the water levels have increased since Green Bay ceased using its wells. The suburbs and industries are not practicing areawide ground-water management, and there is a local interference between wells. The overall withdrawal is not excessive or approaching safe yield at this time, but the projected water consumption figures indicate that another source may have to be considered in a few years.[59] One solution would be to extend the use of Lake Michigan water to the entire area and operate a combined utility or commission.

The cities that now use Lake Winnebago as a source could possibly use Lake Michigan water instead. Although at least two engineering studies have been conducted, no action has been taken and none seems likely in the near future.

The City of Fond du Lac uses ground water entirely, drawn mainly from Cambrian sandstones. There is controversy in this area over well interference between the city, other municipalities, industries, and institutions. The safe yield of the sandstone has not been approached, but the declining water levels in this area, as near Green Bay, are due to well locations.[62] The ultimate solution may be the use of either Lake Winnebago or Lake Michigan water, but cooperative efforts of proper well location could delay this for many years. Another alternative may be to use excess surface waters during periods of high levels and flows to periodically recharge the depleted storage of underground aquifers in this region.

The northern one-third to one-half of the area contained in Planning Subarea 2.1 is underlain by Precambrian rocks that are of no value as aquifers. The communities must develop wells in the glacial drift that vary in thickness and lithology and could create water shortage problems at some locations. The number of communities located in this area is small and there is little potential for growth. Tables 6–42 through 6–44 contain information on municipal water supply for Planning Subarea 2.1.

4.2.4.2 Industrial Water Use

The majority of manufacturing establishments, because of their small daily water requirement, are able to meet their water needs by purchase from public systems. The public systems provide only approximately 11 percent of the manufacturing sector supply at present. In general the large water-using industries, primarily those in SIC 26, are so located that public water system supplies are unavailable or uneconomic. Total water withdrawals by the manufacturing sector in 1970 are estimated to have averaged 359 mgd, but only 39 mgd were supplied by municipal systems. Of the 320 mgd self-supplied, approximately 305 mgd were obtained from surface-water sources, primarily rivers and inland lakes, and approximately 15 mgd were obtained from company-owned wells.

Table 6–45 presents the base-year estimates and projections of five water-use parameters and constant dollar estimates of value added by manufacture for the five major water-using SIC two-digit industry groups and the other manufacturing groups that comprise the sector. It is most apparent from this table that the industrial water requirements of Planning Subarea 2.1 are influenced to a great extent by the water needs of the mills and factories in the SIC 26 industry group. In 1970 the gross water requirements of SIC 26 were 936 mgd, but by maintaining an industrywide average recirculation rate of 3.14, the required water withdrawals were held to only 298 mgd. Those withdrawals amounted to 80 percent of all industrial water used by the manufacturers of the region. Industry group SIC 20, the next largest SIC two-digit group, required water withdrawals of only 19 mgd.

Expansion of industry output has been derived from OBERS economic projections in terms of estimated constant dollar values added by manufacture for each group of industries (Table 6–45). Throughout the planning period the SIC 26 industry group will continue as the dominant factor in industrial water supply. Even though the industry as a whole is expected to be able to reduce its withdrawal requirements per dollar output by improving the effective recirculation of water from the present rate of 3.14 to 8.0 by the year 2000, this group of industries is estimated to require 446 mgd by the year 2020.

Table 6–45 indicates that as a result of expected improvements in recirculation and reuse of water by industry groups SIC 20, 26, and 33, water withdrawals by those groups will decrease in the early years of the planning period. Due primarily to the dominant role of SIC 26, the total withdrawals of the manufacturing sector are expected to decline similarly. However, in the later years withdrawals for all industry categories may be expected to increase as opportunities for further conservation of water by increasing the recircu-

TABLE 6–42 Municipal Water Supply, Planning Subarea 2.1, Wisconsin and Michigan (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Con-sumption
1970	GL	949.1	154.8	30.9	40.0	53.3	2.8
	IS		140.5	25.0	28.8	36.7	2.3
	GW		264.0	36.9	44.2	55.1	3.7
1980	GL	1082.2	228.8	53.4	64.1	80.2	5.6
	IS		179.1	34.6	41.5	52.0	3.5
	GW		284.5	40.9	49.1	61.4	4.2
2000	GL	1357.6	313.6	77.5	93.0	116.4	11.2
	IS		259.6	53.4	64.1	80.2	7.3
	GW		394.6	62.0	74.4	93.0	7.6
2020	GL	1726.0	425.8	111.1	133.6	166.7	18.3
	IS		369.1	80.1	96.1	120.2	12.3
	GW		541.2	89.5	107.3	134.2	12.1

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Con-sumption	Municipally Supplied Industrial Water: Average Demand	Con-sumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
1970	GL	95	14.9	1.5	16.0	1.3	80.6
	IS		13.9	1.4	11.1	0.9	78.3
	GW		23.9	2.6	13.0	1.1	133.1
1980	GL	105	24.6	2.5	28.8	3.1	21.5
	IS		19.2	1.9	15.4	1.6	9.2
	GW		29.1	2.9	11.8	1.3	3.5
2000	GL	113	35.6	3.6	41.9	7.6	48.4
	IS		29.5	3.0	23.9	4.3	29.6
	GW		44.0	4.4	18.0	3.2	24.7
2020	GL	119	50.8	5.0	60.3	13.3	86.1
	IS		44.2	4.4	35.9	7.9	59.7
	GW		63.6	6.3	25.9	5.8	56.5

TABLE 6–43 Municipal Water Supply, Planning Subarea 2.1, Wisconsin (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Con-sumption
1970	GL	885.1	143.4	29.7	38.6	51.5	2.7
	IS		128.2	23.8	27.3	34.8	2.2
	GW		237.7	34.2	41.0	51.1	3.5
1980	GL	1016.1	216.7	52.1	62.5	78.2	5.5
	IS		166.3	33.2	39.8	49.9	3.4
	GW		257.3	37.9	45.5	56.9	3.8
2000	GL	1283.5	299.1	75.6	90.7	113.5	10.9
	IS		244.7	51.4	61.7	77.2	7.0
	GW		363.9	57.9	69.5	86.9	7.2
2020	GL	1639.9	407.8	108.6	130.6	162.9	18.0
	IS		351.1	77.6	93.1	116.4	12.0
	GW		505.1	84.5	101.3	126.7	11.5

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	con-sumption	Municipally Supplied Industrial Water: Average Demand	Con-sumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
1970	GL	95	13.9	1.4	15.8	1.3	78.8
	IS		12.9	1.3	10.9	0.9	76.4
	GW		21.7	2.4	12.5	1.1	129.1
1980	GL	106	23.5	2.4	28.6	3.1	21.4
	IS		18.0	1.8	15.2	1.6	9.1
	GW		26.6	2.6	11.3	1.2	3.4
2000	GL	113	34.0	3.4	41.6	7.5	47.9
	IS		27.9	2.8	23.5	4.2	29.2
	GW		40.6	4.1	17.3	3.1	24.0
2020	GL	119	48.7	4.8	59.9	13.2	85.0
	IS		42.1	4.2	35.5	7.8	58.8
	GW		59.5	5.9	25.0	5.6	55.0

TABLE 6–44 Municipal Water Supply, Planning Subarea 2.1, Michigan (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Con-sumption
1970	GL	64.0	11.4	1.2	1.4	1.8	0.1
	IS		12.3	1.2	1.5	1.9	0.1
	GW		26.3	2.7	3.2	4.0	0.3
1980	GL	66.1	12.1	1.3	1.6	2.0	0.1
	IS		12.8	1.4	1.7	2.1	0.1
	GW		27.2	3.0	3.6	4.5	0.4
2000	GL	74.1	14.5	1.9	2.3	2.9	0.3
	IS		14.9	2.0	2.4	3.0	0.3
	GW		30.7	4.1	4.9	6.1	0.4
2020	GL	86.1	18.0	2.5	3.0	3.75	0.3
	IS		18.0	2.5	3.0	3.75	0.3
	GW		36.1	5.0	6.0	7.5	0.6

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Con-sumption	Municipally Supplied Industrial Water: Average Demand	Con-sumption	Source Capacity (1970) & Needs (1980, 2000,2020)
1970	GL	83.8	1.0	0.1	0.2	0.0	1.8
	IS		1.0	0.1	0.2	0.0	1.9
	GW		2.2	0.2	0.5	0.1	4.0
1980	GL	92.6	1.1	0.1	0.2	0.0	0.1
	IS		1.2	0.1	0.2	0.0	0.1
	GW		2.5	0.3	0.5	0.1	0.1
2000	GL	109.2	1.6	0.2	0.4	0.1	0.5
	IS		1.6	0.2	0.7	0.1	0.4
	GW		3.4	0.3	0.4	0.1	0.7
2020	GL	115.2	2.1	0.2	0.4	0.1	1.1
	IS		2.1	0.2	0.4	0.1	0.9
	GW		4.1	0.4	0.9	0.2	1.6

Preliminary 1970 Census figures for these three counties total 61,150 persons.

TABLE 6–45 Estimated Manufacturing Water Use, Planning Subarea 2.1 (mgd)

	SIC 20	SIC 26	SIC 28	SIC 29	SIC 33	Other Mfg.	Total
1970							
Value Added (Millions 1958$)	172	502	38	29	51	833	1625
Gross Water Required	37	936	9	30	18	49	1079
Recirculation Ratio	1.93	3.14	1.77	5.96	2.03	2.12	--
Total Water Withdrawal	19	298	5	5	9	23	359
Self Supplied	--	--	--	--	--	--	320
Water Consumed	1.3	35.3	0.3	0.6	0.3	1.9	40
1980							
Value Added (Millions 1958$)	226	721	80	54	71	1290	2442
Gross Water Required	47	1296	17	71	22	76	1529
Recirculation Ratio	2.77	6.03	3.32	8.90	3.63	2.80	--
Total Water Withdrawal	17	215	5	8	6	27	278
Self Supplied	--	--	--	--	--	--	222
Water Consumed	1.9	48	1.0	1.3	0.6	2.9	56
2000							
Value Added (Millions 1958$)	364	1383	328	84	90	2964	5213
Gross Water Required	72	2176	94	98	29	187	2656
Recirculation Ratio	3.15	8.00	11.70	19.61	9.63	4.80	--
Total Water Withdrawal	23	272	8	5	3	39	351
Self Supplied	--	--	--	--	--	--	269
Water Consumed	2.9	80	4.0	1.9	0.6	7.0	97
2020							
Value Added (Millions 1958$)	617	2640	940	386	347	6850	11,780
Gross Water Required	137	3568	255	454	96	428	4938
Recirculation Ratio	3.50	8.00	15.00	23.92	12.0	5.86	--
Total Water Withdrawal	39	446	17	19	8	73	601
Self Supplied	--	--	--	--	--	--	481
Water Consumed	5.4	131	12.5	8.7	1.6	16	176

lation rate become fewer. Eventually practical limits on reuse and recirculation of water will require that water withdrawals increase in direct relation to increases in industrial production. The ultimate constraints upon multiple recirculation are the comsumptive losses of water that affect both the quantity and quality of the water retained for re-use.

In preparing forecasts of industrial withdrawals (Table 6–45), the possibility of the consumptive constraints being reached before year 2020 was avoided by applying different rates of improvements in recirculation for the period 1970 to 2000 than for the period 2000 to 2020. During the last 20-year period the slower rates of improvements result in sharp increases in withdrawal demands to satisfy the continued expansion of industrial activity.

4.2.4.3 Rural Water Use

Rural water requirements and consumption were estimated according to the methodology outlined in Subsection 1.4. Table 6–46 divides total requirements and consumption into categories of rural nonfarm and rural farm. Rural farm is further divided into domestic, livestock, and spray water requirements.

TABLE 6–46 Rural Water Use Requirements and Consumption, Planning Subarea 2.1 (mgd)

	1970	1980	2000	2020
REQUIREMENTS				
Rural Farm				
Domestic	8.1	9.7	7.4	6.9
Livestock	20.5	27.8	36.2	46.2
Spray Water	0.1	0.1	0.1	0.1
Subtotal	28.8	37.6	43.8	53.2
Rural Nonfarm	18.7	19.8	26.8	29.5
Total	47.5	57.4	70.6	82.7
CONSUMPTION				
Rural Farm				
Domestic	2.0	2.4	1.9	1.7
Livestock	18.5	25.0	32.6	41.6
Spray Water	0.1	0.1	0.1	0.1
Subtotal	20.7	27.6	34.6	43.4
Rural Nonfarm	2.8	3.0	4.0	4.4
Total	23.5	30.5	38.6	47.8

4.2.5 Needs, Problems, and Solutions

4.2.5.1 Municipal

The presently developed quantity of water supply is not adequate to meet all projected future requirements. If properly managed the available water resource will be adequate to meet the projected future requirements. Only development and proper management of the water resource is necessary.

To meet projected growth, municipal water supply should be developed to provide 34 mgd by 1980, 103 mgd by 2000, and 202 mgd by 2020. Additional development will occur in all major sources of raw water, e.g., Lake Michigan, inland lakes and streams, and ground water. In some cases the present supply source does not provide the best water available in an area, and new sources will need to be developed to provide higher quality water.

Several communities now use surface water from Lake Winnebago as a source of public water supply. This source is adequate for present and projected requirements, but the quality of treated water is not as high as that enjoyed by many other communities, and the cost of treatment is generally high. The primary quality problems associated with Lake Winnebago water are algae (producing taste and odor problems), temperature, and hardness. The maximum depth of the lake is 20 feet and the poor quality is mainly due to natural conditions rather than pollution by municipal and industrial wastes. The Lake Michigan water quality in the basin is excellent except where rivers receive discharges from urban areas. Complete treatment of raw water is required of all municipalities using Lake Michigan water.

The ground water in both the upper dolomite and lower sandstone aquifers within the basin is without exception quite hard and often contains objectionable iron. In addition, some of the sandstone contains water with excessive sulfate and total solids concentrations. A few of the municipal systems practice iron removal and softening.

The problem of supplying high quality water at low cost to the Fox River valley communities can be solved by a variety of methods. Individual systems, systems that use combinations of surface and ground water, and joint systems with sophisticated treatment that use Lake Michigan water are all possible alternatives. An informal proposal was made several years ago to provide a unified system of water supply using Lake Michigan. The water would be conveyed to the cities along the south and west sides of Lake Winnebago and down the lower reaches of the Fox River. This project did not materialize, probably because of extensive funding needs and the problems of getting so many separate governmental units to cooperate on such a massive project. To establish such a project, detailed planning would be required to advise the communities involved of the costs and benefits that would accrue. It is also likely that outside funding of a significant share of the total cost would be required to serve as an incentive to the local communities to organize such a project.

In areas where ground-water levels have severely declined, a ground-water management program is warranted. Required well spacings should minimize overlapping cones of depression. A system of ground-water recharge may be feasible. Excess surface waters during periods of high levels and flows can be stored in underground aquifers.

In areas where growth is predicted and ground water is the principal raw water source, there will have to be a reassessment of existing practices and water use to avoid water shortages and controversies over lowered ground-water levels. These problems can be alleviated by wise management of available ground waters, but if the projected demands occur, especially in Brown County, it appears that another source must be developed. Domestic water conservation and changes in industrial process water use and recycling could allow for a reduction in the size of a pipeline to Lake Michigan if this supply is developed. Developments in technology may make it feasible to obtain satisfactory water from Green Bay. A combination of water pollution abatement and new, economical water treatment methods may make Green Bay more desirable as a source of water, but its shallowness could be a drawback. Before any other source is developed, a study of alternative methods that could lower the investment in surface-water supply development is recommended. It is not possible to consider the amount of reduction in water demands due to alternatives without an analysis beyond the scope of this study.

The amount of ground water that can safely be pumped year after year in any area depends on the amount of water stored in underground formations and the amount of water replenished to the ground-water source. Water already contained in a natural ground-water reservoir has been accumulating for years. Most underground aquifers have the capacity to store tremendous quantities of water to carry through periods of little or no rainfall and recharge. However, if pumpage is greater than the replenishment, inroads will be made on the water already stored in the earth, as in the Green Bay area. In such cases continued pumping slowly lowers the water table.

Thus, despite the abundance of ground water in many parts of this region, it is not an inexhaustible resource. Like all natural resources it must be conserved and properly developed to insure its availability in the future. A program of ground-water management would be beneficial in this area. The spacing of wells (especially new wells) should cause the least amount of interference with adjacent wells.

Nearly every year surface waters flow excessively. Lake Michigan levels have been higher than desired in recent years. This excess water could be withdrawn and stored for use during a shortage.

Further study is needed, but it may be practical to store excess surface waters in large reservoirs of underground aquifers. Such artificial recharge is especially applicable in areas where underground water in storage has been depleted by heavy pumpage.

The estimated costs for new construction and associated operations are listed in Table 6–47. All estimates are adjusted to January 1970 price levels. As described in the methodology, the costs include conveyance of the raw water supply and water treatment but not surface-water storage or urban distribution. In addition to water supply costs resulting from growth demands, expenditures must be made to replace equipment and facilities that will wear out or become obsolete.

4.2.5.2 Industrial

The output of the manufacturing sector in Planning Subarea 2.1 is expected to increase 740 percent by 2020. However, as discussed earlier, the demand for water by manufacturers is expected to increase by less than 70 percent, from 360 mgd to 600 mgd, between now and 2020. Because water is available, increases in withdrawals should not strain the

TABLE 6–47 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Planning Subarea 2.1 (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
Great Lakes	Capital	6.428	8.043	11.272	14.471	25.743
	Annual OMR	.320	1.041	2.004	1.361	3.365
	Total OMR	3.203	20.830	40.081	24.033	64.114
Inland Lakes and Streams	Capital	2.750	6.099	8.999	8.850	17.850
	Annual OMR	.137	.578	1.330	.715	2.045
	Total OMR	1.370	11.562	26.611	12.933	39.544
Ground Water*	Capital	.590	3.578	5.367	4.169	9.537
	Annual OMR	.064	.523	1.506	.588	2.094
	Total OMR	.649	10.462	30.125	11.111	41.236
Total	Capital	9.770	17.721	25.640	27.491	53.131
	Annual OMR	0.522	2.143	4.841	2.665	7.506
	Total OMR	5.224	42.855	96.818	48.078	144.896

*Ground water unit cost assumptions are as follows:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells & pumping (see Figure 6-4)	48,800	29,500
total	168,800	37,100

resource base. If all new manufacturing production were to occur through the expansion of existing production plants, then much of the new water need could be met with water conserved through recirculation, and only a few new sources would be needed. But it is highly unlikely that this will occur. Existing manufacturing plants probably will be enlarged to account for most of the early increases in output, but new plants will also be built, and it is probable that the largest share of manufacturing activity in the later years of the planning period will occur in plants that do not now exist.

Figure 6-24 illustrates the hypothetical change in water supply needs between existing and new manufacturing locations. In preparing this set of curves, it is assumed that the first 100 percent increase in value added by manufacture results from expansion of existing production facilities, and that all later increases occur in new plants at new locations. Curve 1 represents the withdrawals required to maintain existing production levels at existing plants. Curve 2 represents the withdrawal demands to maintain existing production plus the first 100 percent production increase. Curve 3 represents the demand for all manufacturing production. The area between Curves 2 and 3 represents the withdrawal demand at new locations. Under these circumstances then, the new supply needs for manufacturing are estimated to be 125 mgd by the year 2000 and 435 mgd by the year 2020.

It is not now known where new manufacturing plants will be built, but they will probably be built in the same general areas in which manufacturing now takes place. The mills and factories of the SIC 26 industry group, which represents the major portion of the industrial demand, will probably continue to build in regions that are relatively remote from central water supply systems large enough to satisfy their needs. The SIC 26 industry group would account for about 95 mgd of the estimated 125 mgd new supply needs for the year 2000 and approximately 325 mgd of the 435 mgd estimated for the year 2020. The remaining quantities of new water supply for all other manufacturing groups are not very large and can be provided for by enlarged municipal water supply systems.

4.2.5.3 Rural

Future rural water requirements are assumed to draw primarily from ground-water sources, although in some areas streams will play an increasingly important role. The location and quality of ground water will be very important in channeling additional development, particularly the location of rural nonfarm dwellings. In areas where ground water is in short supply, development should proceed only after water supplies have been discovered. Some areas will not develop until a central supply is available.

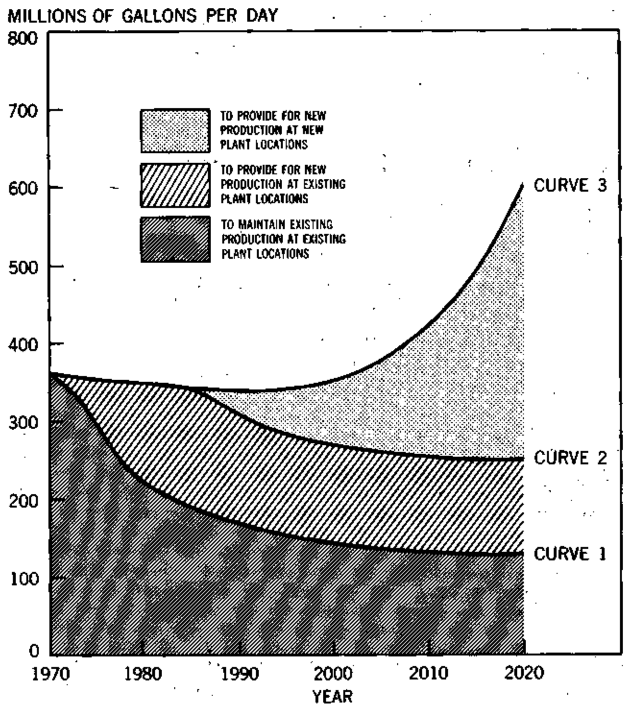


FIGURE 6-24 Total Withdrawal Demands for Manufacturing—Planning Subarea 2.1

Rural water requirements are projected to increase 74 percent between 1970 and 2020, and consumption is projected to increase 103 percent during the same period.

Lowered water levels are common in parts of the planning subarea near urban centers. Aquifers have been polluted and this trend is a constant potential threat. Ground water with a high sulfate content exists in several counties. Hard water and high iron content are common problems. Water quality is a general problem only in the upper Menominee River basin.

4.3 Lake Michigan Southwest, Planning Subarea 2.2

4.3.1 Description of Planning Subarea

4.3.1.1 Location

Planning Subarea 2.2 borders the southern and western shore of Lake Michigan and includes seven Wisconsin counties, six Illinois counties, and four Indiana counties (Figure 6–25). This planning subarea is approximately 160 miles long and 90 miles wide at its broadest point.

4.3.1.2 Topography and Geography

Planning Subarea 2.2 ranges from level to gently rolling land on glaciated plains. Elevation ranges from 580 feet at Lake Michigan to more than 1,000 feet in several northwest counties. Belts of morainic hills, beach ridges, and outwash, roughly paralleling the Lake Michigan shore, traverse the Wisconsin and Illinois counties. Relief in these belts may rise to 100 or 200 feet. Moraines in Indiana are typically northeast to southwest in orientation. Along the entire planning subarea, the top of the divide lies anywhere from 10 to 50 miles from the shore, limiting drainage to Lake Michigan.

Bedrock formations in the region consist largely of limestone, sandstone, and shale. During the Pleistocene epoch these sedimentary rocks were completely buried under deposits left by great glaciers that moved slowly and repeatedly over the planning subarea. The thickest drift occurs where these glaciers buried old valleys or built moraines. Depths of 200 feet are not uncommon. At the southern tip of Lake Michigan along Cook, Lake, Porter, and La Porte Counties is a narrow lacustrine plain that was deposited by the waters of glacial Lake Chicago. This flat region contains extensive sand dune deposits along its Indiana shoreline. The major drainage basin is the Chicago-Milwaukee complex, which drains 1,344 of the 8,244 square miles of the planning subarea.

4.3.1.3 Climate

Climate in Planning Subarea 2.2 is typically humid continental with some modification by Lake Michigan. Both temperature and precipitation are controlled by geographical location. Wisconsin counties are cooler and drier than the more southern Indiana counties. Mean annual precipitation ranges from 28 inches in Ozaukee County to 36 inches along the Lake Michigan shoreline in Illinois and Indiana. Precipitation is highest in the spring and lowest during the late summer. A relatively long frost-free period, 180 days along the shore and decreasing inland, is suitable for agriculture. Mean temperature ranges from 78°F to 80°F in the summer and 28°F to 32°F in the winter.

4.3.2 Water Resources

4.3.2.1 Surface-Water Resources

Discharges are not large and streams are typically short and slow moving. Streams reach their highest levels in the spring, and their lowest flows in late summer. The Chicago River has been diverted, and its flow was reversed to follow the Chicago Sanitary and Ship Canal to the Illinois River. The Milwaukee River drainage basin is the largest in the planning subarea. In Appendix 2, *Surface Water Hydrology*, it was reported that the existing and potential reservoir storage capacity in Planning Subarea 2.2 is considered to be negligible. No municipal water supplies use inland streams as a source of supply in the planning subarea.

A significant number of inland lakes dot the area. The northern portion of Lake and McHenry Counties in Illinois contain a major concentration of lakes in the Fox Chain O' Lakes. Most available inland lake frontage is in private ownership, resulting in problems of public access. Only one inland lake in Indiana, supplying a maximum safe yield of approximately 1.1 mgd, is used in Planning Subarea 2.2 as a source of public water supply.

Potential capacities and yield relate to the total resource. No attempt has been made to identify that portion of the resource that may not be suitable or practical for use.

Until recently water that was diverted from Lake Michigan for domestic water supply was not limited except for water diverted into the Chicago Sanitary District Drainage and Ship Canal, which was limited to 1,500 cfs. The United States Supreme Court decree of June 12, 1967, placed a limit of 3,200 cfs (approximately 2,069 mgd), which took effect March 1,

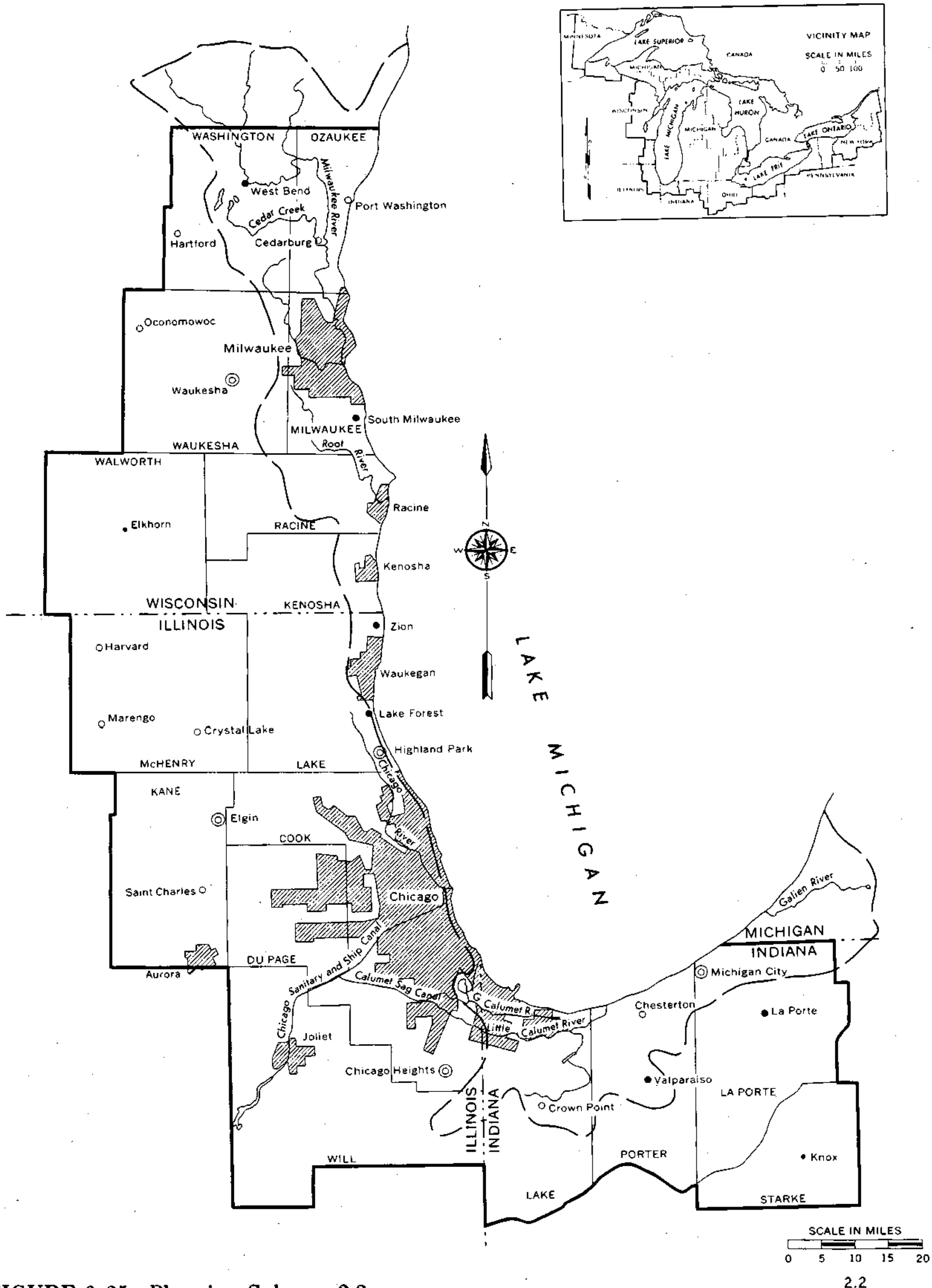


FIGURE 6–25 Planning Subarea 2.2

1970, on all water diverted from Lake Michigan by the State of Illinois. If the total diversion for domestic water supply used by Chicago and other northeastern Illinois communities increases and exceeds 1,700 cfs, the excess diversion over 1,700 cfs must be subtracted from the 1,500 cfs formerly allocated for the dilution of sewage effluent.

The Illinois State Legislature has passed a bill that places the responsibility for allocation of Lake Michigan water diversion for water supply purposes on the Illinois Department of Transportation and its Division of Water Resources Management. Increasing demands for municipal water supply will increase competition for water in northeastern Illinois. Even with fair and intelligent allocations of the available supply, the current limitation on Lake Michigan water of 3,200 cfs may become critical before 2020.

4.3.2.2 Ground-Water Resources

A large supply of good quality ground water is available in Planning Subarea 2.2. However, this highly developed area is the most heavily pumped ground-water region in the Great Lakes Basin. As a result, extensive lowering of the piezometric level and deep pumping levels have occured in the sandstone aquifer.

In Wisconsin two bedrock aquifers generally underlie the counties. The lower one, consisting primarily of Cambrian and St. Peter sandstones, is the principal bedrock source and is generally capable of yielding at least 50 gpm. A dolomite aquifer, consisting principally of the Niagara dolomite, overlies the sandstone aquifer and also provides ample supply. Glacial drift, consisting of alluvial sand and gravel, also contains available ground-water quantities. Ground-water yield in the Wisconsin portion of River Basin Group 2.2 (from 70 percent flow-duration data) is estimated to be 250 mgd.[21] Both the sandstone aquifer and the shallow (dolomite and glacial drift) aquifer are heavily pumped, and major water level declines in county wells are common.

With dependable sandstone bedrock aquifers overlain by thick sand and gravel aquifers of glacial drift in Illinois planning subarea counties, ground-water yields are typically high. The Illinois State Water Survey calculated for the Northeastern Illinois Planning Commission that a potential sustained yield of 567 mgd could be continuously pumped from the shallow and deep aquifers in the Illinois portion of Planning Subarea 2.2. Ground-water yield (based on 70 percent flow-duration data) in the portion of this area that is in the Lake Michigan drainage basin (River Basin Group 2.2) is estimated to be 90 mgd.[21] Bedrock aquifers extending along the Cook County-Lake Michigan shore have an estimated potential yield of 50,000 to 100,000 gpd per square mile. Bedrock areas inland are generally capable of producing twice that quantity. Wells completed in sand and gravel aquifers produce from 100 to 500 gpm.

Most wells in Indiana are completed in glacial drift, although some penetrate bedrock. Well depths range from less than 100 feet along Lake Michigan to more than 400 feet in inland deposits. Average depth of wells completed in glaciofluvial sand and gravel reaches range from approximately 150 feet with yields of several hundred gallons per minute up to as much as 2,000 gpm in the eastern portion of the planning subarea. The total sustained ground-water yield in the Indiana portion of River Basin Group 2.2 is estimated to be 110 mgd. The Indiana part of the area has saline water in most of the bedrock formations, with the only good quality water available in the Silurian-Devonian aquifer in the northwest portion. Most supplies have relatively high iron and manganese content and are considered hard.

4.3.3 Water-User Profile

4.3.3.1 Municipal Water Users

In 1970, 9.4 million people resided in Planning Subarea 2.2. Eighty-six percent of the population used central water systems in 1970. The population of Planning Subarea 2.2, with a density of 1,140 people per square mile, is highly concentrated along the Lake Michigan shoreline. Milwaukee, Chicago, Gary, and Hammond accounted for more than 54 percent of the population, which increased 10 percent from 1960 to 1970. The total population in 2020 is projected to be 17.4 million, an 89 percent increase from 1970. The planning subarea becomes rural as one travels inland from shore. By 2020, 16.1 million people are expected to be served by municipal water supplies. Average annual per capita income (in 1970 dollars) in the planning subarea was $5,063 in 1970.

4.3.3.2 Industrial Water Users

The southwestern shoreline of Lake Michigan is one of the most heavily industrialized areas of the nation. The Gary-Hammond-Chicago industrial complexes, extending for more than 50 miles along the shore, form the backbone of an economy that accounts for much of the total economic activity of Indiana and Illinois. Along the western shoreline, industry in Milwaukee, Kenosha, and Racine adds to the hard manufacturing output of the planning subarea.

Nearly 8 percent of the total national value added by manufacture originates in the 17 counties of this planning subarea. Manufacturing output of one of its counties, Cook County, Illinois, exceeds that of 44 of the individual States. Growth in manufacturing output increased from slightly more than $15 billion in 1963 to nearly $19.5 billion value added in 1967, due to increases in employee productivity and total employment.

The planning subarea is noted for its steel-associated industries such as processing and fabricating, as well as basic chemicals production, petroleum refining and processing, machinery, and transportation equipment. However, the manufacturing sector is quite diversified. With very few exceptions, nearly every SIC four-digit industry that is found in the United States is found also in Planning Subarea 2.2. Most of them, however, are small manufacturers in terms of employment. Of the 17,637 manufacturing establishments operating in 1967, more than 10,000 employed less than 20 people each, and less than 2,400 employed as many as 100 people.

Water requirements for the vast diversified manufacturing activities of the planning subarea are very large. This amount was estimated to be more than 5,100 mgd in 1970. This large water requirement would be difficult to meet anywhere else in the United States. There is little doubt that Lake Michigan water has been a key factor in the concentration of industries in the basin.

Information on water use by individual manufacturing establishments in the area is available, but somewhat limited.

4.3.3.3 Rural Water Users

Even though Planning Subarea 2.2 is the most highly populated and industrialized of all the planning subareas, according to the 1964 census there were approximately 3.2 million acres in farms. Cash grain and dairy typify the agriculture of the area. Important crops are corn, soybeans, oats, and meadow grass. However, truck crops, which are heavy water users, are grown near the urban centers. Dairying, also a heavy water user, is very important, especially in the Wisconsin portion of the area. Nearly half of the livestock and livestock product receipts in the area come from dairying. Crop sales were approximately $132 million, and livestock and livestock product sales were nearly $153 million in 1964. According to the 1960 census 95,000 people lived on farms and 39,000 were employed on farms.

4.3.4 Present and Projected Water Withdrawal Requirements

4.3.4.1 Municipal Water Use

Lake Michigan supplies the major portion of water for industrial and municipal use. Rural water use comes largely from individual wells. Figure 6–26 and Table 6–48 show that Planning Subarea 2.2 counties demanded more than 6,500 mgd in 1970 to satisfy water supply requirements, of which approximately 4,800 mgd or 73 percent was for industrial water supply. Of the 1,645 mgd municipal withdrawal in 1970, Cook County, Illinois, alone required 1,200 mgd, more than one billion gallons of which were treated and used in Chicago and its suburbs. Lake Michigan supplies the greatest volume of water for shoreline areas, approximately 6,100 mgd of the total 1970 demand.

As urban sprawl continues, this source will probably be used by more of the systems presently using ground water. Inland lakes or streams are not sources for public water supply systems in any of the Wisconsin or Illinois counties. One inland lake in Indiana supplies 0.9 mgd for municipal use. Considering the limitation of potential reservoir storage capacity and safe yield of existing inland lake and stream water supply sources, it does not seem likely that there will be additional use of this source in Planning Subarea 2.2.

Total water withdrawal requirements are projected to decrease through the planning period 1980 to 2000 because of greater incentives for recirculation of water by manufacturers. By the year 2020, however, the total water withdrawal is expected to increase by 124 percent of the 1970 withdrawal to 8,120 mgd.

During 1970 the average daily withdrawal in Planning Subarea 2.2 from Lake Michigan was approximately 1,500 mgd. The projected figure for 2020 is 2,500 mgd, a total increase of approximately 1,000 mgd, based upon the increase in the present population served by Lake Michigan water and the expected water use by that population.

Domestic and commercial municipal water use from Lake Michigan is expected to increase from 1,100 mgd in 1970 to 1,800 mgd by 2020, or approximately 161 percent. Both the municipally supplied industrial water and the consumption of Lake Michigan water will increase greatly during the projection period. At present, an average of 368 mgd is supplied to industries by municipalities. It is predicted that this will increase to 790 mgd in 2020. In 2020 it is expected that 227 mgd will be consumed by industry. Continued use of Lake Michigan as the dominant water supply source is the only reasonable basis for planning. In addition to the consideration of legal problems associated with additional use and diversion of lake water, considerable planning and construction will be necessary to provide treatment and conveyance facilities to the inland population. The planning of areawide utilities or water districts should begin without delay to allow time for the resolution of the technical and political problems that are certain to occur.

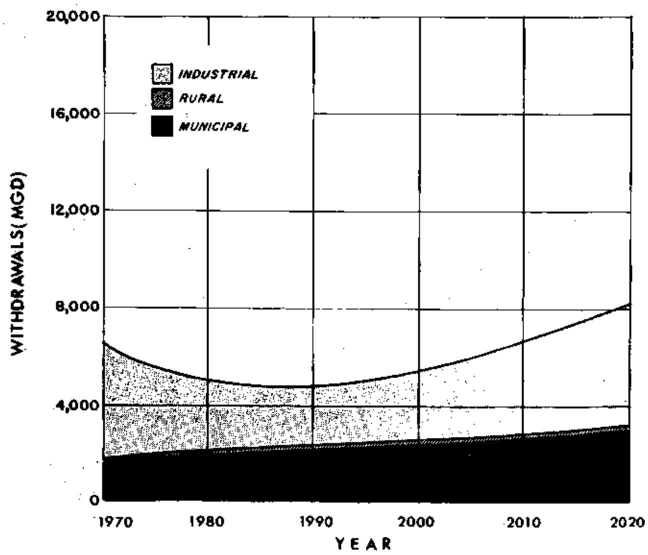


FIGURE 6–26 Municipal, Industrial, and Rural Water Withdrawal Requirements—Planning Subarea 2.2

Planning Subarea 2.2 has the highest population concentration of any of the planning subareas in the Great Lakes Basin, with 9.4 million people residing in the area as of 1970. Municipal water supplies served 85 percent or 8.0 million people in 1970, and this is expected to increase to 16.1 million by 2020.

Despite major urban concentrations along the Lake Michigan shoreline, agriculture uses a sizeable acreage. Corn, oats, soy bean and truck crop production, and dairying are the principal agricultural activities.

The southwestern shoreline of Lake Michigan is one of the most heavily industrialized areas in the nation. Heavy industry dominates manufacturing. Production of primary metals, heavy machinery, chemical, petroleum and coal products, and food processing constitute a major portion of the industrial activity.

The use of ground water in Planning Subarea 2.2 is projected to increase from an average of 156 mgd to 561 mgd by 2020. There will undoubtedly be an increase in ground-water withdrawal in cities located some distance from Lake Michigan. It is expected that there will also be some abandonment of wells in favor of the Lake. At this time it is not possible to determine the number of systems or the quantity of water involved. The population served by ground water is expected to grow from 1,408,100 to 3,788,400 by 2020. If the present system of ground-water development continues to 2020, the water levels in deep wells in major pumping centers are expected to continue to fall. Increased competition between wells will result in an unnecessary reduction of well yields, because the 927 mgd of ground-water resource available is in excess of the current and projected future demand. A regionwide system of ground-water management is needed to avoid haphazard withdrawals that can result in waste of the available resource and increased development costs.

The capacity of existing source development is shown for 1970 in Tables 6–49, 6–50, 6–51, and 6–52. Municipal water supply needs are shown in the 1980, 2000, and 2020 columns. Because of the economy of scale and fluctuations in water use, excess capacity is developed in municipal systems. A cushion of excess capacity is assumed to always be necessary. Additional water needs are therefore projected as the water needs of net population increases.

(continued on page 106)

TABLE 6-48 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Planning Subarea 2.2 (mgd)

Use	1970				1980			
	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
Illinois	1337.0	1348.0	39.8	2724.8	1490.0	1150.0	42.8	2682.8
Indiana	96.8	3184.0	19.7	3300.5	127.4	1728.0	21.2	1876.6
Wisconsin	211.1	257.6	28.1	496.8	329.0	127.9	30.2	487.1
Total	1644.9	4789.6	87.6	6522.1	1946.4	3005.9	94.2	5046.5
Consumption								
Illinois	127.8	99.5	10.2	237.5	149.5	195.7	10.8	356.0
Indiana	9.0	278.6	5.1	292.7	12.8	333.1	5.4	351.3
Wisconsin	19.4	16.2	7.2	42.8	32.9	12.1	7.7	52.7
Total	156.2	394.3	22.6	573.0	195.2	540.9	23.9	760.0
1970 Capacity-Future Needs								
Illinois	1844.0	1348.0	39.8	3231.8	209.6	182	3.0	394.6
Indiana	183.0	3184.0	19.7	3386.7	27.3	225	1.5	253.8
Wisconsin	733.8	257.6	28.1	1019.5	117.6	33	2.1	152.7
Total	2760.8	4789.6	87.6	7638.0	354.5	440	6.6	801.1

Use	2000				2020			
	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
Illinois	1759.0	1775.0	49.6	3583.6	2081.0	3356.0	52.2	5489.2
Indiana	188.2	1083.0	24.6	1295.8	270.1	1407.0	25.8	1702.9
Wisconsin	493.2	86.5	35.1	614.8	715.2	176.2	36.9	928.3
Total	2440.4	2944.5	109.3	5494.2	3066.3	4939.2	114.9	8120.4
Consumption								
Illinois	196.7	669.3	12.1	878.1	245.7	1561.0	12.5	1819.2
Indiana	22.7	431.6	6.0	460.3	35.6	670.2	6.2	712.0
Wisconsin	61.1	4.2	8.6	73.9	96.9	32.8	8.9	138.6
Total	280.5	1105.1	26.7	1412.3	378.2	2264.0	27.6	2669.8
1970 Capacity-Future Needs								
Illinois	587.9	1130	9.8	1727.7	1024.0	2647	12.4	3683.4
Indiana	93.5	611	4.9	709.4	184.2	1053	6.1	1243.3
Wisconsin	304.7	149	7.0	460.7	559.4	320	8.8	888.2
Total	986.1	1890	21.7	2897.8	1767.6	4020	27.3	5814.9

TABLE 6–49 Municipal Water Supply, Planning Subarea 2.2, Illinois, Indiana and Wisconsin (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Con-sumption
1970	GL	9379.6	6705.6	1487.7	1785.0	2231.9	141.3
	IS		8.2	0.9	1.1	1.8	0.1
	GW		1408.1	156.2	188.3	234.5	14.7
1980	GL	10998.8	7855.0	1715.6	2058.6	2573.4	171.9
	IS		7.5	0.9	1.1	1.8	0.1
	GW		1878.5	230.3	276.4	345.6	23.1
2000	GL	13844.4	9874.4	2066.7	2480.0	3100.1	238.5
	IS		7.1	0.9	1.1	1.8	0.1
	GW		2705.3	372.6	447.2	558.9	41.9
2020	GL	17385.8	12332.9	2503.9	3004.6	3755.9	311.1
	IS		6.7	0.9	1.1	1.8	0.1
	GW		3788.4	561.1	673.2	841.9	67.0

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Con-sumption	Municipally Supplied Industrial Water: Average Demand	Con-sumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
1970	GL	155	1146.9	114.7	340.8	26.7	2377.4
	IS		0.8	0.1	0.1	--	1.1
	GW		129.0	12.8	27.2	1.9	382.3
1980	GL	153	1302.4	130.3	413.2	41.6	285.4
	IS		0.8	0.1	0.1		
	GW		186.4	18.6	43.9	4.5	69.1
2000	GL	147	1542.0	153.9	524.7	84.6	777.8
	IS		0.8	0.1	0.1	--	--
	GW		296.4	29.6	76.2	12.3	208.3
2020	GL	141	1835.2	183.6	668.7	127.5	1363.2
	IS		0.8	0.1	0.1	--	--
	GW		440.2	44.0	120.9	23.0	404.0

Notes: Per capita water use is expected to decrease in Chicago because of greater emphasis and improved techniques in leak detection. Suburban per capita water use is however expected to increase. The net result is a projected decrease of six-tenths gallons per capita per day each year as shown.

TABLE 6–50 Municipal Water Supply, Planning Subarea 2.2, Illinois (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply Average Demand	Maximum Month	Maximum Day	Con-sumption
1970	GL	6940.0	5008.3	1213.5	1456.2	1820.3	116.2
	GW		1193.4	123.4	149.0	185.2	11.6
1980	GL	7884.8	5558.9	1308.2	1569.8	1962.3	131.1
	GW		1587.5	182.2	218.6	273.4	18.3
2000	GL	9625.8	6598.5	1458.2	1749.8	2187.3	163.3
	GW		2289.0	300.6	360.8	450.9	33.4
2020	GL	11782.1	7829.3	1622.6	1947.1	2434.0	192.0
	GW		3214.4	458.0	549.5	687.2	53.7

Year	Source	Domestic and Commercial Municipal Water Supply Gallons per capita daily	Average Demand	Con-sumption	Municipally Supplied Industrial Water Average Demand	Con-sumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
1970	GL	175	978.5	97.8	235.0	18.4	1566.0
	GW		106.0	10.5	17.4	1.1	277.9
1980	GL	169	1052.4	105.3	255.8	25.8	156.1
	GW		153.3	15.3	28.9	3.0	53.5
2000	GL	159	1168.6	116.6	289.6	46.7	422.2
	GW		246.9	24.7	53.7	8.7	165.7
2020	GL	151	1294.5	129.5	328.1	62.5	698.2
	GW		369.6	36.9	88.4	16.8	325.4

Notes: Per capita water use is expected to decrease in Chicago because of greater emphasis and improved techniques in leak detection. Suburban per capita water use is however expected to increase. The net result is a projected decrease of six-tenths gallon per capita per day each year as shown.

TABLE 6-51 Municipal Water Supply, Planning Subarea 2.2, Indiana (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Con-sumption
	GL		527.5	84.4	101.3	126.6	7.8
1970	IS	780.2	8.2	0.9	1.1	1.8	0.1
	GW		82.9	11.5	13.8	17.3	1.1
	GL		641.0	111.7	134.0	167.5	11.2
1980	IS	914.6	7.5	0.9	1.1	1.8	0.1
	GW		104.5	14.8	17.8	22.2	1.5
	GL		904.0	165.3	198.4	248.0	20.3
2000	IS	1221.6	7.1	0.9	1.1	1.8	0.1
	GW		149.0	22.0	26.4	33.0	2.3
	GL		1237.0	238.7	286.4	358.0	32.1
2020	IS	1611.2	6.7	0.9	1.1	1.8	0.1
	GW		205.9	30.5	36.6	45.8	3.4

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Con-sumption	Municipally Supplied Industrial Water: Average Demand	Con-sumption	Source Capacity (1970) & Needs (1980, 2000,2020)
	GL		52.6	5.3	31.8	2.5	146.8
1970	IS	103	0.8	0.1	0.1	--	1.1
	GW		10.1	1.0	1.4	0.1	35.1
	GL		69.6	7.0	42.1	4.2	23.5
1980	IS	111	0.8	0.1	0 1	--	--
	GW		13.0	1.3	1.8	0.2	3.8
	GL		103.0	10.3	62.3	10.0	81.5
2000	IS	116	0.8	0.1	0.1	--	--
	GW		19.3	1.9	2.7	0.4	12.0
	GL		148.7	14.9	90.0	17.2	161.8
2020	IS	122	0.8	0.1	0.1	--	--
	GW		26.8	2.7	3.7	0.7	22.4

TABLE 6–52 Municipal Water Supply, Planning Subarea 2.2, Wisconsin (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply Average Demand	Maximum Month	Maximum Day	Consumption
1970	GL	1659.4	1169.8	189.82	227.50	285.00	17.4
	GW		131.82	21.29	25.46	32.04	2.0
1980	GL	2199.4	1655.1	295.7	354.8	443.6	29.6
	GW		186.5	33.3	40.0	50.0	3.3
2000	GL	2997.0	2371.9	443.2	531.8	664.8	54.9
	GW		267.3	50.0	60.0	75.0	6.2
2020	GL	3992.5	3266.6	642.6	771.1	963.9	87.0
	GW		368.1	72.6	87.1	108.9	9.9

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Consumption	Municipally Supplied Industrial Water: Average Demand	Consumption	Source Capacity (1970) & Needs (1980, 2000,2020)
1970	GL	98	115.80	11.6	74.02	5.8	664.55
	GW		12.85	1.3	8.44	0.7	69.3
1980	GL	109	180.4	18.0	115.3	11.6	105.8
	GW		20.1	2.0	13.2	1.3	11.8
2000	GL	114	270.4	27.0	172.8	27.9	274.1
	GW		30.2	3.0	19.8	3.2	30.6
2020	GL	120	392.0	39.2	250.6	47.8	503.2
	GW		43.8	4.4	28.8	5.5	56.2

4.3.4.2 Industrial Water Use

Demands for industrial water in Planning Subarea 2.2 far overshadow the municipal demand. It is estimated that withdrawals or purchase of water by the manufacturing sector exceeded 5,000 mgd in 1970, of which only 7.2 percent of the demand, or 360 mgd, was supplied by municipal systems.

Lake Michigan is the principal source of self-supplied industrial water because of the location of the majority of large water-using manufacturing establishments along the lakefront, and because of the low costs of water withdrawn from that source. There is no complete inventory of quantities of well water self-supplied by industry, but it is estimated to be less than 100 mgd. Nor is there an inventory of quantities withdrawn from surface streams. However, if we assume that surface streams provide the same portion of industrial self-supply as they do for the municipalities, industries in the area probably withdrew less than 50 mgd from those sources. Therefore, of the estimated 5,150 mgd required by the planning subarea's manufacturers, 4,650 mgd was self-supplied from Lake Michigan.

These large quantities of water enabled manufacturers to meet their larger gross water requirement of 11,600 mgd by recirculation at various rates within their plants. As may be seen in Table 6–53, there are differ-

TABLE 6–53 Estimated Manufacturing Water Use, Planning Subarea 2.2 (mgd)

	SIC 20	SIC 26	SIC 28	SIC 29	SIC 33	Other Mfg.	Total
1970							
Value Added (Millions 1958$)	2,423	458	2,183	597	2,618	11,364	19,673
Gross Water Required	317	857	2,260	1,577	5,814	726	11,605
Recirculation Ratio	2.11	3.47	6.76	5.96	1.53	2.22	--
Total Water Withdrawal	176	247	335	269	3,800	327	5,154
Self Supplied	--	--	--	--	--	--	4,790
Water Consumed	32	42	67	51	205	26	423
1980							
Value Added (Millions 1958$)	2,924	681	3,828	946	3,367	16,821	28,567
Gross Water Required	435	1,218	4,245	2,497	7,067	1,090	16,552
Recirculation Ratio	2.77	6.03	8.73	8.90	3.63	2.86	--
Total Water Withdrawal	157	202	486	288	1,947	381	3,461
Self Supplied	--	--	--	--	--	--	3,006
Water Consumed	35	58	128	90	237	38	587
2000							
Value Added (Millions 1958$)	4,138	1,385	12,130	2,316	5,228	35,416	60,613
Gross Water Required	536	1,976	15,152	5,948	9,700	2,386	35,698
Recirculation Ratio	3.15	8.00	11.70	19.61	9.63	4.80	--
Total Water Withdrawal	170	247	1,295	327	1,007	497	3,543
Self Supplied	--	--	--	--	--	--	2,944
Water Consumed	42	93	452	212	324	80	1,202
2020							
Value Added (Millions 1958$)	6,479	2,759	30,267	4,876	8,320	76,267	128,968
Gross Water Required	697	3,744	37,830	11,670	13,145	5,221	72,307
Recirculation Ratio	3.50	8.00	15.00	23.92	12.00	5.86	--
Total Water Withdrawal	199	468	2,522	548	1,238	891	5,867
Self Supplied	--	--	--	--	--	--	4,939
Water Consumed	55	188	1,130	440	440	170	2,415

ences in present day estimated recirculation rates between the various industry groupings. For example, SIC 33, Primary Metals, has the largest water requirements and the poorest recirculation rate. For that industry group in particular and all other industries in general, reasonable improvements in recirculation rates can bring about dramatic reductions in the water supply. This is clearly shown in the projections, which have had gradually improving recirculation rates applied to them for the various industry groups. The projection of improved recirculation rates was made according to the views presented in the discussions of methodology.

Table 6-53 presents the base year estimates and projections of five water-use parameters and the annual value added by manufacture for the five major water-using SIC two-digit industry groups and the residual manufacturing groups that constitute the manufacturing sector. Although the large water-using industries (those with withdrawal requirements of 20 million gallons or more per year) account for more than 98 percent of the base year withdrawal requirement, the estimates include the small water-using manufacturing establishments as well. The value-added parameter is derived from the OBERS projections and is included to serve as an index of the rate of growth of the industry groups and sectors.

These projections indicate that withdrawal requirements for the manufacturing sector may be expected to decrease during the early years of the planning period and begin to increase in the later years to approach the present day withdrawal demands in approximately 2020.

All industry groups shown in the table are projected to have increasing withdrawal demands except SIC 26 in the early years and SIC 33 throughout the planning period. SIC 33 accounted for approximately 75 percent of the water demand of the manufacturing sector in 1970, but it is the least efficient in water use as indicated by its recirculation rate. It also has the slowest growth rate of the industry groups considered, with the exception of SIC 20. Because of its relatively slow growth and the projected increased water reuse, the withdrawal requirement is expected to decrease even though the gross water demand of the industry increases. Because of the expected improvements in water management by this industry group, the manufacturing sector water requirements are projected to decline.

However, Industry Group SIC 28 is projected to grow at such a rapid rate (approximately 1,400 percent during the 50-year planning period) that even with the improvements in recirculation rates, the withdrawal requirements of the industry group will increase nearly 600 percent over the 1970 requirement. By the year 2020 the SIC 28 industry group will have a gross water demand of nearly 38,000 mgd. Even though an average recirculation rate of 15:1 may be achieved, more than 2,500 mgd will need to be withdrawn to meet its water needs.

Table 6–53 also shows that consumption of water by manufacturing will increase to more than 2,400 mgd. To place the size of this water loss into perspective, the total present day withdrawal requirements by Chicago are 1,000 mgd. Three industry groups will account for 2,000 mgd of the water consumption: SIC 28, 1,130 mgd; SIC 29, 440 mgd; and SIC 33, 440 mgd.

One additional comment on the projected water requirements concerns the broad industry category of other manufacturing. Although this group includes other large water-using industries, it comprises small establishments that obtain water from public systems. The growth of its withdrawal requirement from 327 mgd in 1970 to 891 mgd in the year 2020 suggests that municipal systems can be expected to increase the quantity of their service to that sector.

Table 6–54 presents estimates and projections of the manufacturing withdrawal requirements for the portions of Illinois, Indiana, and Wisconsin in Planning Subarea 2.2. For the base year, 1970, the estimates for SIC 33 were derived by assuming that the 3,000 mgd reported by Indiana industries in the 1967 State of Indiana survey had not changed by 1970.[12] The remaining estimated withdrawal requirements of 800 mgd were distributed between Illinois and Wisconsin industries in proportion to the 1967 value added by manufacture for industries in SIC 33 in the major SMSAs of the two States. All other SIC two-digit industry groups and the industries in the category of other manufacturing were estimated by the ratios of the 1967 value added by manufacture of the major SMSAs. The 1967 ratios were held constant for the projections.

4.3.4.3 Rural Water Use

Rural water requirements and consumption were estimated for Planning Subarea 2.2 following the methodology outlined in Subsection 1.4. Table 6–55 divides total requirements and consumption into categories of rural non-

TABLE 6–54 Estimated Total Manufacturing Water Withdrawals by State, Planning Subarea 2.2 (mgd)

	SIC 20	SIC 26	SIC 28	SIC 29	SIC 33	Other Mfg.	Total
1970 Estimates							
Illinois	133	216	284	115	613	244	1605
Indiana	5	6	35	154	3000	28	3228
Wisconsin	38	25	16	--	187	75	341
1980 Estimates							
Illinois	119	177	413	124	314	284	1431
Indiana	5	3	51	164	1537	15	1775
Wisconsin	34	21	23	--	96	82	256
2000 Estimates							
Illinois	129	216	1099	140	162	371	2117
Indiana	5	6	135	187	795	19	1147
Wisconsin	36	25	61	--	50	107	279
2020 Estimates							
Illinois	150	410	2141	235	178	665	3779
Indiana	6	11	262	313	868	34	1494
Wisconsin	43	48	119	--	192	192	594

farm and rural farm used. Rural nonfarm includes large numbers of individual wells for suburban areas in this planning subarea. Rural farm is further divided into domestic, livestock, and spray water requirements.

4.3.5 Needs, Problems, and Solutions

4.3.5.1 Municipal

Table 6–49 shows that the projected need for additional municipal water supply capacity in Planning Subarea 2.2 is 1,767 mgd by 2020. Of this total need, 78 percent, or 1,363 mgd, is projected as derived from Lake Michigan sources.

The estimated costs necessary to provide the projected water supply needs for each of the planning years are listed in Table 6–56. The costs include conveyance of the raw water supply and water treatment. They do not include surface water storage, urban distribution, or debt financing.

Much of the urban area in Planning Subarea 2.2 has traditionally relied on Lake Michigan as the main source of municipal and industrial water. As urban growth continues much of the demand will spread with it into the Mississippi River basin. For reasons of economy and projected future growth, it is logical for these areas to also consider Lake Michigan as a source of water.

The 927 mgd of ground-water resource that is estimated to be available in Planning Subarea 2.2 is greater than the projected 561 mgd of use by the year 2020. However, heavy local withdrawals from certain aquifers have lowered water levels in wells and reduced well yields. Many ground-water supplies have problems with the continuous fall of deep well water levels.

It is not anticipated that there will be many additional water supply systems, but population growth will increase. In fact, it is very possible that the number of individual systems will decrease as systems merge or are

TABLE 6–55 Rural Water Use Requirements and Consumption, Planning Subarea 2.2 (mgd)

	1970	1980	2000	2020
REQUIREMENTS				
Rural Farm				
Domestic	5.0	3.0	2.8	2.3
Livestock	11.7	12.5	13.3	13.4
Spray Water	0.2	0.1	0.1	0.1
Subtotal	16.9	15.6	16.1	15.8
Rural Nonfarm	70.7	78.6	93.2	99.1
Total	87.6	94.2	109.3	114.9
CONSUMPTION				
Rural Farm				
Domestic	1.2	0.8	0.7	0.6
Livestock	10.6	11.2	11.9	12.0
Spray Water	0.2	0.1	0.1	0.1
Subtotal	12.0	12.1	12.7	12.7
Rural Nonfarm	10.6	11.8	14.0	14.0
Total	22.7	23.9	26.6	27.6

TABLE 6–56 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Planning Subarea 2.2 (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
Great Lakes	Capital	85.334	147.227	175.034	232.562	407.596
	Annual OMR	4.252	15.841	31.900	20.094	51.995
	Total OMR	42.524	316.833	638.018	359.338	997.376
Ground Water*	Capital	11.594	23.357	32.838	34.952	67.791
	Annual OMR	1,247	5.007	11.052	6.254	17.306
	Total OMR	12.472	100.141	221.040	112.613	333.654
Total	Capital	96.930	170.586	207.873	267.515	475.388
	Annual OMR	5.499	20.849	42.953	26.348	69.301
	Total OMR	54.998	416.975	859.061	471.972	1331.030

*Ground water unit cost assumptions are as follows:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells & pumping (see Figure 6-4)	47,800	28,500
total	167,800	36,100

consolidated into areawide utilities. More emphasis should be placed on developing plans for areawide utilities and cooperative efforts. Problems such as water quality, well interference, and efficient and competent operation could be solved by preventing the proliferation of small water systems. Instead of relying on wells in the immediate area, larger utilities should cross corporate boundaries to develop the best water sources. Preparation of such plans should begin now before increased population and water use necessitate independent crash programs. Local, county, and regional planning commissions should be involved. The implementation of plans for areawide utilities may require new laws and regulations.

Based on studies by Schicht and Moench,[69] some areas in the Illinois portion of Planning Subarea 2.2 now dependent upon ground water will need to import water as early as 1990. Demands in these areas will exceed recharge to shallow and deep aquifers and exceed the additional water available from mining the deep aquifers. The effects of high withdrawal rates from deep aquifers in Illinois on deep aquifers in Wisconsin should be included in a more detailed study of the water available from deep aquifers. The effects of withdrawals from shallow aquifers are a local problem.

In Planning Subarea 2.2 intensive metropolitan and industrial development is expected to continue. It is fortunate that surface water from Lake Michigan and ground water from two principal aquifer systems are in relative abundance. However, water supply problems do exist. The issue of interbasin diversion places a constraint on withdrawal of Lake Michigan waters. Severely declining ground-water levels will eventually restrict the availability of the ground water, particularly in the lower sandstone aquifer.

Through planning studies and investigations in Illinois and Wisconsin, problems have been identified and solutions presented. Although solutions may be difficult to implement, more emphasis should be placed on developing plans for areawide and regional utilities. Government and concerned parties should be aware of future water supply problems and should be taking steps for implementation of the planning studies at an early date to avoid having to apply short-range solutions to long-range problems.

Regional councils actively involved in planning in the planning subarea include the Council of Governments of Cook County and the Northeastern Illinois Planning Commission in Illinois; the Lake-Porter Regional Transportation and Planning Commission in Indiana; and the Southeastern Wisconsin Regional Planning Commission in Wisconsin. These institutions are involved in detailed regional plans that include public water supply. Before embarking on a definite municipal water supply course of action, further study and coordination with these organizations would be warranted.

4.3.5.2 Industrial

The total withdrawal demands by the manufacturing sector in Planning Subarea 2.2 are expected to decrease dramatically between 1970 and the mid-1980s as water reuse is expanded. By the mid-1980s water withdrawals may be only 60 percent of the present 5,150 mgd withdrawn, even though the output of the manufacturing sector will have doubled. Beginning in 1990 the rate of withdrawals will accelerate annually and eventually match the rate of growth of manufacturing output.

For the total manufacturing sector, output measured in the value added by manufacture is forecast to increase from $19.7 billion in 1970 to $129.0 billion in 2020 (expressed in constant 1958 dollars). If it is assumed that existing plants can enlarge their operations at their present locations by 100 percent, approximately $109 billion of manufacturing activity will occur at new locations for which new water supplies must be developed.

Figure 6–27 illustrates the changing characteristics of the industrial water demand during the 50-year planning period. In the preparation of this chart on the effects of improved recirculation practices on the major water-using industries, it was assumed that existing plants would provide the first 100 percent increase in manufacturing output. Curve 1 represents the withdrawal demand to maintain 1970 production levels at existing plants. Curve 2 represents the withdrawal demands to maintain 1970 levels plus the first 100 percent increase in production occurring at existing plants. Curve 3 represents the total withdrawal demand for all old and new production. The area between Curves 2 and 3 represents the withdrawal requirements for new production assumed to occur at new locations.

From these curves it can be seen that by the year 2000 approximately 1,200 mgd of industrial water will be required at locations where plants do not currently exist, and by the year 2020 the demand at new locations will increase to 4,000 mgd. The problems associated with meeting those new withdrawal needs and the range of their solutions will be influenced strongly by other planning goals, such as land use, environmental quality, subregional economic development, the availability of the water supply, and facilities for its return to the resource base. Undoubtedly, much of the new industrial development will occur at locations inland from the Lake Michigan shoreline, provided that adequate water supplies are available. The inland dispersal of new industries should be encouraged, and the management of the water resource base could be achieved best by the enlargement of municipal systems and the development of regional systems to provide industrial water and control its disposal.

4.3.5.3 Rural

Future rural water requirements will be drawn primarily from ground-water sources, although in some areas streams will become increasingly more important. The location and quality of ground water will be important in channeling additional development, particularly for rural nonfarm dwellings. In areas where ground water is in short supply, development should proceed only after water supplies are located. Some areas will not develop until a central supply is available. Rural water requirements are projected to increase 26 percent between 1970 and 2020, and consumption is expected to increase 22 percent during the same period.

Heavy metropolitan usage decreases ground-water quality and quantity. Salinity is a problem in the southern part of this area. Hardness and a high sulfate content are problems in some areas. Restrictions on well drilling operations are necessary to inhibit deep drilling and the accompanying spread of saline water.

4.4 Lake Michigan Southeast, Planning Subarea 2.3

4.4.1 Description of Planning Subarea

4.4.1.1 Location

Planning Subarea 2.3 is located along the southeastern shore of Lake Michigan and includes 19 southwestern Michigan counties

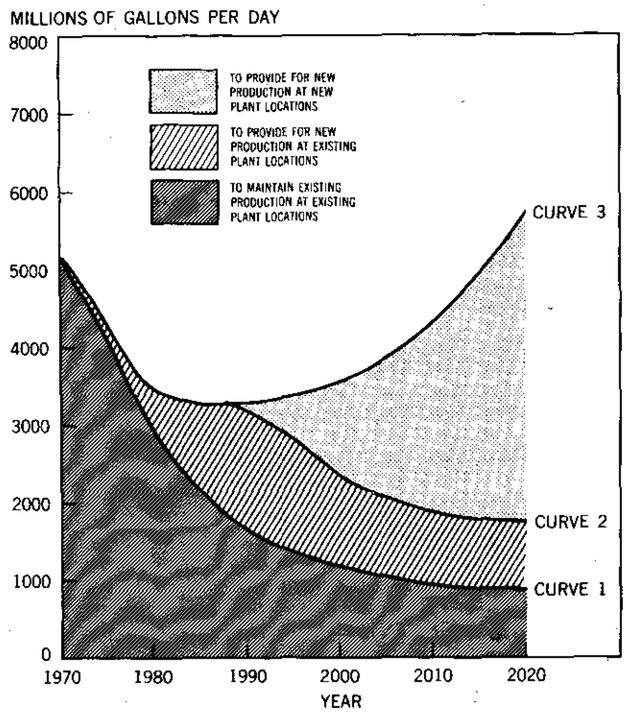


FIGURE 6–27 Total Withdrawal Demands for Manufacturing—Planning Subarea 2.2

and six northern Indiana counties (Figure 6–28). The planning subarea is approximately 150 miles long and 115 miles wide.

4.4.1.2 Topography and Geography

Pleistocene glaciers created the gently rolling topography across this area. Belts of morainic hills with stronger slopes occur throughout the planning subarea. Elevations vary across the region from 600 feet near the Lake Michigan shore to more than 1,100 feet inland. Flat to undulating lowland with scattered gently to strongly rolling morainic hills with prominent sand dunes and ridges characterize the shoreline near Muskegon and extend to the Michigan-Indiana State line. The broad glaciated plains inland are deeply mantled by till and outwash. Relief in the inland morainic belts reaches 100 to 200 feet in local areas. Glacial deposits are typically deep with some local bedrock outcroppings. Bedrock formations consist largely of shales, limestones, and sandstones. Surface formations, formed primarily by the receding Wisconsin glacier 20,000 years ago, consist of moraines, till plains, and thick glacial outwash. Most of the rivers were created by meltwaters of the receding glacier.

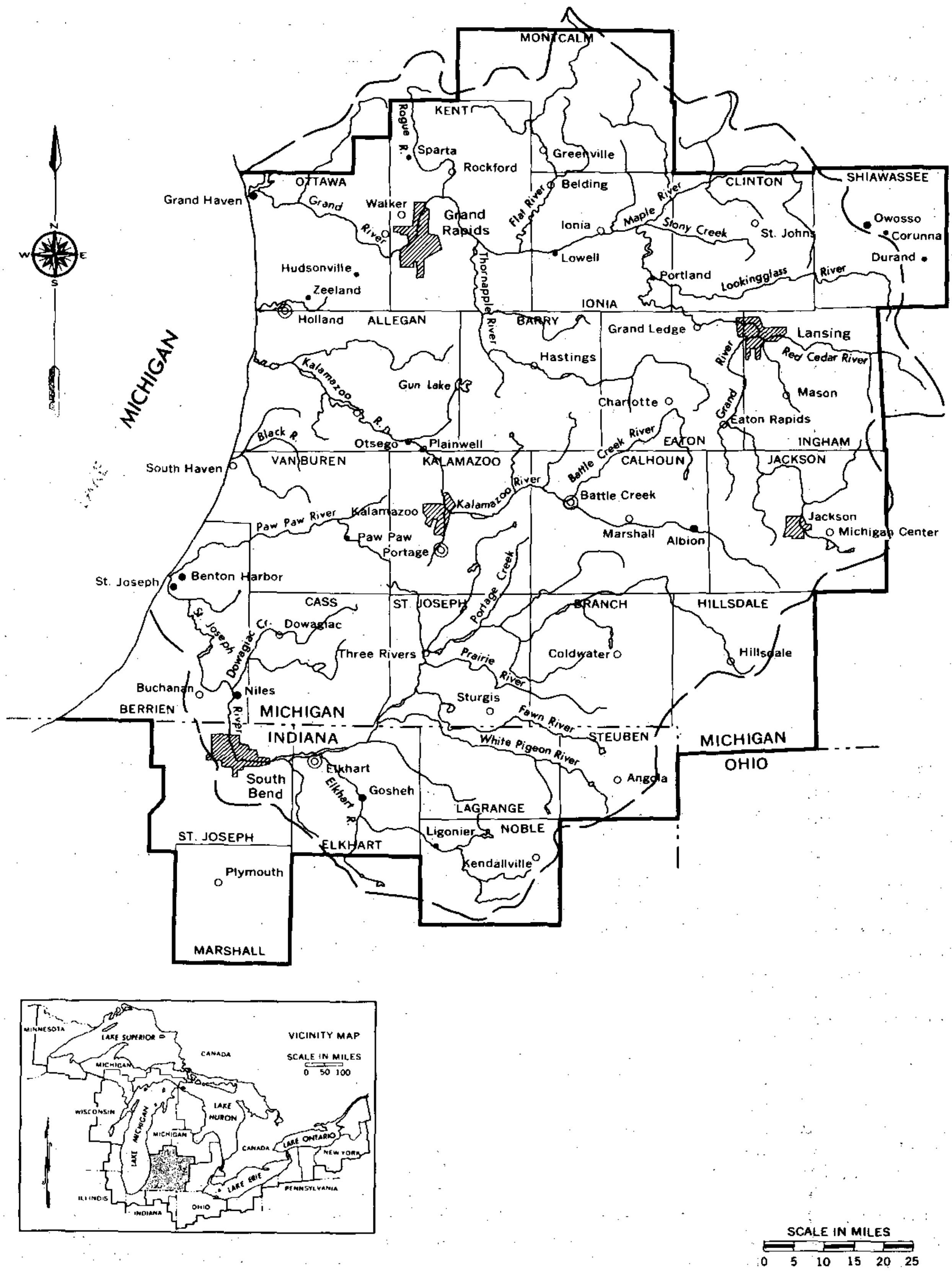


FIGURE 6–28 Planning Subarea 2.3

This area is drained by the Grand, Black, Kalamazoo, and St. Joseph Rivers, and the Ottawa complex. The total drainage area is 12,956 square miles.

4.4.1.3 Climate

Planning Subarea 2.3 has a humid continental climate and is subject to a variety of weather. Mean annual precipitation ranges from 32 inches in the northeast to 36 inches in the south and southwest portions of the planning subarea. Temperatures vary across the planning subarea. Lake Michigan has a tempering effect on the climate: winters are milder and summers cooler along the shore than in inland areas. The prevailing winds blow from the west and southwest. Growing seasons range from 140 days in the eastern portion to 180 days along the Lake Michigan shoreline and south. Annual snowfall averages range from 35 to 65 inches, the depth increasing with elevation and latitude. The mean temperature ranges from 78°F to 80°F in the summer and 28°F to 32°F in the winter.

4.4.2 Water Resources

4.4.2.1 Surface-Water Resources

More than 2,500 lakes cover nearly 125,000 acres in the planning subarea. Michigan lakes constitute approximately 90 percent of the total. Although public access is limited on most lakes, recreation on lakes and streams is considered a major use of the water resources. Annual runoff averages 10 inches in the planning subarea. In Planning Subarea 2.3 the water supplies of the Great Lakes and connecting waters may have a total capacity of 139.1 mgd. The inland surface supplies have a total capacity of 2 mgd.

Fully developed water storage areas in inland lakes and streams provide an existing storage capacity of 23,200 acre-feet. If all inland lakes and streams suitable for development as surface-water impoundments were developed, the total potential storage capacity in Planning Subarea 2.3 would increase to 4.38 million acre-feet.[45]

Presently developed water storage areas can produce a sustained water supply yield of 626 mgd. If all potential water storage areas were fully developed in Planning Subarea 2.3, impounded inland lakes and streams could produce a sustained water supply yield of 4,071 mgd.[45]

Potential capacities and yields used in this section relate to the total water resource. No attempt has been made to identify that portion of the water resource not suitable or available for use.

4.4.2.2 Ground-Water Resources

The availability of ground water varies with the geology at any particular location. In general ground-water supplies are available throughout the planning subarea. Ground water from bedrock comes largely from sandstones, while the shales in the region are the least productive rock types. The western and southwestern sections are underlain by shales which sometimes create problems of quantity and quality for water supply. The glacial deposits in the region vary considerably in their water yielding characteristics. Outwash deposits in the central and western portions are potential sources of large water supplies, while the morainic areas in the eastern and southern areas may produce spotty and unfavorable water supply. Thick glacial drift in Indiana counties makes ample water available for use. Throughout the planning subarea, ground water falls into the hard to very hard classification and often contains objectionable amounts of iron and manganese. In general these characteristics are susceptible to treatment if better quality is required. Raw water of the Quaternary and Pennsylvanian aquifers contains total dissolved solids in excess of the USPHS recommended drinking water standard.

Ground-water yield (based on 70 percent flow-duration data) in River Basin Group 2.3 is estimated to be 2,850 mgd.[21]

4.4.3 Water-User Profile

4.4.3.1 Municipal Water Users

In 1970, 2.5 million people inhabited Planning Subarea 2.3. In 1960, 59 percent of the total population was classified as urban, while rural population levels constituted 41 percent. The populace is spread quite evenly with an average population density of 179 people per square mile, although a few major cities account for more than 60 percent of the total urban population. In all the counties a positive net change in population occurred from 1960 to 1970. Those counties along the Lake Michigan shore and those containing major urban centers experienced the highest percentage increases, while the rural counties and those in Indiana had lower increases.

Municipal water supplies served 1,550,000 people, 61 percent of the total population of the area in 1970. The estimated annual average per capita income is $4,040 (1970 dollars) with the majority of the people employed in manufacturing (36 percent) and trades and services (40 percent). A small percentage (5 percent) are employed in agriculture, construction, transportation and utilities, government, and military.

4.4.3.2 Industrial Water Users

Planning Subarea 2.3 is a region of growing manufacturing importance. Between 1963 and 1967 more than 100 new factories were constructed, bringing the total number of plants to nearly 4,600. During the same period manufacturing employment increased by 47,000 new jobs to a total of 337,000, 40 percent of all jobs in the region. Value added by manufacture in 1967 reached $5.1 billion, an increase of more than 40 percent in current dollars. Of the 15 planning subareas in the Great Lakes Basin, Planning Subarea 2.3 ranks fourth in manufacturing output. The three planning subareas that outrank it in manufacturing activity contain major cities and ports, such as Chicago, Milwaukee, Detroit, and Cleveland, but this planning subarea has no cities of that size and no major Great Lakes port.

Manufacturing is well distributed throughout the 25-county region, but is most concentrated in the vicinities of Elkhart and South Bend, Indiana, and Jackson, Kalamazoo, Lansing, and Grand Rapids, Michigan. Approximately one quarter of the manufacturing plants are located in the Indiana counties where the major industrial activities and larger plants are involved in food processing, paper products, chemicals, metals foundries and fabrication, machinery, and transportation equipment manufacture.

Michigan manufacturing plants, which number approximately 3,500, are diversified in their activities. This region is particularly famous for the manufacture of cereal grain foods and products, furniture, and vehicles, but other major industrial activities are also prominent. These include other food processing, paper and paper products, basic and refined chemicals, petroleum products, primary metals, and industrial equipment.

Only four Michigan counties have frontage on Lake Michigan. Two of these counties, Berrien and Ottawa, have relatively large manufacturing sectors. In Berrien County in 1967, employment in manufacturing totaled 29,000, and value added by manufacture totaled $364 million (1967 dollars). In Ottawa County during the same year, 16,000 were employed in manufacturing and value added by manufacture was $227 million (1967 dollars). However, manufacturing activities are centered in the inland counties such as Elkhart and St. Joseph Counties in Indiana, and Calhoun, Ingham, Jackson, Kalamazoo, and Kent Counties in Michigan.

There is insufficient information on the sources of water for manufacturing, but present knowledge indicates that there are no industrial water pipelines from Lake Michigan to the inland county manufacturing locations at this time. The water supply at the inland locations is obtained mainly from the St. Joseph, Kalamazoo, and Grand Rivers and their tributaries, and to a lesser extent from municipal systems and company-owned wells.

The manufacturing sector is expected to continue its growth and diversified character throughout the planning period, expanding its output at an above average rate compared to the Great Lakes Region as a whole. Projections of value added by manufacture indicated a growth by the year 2020 of 770 percent over the 1970 level, bringing the total value added to a 1958-dollar level of $28,447 million.

4.4.3.3 Rural Water Users

In 1964, 6.3 million acres of land were in farm in Planning Subarea 2.3. The area has a high concentration of fruit and vegetable crops which are heavy water users. In 1964 there were more than 123,000 acres of orchard and vines and more than 43,000 acres of vegetable crops. Dairy farming is also important, contributing 44 percent of livestock and livestock product receipts. Crop sales amounted to approximately $176 million, while livestock and livestock product sales were more than $234 million. Approximately 224,000 people lived on farms, and 47,000 people were employed on farms, according to the 1960 census.

4.4.4 Present and Projected Water Withdrawal Requirements

Table 6–57 presents a summary of municipal, and self-supplied industrial water use for Planning Subarea 2.3.

4.4.4.1 Municipal Water Use

Total municipal water use in Planning Subarea 2.3 reached 266 mgd in 1970 (Tables 6–58 through 6–60). Of this total, municipal ground-water systems supplied 65.1 percent, while the Great Lakes systems supplied 34.9 percent. The municipal systems served 62 percent of the resident population, and the remaining 38 percent of the population was served by individual domestic wells.

The water withdrawals should increase to 1,672 mgd by year 2020 (Figure 6–29). As the demand for water increases, more water is expected to be supplied through central distribution systems. Municipal water supply is projected to increase from 33 percent of the total water use in 1970 to 46 percent by 2020.

Of the 182 central water systems operating in the Michigan portion in 1965, 18 obtained water from Lake Michigan, three drew water from inland surface waters, and 161 relied upon ground water. Seventeen new systems have been developed in this part of Michigan since 1965. All 32 of Indiana's municipal systems in this planning subarea depend on wells. In 1970 municipal water supplies served 1.50 million people. This is expected to increase to 3.9 million people by 2020.

4.4.4.2 Industrial Water Use

It is estimated that the manufacturing industries of Planning Subarea 2.3 withdrew water from their own sources and purchased from systems an average of 554 mgd in 1970. In the Indiana portion manufacturing withdrawals totaled approximately 60 mgd, which were obtained in relatively equal quantities from inland river system sources, company-owned wells, and municipal supply systems. Manufacturers in the Michigan portion required 494 mgd, with 88 mgd of the requirement coming from public water supply systems. It is estimated that the manufacturers obtained 20 mgd of the remaining demand from their own wells and 385 mgd from surface-water supplies. The quantity of surface water obtained from Lake Michigan through company-owned intakes is not known, but 37 mgd of the municipally supplied industrial water is obtained from public systems which use Lake Michigan as their source. Some manufacturers have Lake Michigan intakes, but the quantity withdrawn from the Lake is relatively small, because most manufacturing activity occurs at a considerable distance inland.

Table 6–61 presents the base-year estimate and projections of five water-use parameters and value added by manufacture for four major water-using SIC two-digit industry groups and the residual manufacturing

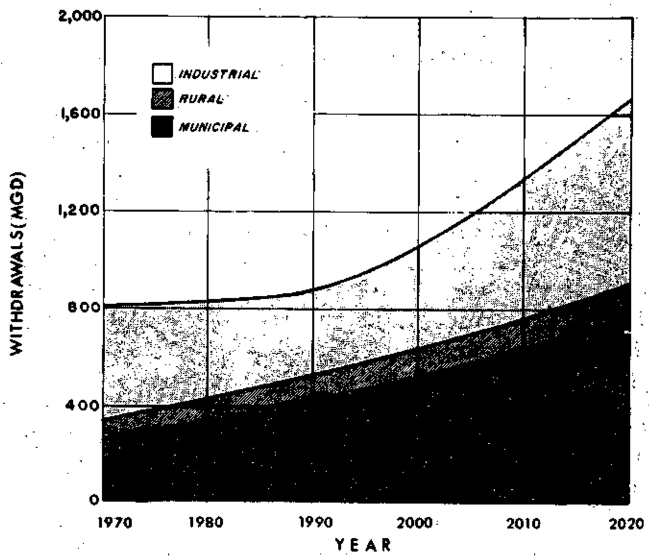


FIGURE 6–29 Municipal, Industrial, and Rural Water Withdrawal Requirements—Planning Subarea 2.3

More than half of the population of Planning Subarea 2.3 is classified as urban. The total population is 2.0 million, and in 1970 municipal water supplies served 1.6 million people. Municipal water supplies are expected to serve 3.9 million by 2020.

This planning subarea is important agriculturally. Fruit and vegetable production is concentrated in the area. Considerable irrigation occurs in this planning subarea. Feed grain and livestock are important products.

Manufacturing employs 15 percent of the population and the planning subarea's primary industrial activity is centered on transportation equipment, fabricated products, machinery industries, paper and allied products, and food and kindred products.

TABLE 6–57 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Planning Subarea 2.3 (mgd)

Use	1970 mun.	1970 ind.	1970 rural	1970 total	1980 mun.	1980 ind.	1980 rural	1980 total
Withdrawal Requirements								
Indiana	45.2	48	14.5	108	52.5	42	16.5	111
Michigan	220.7	406	67.8	695	291.8	356	77.3	725
Total	265.9	454	82.3	803	344.3	398	93.8	836
Consumption								
Indiana	4.0	5	4.3	13	4.9	7	5.3	17
Michigan	17.8	42	19.9	80	25.9	72	24.9	123
Total	21.8	47	24.2	93	30.8	79	30.2	140
1970 Capacity-Future Needs								
Indiana	145.7	48	14.5	208	7.3	6	2.0	15
Michigan	331.1	406	67.8	805	73.7	34	9.5	117
Total	476.8	454	82.3	1013	81.0	40	11.5	132

Use	2000 mun.	2000 ind.	2000 rural	2000 total	2020 mun.	2020 ind.	2020 rural	2020 total
Withdrawal Requirements								
Indiana	72.5	46	20.8	139	100.3	81	23.7	205
Michigan	453.4	379	97.3	930	673.5	683	110.8	1467
Total	525.9	425	118.1	1069	773.8	764	134.5	1672
Consumption								
Indiana	7.9	24	7.5	39	11.7	50	9.4	71
Michigan	50.8	200	35.0	286	83.5	412	43.8	539
Total	58.7	224	42.5	325	95.2	462	53.2	610
1970 Capacity-Future Needs								
Indiana	28.3	19	6.3	54	58.3	50	9.2	118
Michigan	252.8	120	29.5	402	502.0	278	43.0	823
Total	281.1	139	35.8	456	560.3	328	52.2	941

TABLE 6–58 Municipal Water Supply, Planning Subarea 2.3, Indiana and Michigan (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Consumption
1970	GL	2541.1	523.7	92.7	111.2	139.1	7.5
	GW		1026.3	173.2	207.8	259.8	14.3
1980	GL	2914.0	710.9	131.3	157.6	197.0	11.6
	GW		1212.0	213.0	255.6	319.4	18.9
2000	GL	3771.8	1211.2	235.8	283.0	353.7	26.4
	GW		569.5	290.1	348.1	435.1	32.2
2020	GL	4876	1974.6	404.1	484.9	606.2	50.1
	GW		1910.7	369.7	443.7	554.6	45.0

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Consumption	Municipally Supplied Industrial Water: Average Demand	Consumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
1970	GL	107	55.6	5.6	37.1	1.9	139.1
	GW		110.6	11.1	62.7	3.2	337.7
1980	GL	111	78.8	7.9	52.5	3.7	41.5
	GW		135.3	13.5	77.7	5.4	39.5
2000	GL	117	141.4	14.1	94.3	12.3	160.6
	GW		184.5	18.5	105.7	13.7	120.5
2020	GL	123	242.4	24.2	161.6	25.9	356.3
	GW		236.1	23.7	133.6	21.3	204.0

groups that comprise the manufacturing sector. It may be noted that water-use estimates and projections are not given for SIC 29, Petroleum and Coal Products. The water requirements for that industry group were considered and included in the "other manufacturing" category.

In 1970 approximately 30 percent of the total water withdrawals for manufacturing were made by industries in the Paper and Allied Products industry group, SIC 26. Water reuse and recirculation within this group of mills and plants now averages 3.4 times, which is 20 percent higher than the national average for the industry group. Water withdrawals for paper and allied products manufacture in Planning Subarea 2.3 will continue to be the major industrial demand, increasing from 164 mgd in 1970 to 310 mgd by the year 2020.

Industries in SIC 28, Chemicals and Allied Products, had a gross water requirement of 428 mgd and are estimated to have withdrawn 241 mgd to produce $488 million (1958 dollars) value added by manufacture in 1970. By the year 2020, the output of this industry group is projected to grow to a 1958-dollar value added of $6,975 million. The gross water requirements will increase to 7,340 mgd, but with the improvements of water reuse and recirculation of water in their plaints, the industry may need to withdraw only 490 mgd. Consumptive losses of water by this industry group average

TABLE 6–59 Municipal Water Supply, Planning Subarea 2.3, Indiana (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply Average Demand	Maximum Month	Maximum Day	Consumption
1970	GW	487.0	303.0	45.15	54.2	67.8	4.0
1980	GW	527.2	343.2	52.5	63.0	78.7	4.8
2000	GW	635.5	451.5	72.5	87.0	108.7	7.8
2020	GW	778.3	594.3	100.3	120.3	150.5	11.6

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Consumption	Municipally Supplied Industrial Water: Average Demand	Consumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
1970	GW	111	33.55	3.4	11.6	0.6	145.7
1980	GW	113	39.0	3.9	13.5	0.9	7.3
2000	GW	119	53.9	5.4	18.6	2.4	28.3
2020	GW	125	74.5	7.5	25.8	4.1	58.3

5 percent of the gross water use, or 21 mgd in 1970. However, by the year 2020 consumptive losses are estimated to exceed 367 mgd, and consequently, of the 490 mgd of water taken in by the plants, only 125 mgd will be discharged.

Approximately two-thirds of the manufacturing activity in Planning Subarea 2.3 is in industries included in the category of other manufacturing. In 1970 value added by manufacture by this group totaled $2,337 million in 1958 dollars, and by the year 2020 will exceed $17 billion. Many large factories and plants manufacturing transportation equipment, machinery, electrical equipment, and metal fabrications are included in this category. Water withdrawals by this industry group are estimated to have been 81 mgd in 1970. By the year 2020, despite improvements in reuse and recirculation of water, the withdrawal requirement is projected to grow to 188 mgd, or 18 percent of the total withdrawals by the manufacturing sector (Table 6–62).

4.4.4.3 Rural Water Use

Rural water requirements and consumption were estimated for Planning Subarea 2.3 following the methodology outlined in Subsection 1.4. Table 6–63 divides total requirements and consumption into categories of rural nonfarm and rural farm. Rural farm is further divided into domestic, livestock, and spray water requirements.

4.4.5 Needs, Problems, and Solutions

4.4.5.1 Municipal

The total projected need for municipal water supply is 560 mgd (Tables 6–57, 6–58, and 6–64). Ground water in the area is expected to supply 204 mgd of the need, and Lake Michigan will supply the remaining 356 mgd.

TABLE 6-60 Municipal Water Supply, Planning Subarea 2.3, Michigan (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Con-sumption
1970	GL	Not	523.7	92.7	111.2	139.1	7.5
	GW	Projected	723.3	128.0	153.6	192.0	10.3
1980	GL	2386.8	710.9	131.3	157.6	197.0	11.6
	GW		868.8	160.5	192.6	240.7	14.1
2000	GL	3136.3	1211.2	235.8	283.0	353.7	26.4
	GW		118.0	217.6	261.1	326.4	24.4
2020	GL	4098	1974.6	404.1	484.9	606.2	50.1
	GW		1316.4	269.4	323.3	404.1	33.4

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Con-sumption	Municipally Supplied Industrial Water: Average Demand	Con-sumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
1970	GL	106.2	55.6	5.6	37.1	1.9	139.1
	GW		77.0	7.7	51.1	2.6	192.0
1980	GL	110.8	78.8	7.9	52.5	3.7	41.5
	GW		96.3	9.6	64.2	4.5	32.2
2000	GL	116.8	141.4	14.1	94.3	12.3	160.6
	GW		130.6	13.1	87.1	11.3	92.2
2020	GL	122.8	242.4	24.2	161.6	25.9	356.3
	GW		161.6	16.2	107.8	17.2	145.7

Notes: Preliminary 1970 Census population for these 19 counties is 2,022,240 persons. Unlike tabulations for future years and for other planning subareas, the population-served figure for 1970 (1,247,000) is a direct engineer's estimate, not derived from GLBC projections of total population.

TABLE 6-61 Estimated Manufacturing Water Use, Planning Subarea 2.3 (mgd)

	SIC 20	SIC 26	SIC 28	SIC 35	Other Mfg.	Total
1970						
Value Added (Millions 1958$)	318	283	488	268	2,337	3,694
Gross Water Required	35	556	428	99	142	1,260
Recirculation Ratio	1.84	3.39	1.77	2.03	1.75	-
Total Water Withdrawal	19	164	241	49	81	554
Self Supplied	-	-	-	-	-	454
Water Consumed	3.8	22	21	1.9	4.1	53
1980						
Value Added (Millions 1958$)	426	416	915	401	3,531	5,689
Gross Water Required	53	808	856	138	217	2,072
Recirculation Ratio	2.77	6.03	3.32	3.63	2.44	-
Total Water Withdrawal	19	134	258	38	89	538
Self Supplied	-	-	-	-	-	398
Water Consumed	4.8	31.4	42.8	2.6	6.4	88
2000						
Value Added (Millions 1958$)	718	826	3205	762	7,698	13,209
Gross Water Required	82	1448	3375	241	499	5,645
Recirculation Ratio	3.15	8.00	11.70	9.63	4.80	-
Total Water Withdrawal	26	181	288	25	104	624
Self Supplied	-	-	-	-	-	424
Water Consumed	7.7	54.5	169	4.5	13.8	250
2020						
Value Added (Millions 1958$)	1255	1618	6975	1419	17,180	28,447
Gross Water Required	137	2489	7343	384	1,102	11,455
Recirculation Ratio	3.50	8.00	15.00	12.00	5.86	-
Total Water Withdrawal	39	310	490	32	188	1,059
Self Supplied	-	-	-	-	-	764
Water Consumed	12.5	91.7	367	7.0	31	509

TABLE 6-62 Manufacturing Water Withdrawals and Consumption by State, Planning Subarea 2.3 (mgd)

	1970	1980	2000	2020
Indiana				
Self-Supplied	48	42	46	81
Municipally-Supplied	11.6	13.5	18.6	25.8
Consumed	6	9	26	54
Michigan				
Self-Supplied	406	356	379	683
Municipally-Supplied	88.2	116.5	181.4	269.4
Consumed	47	79	224	455

TABLE 6–63 Rural Water Use Requirements and Consumption, Planning Subarea 2.3 (mgd)

	1970	1980	2000	2020
REQUIREMENTS				
Rural Farm				
Domestic	11.8	13.5	12.0	12.4
Livestock	14.0	19.5	31.3	42.2
Spray Water	0.2	0.2	0.2	0.2
Subtotal	25.9	33.2	43.4	54.8
Rural Nonfarm	56.4	60.6	74.7	79.6
Total	82.4	93.8	118.1	134.4
CONSUMPTION				
Rural Farm				
Domestic	2.9	3.4	3.0	3.1
Livestock	12.6	17.6	28.1	38.0
Spray Water	0.2	0.2	0.2	0.2
Subtotal	15.7	21.2	31.3	41.3
Rural Nonfarm	8.5	9.1	11.2	11.9
Total	24.2	30.2	42.5	53.2

Water needs resulting from the demands of population growth are shown in the 1980, 2000, and 2020 columns of Table 6–57. The current capacity of existing facility developments is shown for 1970. Additional capacity totaling 132 mgd will be needed by 1980. In the time period from 1980 to 2000 an additional 324 mgd in facility capacity will be required. Fifty-two percent of the total need, 485 mgd, is required from 2000 to 2020. Estimates of the costs incurred in meeting the projected needs of the planning subarea are shown in Table 6–64.

4.4.5.2 Industrial

Figure 6–30 illustrates the changing characteristics of the industrial water demand during the 50-year planning period. The total withdrawal of water for manufacturing is forecast to decline gradually until the mid-1980s because of water conservation through recirculation. Then the total withdrawal of water will begin to increase as the ability to meet new water demands in new and old plant locations by further improvements in water conservation no longer matches the industry growth rate.

TABLE 6–64 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Planning Subarea 2.3 (millions of 1970 dollars)

Source	Cost	1970–1980	1980–2000	2000–2020	1970–2000	1970–2020
	Capital	12.408	35.610	58.514	48.019	106.533
Great Lakes	Annual OMR	.618	3.011	7.701	3.629	11.331
	Total OMR	6.183	60.225	154.036	66.409	220.445
	Capital	6.320	12.960	13.360	19.280	32.640
Ground water*	Annual OMR	.746	3.024	6.133	3.770	9.903
	Total OMR	7.465	60.480	122.661	67.945	190.606
Long distance transport of Great Lakes	Capital	5.850	21.450	78.000	27.300	105.300
	Annual OMR	0.200	0.720	2.630	0.920	3.550
	Total OMR	2.000	14.400	52.600	16.400	121.600
	Capital	24.579	70.021	150.074	94.599	244.474
Total	Annual OMR	1.565	6.755	16.465	8.320	24.785
	Total OMR	15.649	135.106	329.297	150.755	532.652

*Ground water unit cost assumptions are as follows:

		Capital ($/mgd)	Annual OMR ($/mgd-yr)
	transmission	120,000	7,600
(see Figure 6-4)	wells and pumping	40,000	30,200
	Total	160,000	37,800

For the total manufacturing sector in the planning subarea, output measured in constant 1958-dollar value added by manufacture is expected to increase from $3.7 billion in 1970 to $28.5 billion in 2020. If it is assumed that manufacturers can enlarge their output at existing plant locations to double the 1970 value added, then $21 billion of new manufacturing production must occur at new locations for which new water supplies must be developed. In Figure 6–30 the three curves illustrate the changing demand and possible new supply requirements for manufacturing. Curve 1 represents the withdrawal demand necessary to continue present production at existing plants assuming that improvements in reuse of water continue. Curve 2 represents the withdrawal demand at existing locations to meet an assumed 400 percent increase in production with water reuse improvements incorporated. Curve 3 represents the total withdrawal demand for all old and new production at all locations. The area between Curves 2 and 3 represents the new withdrawal demands that are assumed to occur at new locations.

From these curves it can be seen that by the year 2000, 310 mgd of industrial water will be required at locations where plants do not now exist, and by the year 2020 the demand at new locations may increase to 780 mgd. The problems associated with meeting the new withdrawal demands will be influenced by other planning goals, such as land use, environmental quality, subregional economic development, availability of the water supply at its point of use, and facilities for return of the water to the resource base. Much of the new industrial development will occur at locations inland from the Lake Michigan shoreline, provided that adequate water supplies are available. The inland dispersal of new industries can be encouraged and management of the water resource best achieved by the enlargement of municipal systems and the development of regional systems to provide industrial water and control its disposal.

4.4.5.3 Rural

Future rural water requirements will be drawn primarily from ground-water sources, although in some areas streams will be increasingly important. The location and quality of ground water will be important in channeling additional development, particularly in the location of rural nonfarm dwellings. In areas where ground water is in short supply, development should proceed only after water supplies are located. Some areas will not develop until a central supply is available.

Rural water requirements are projected to increase 63 percent between 1970 and 2020, and consumption is expected to increase 120 percent during the same period.

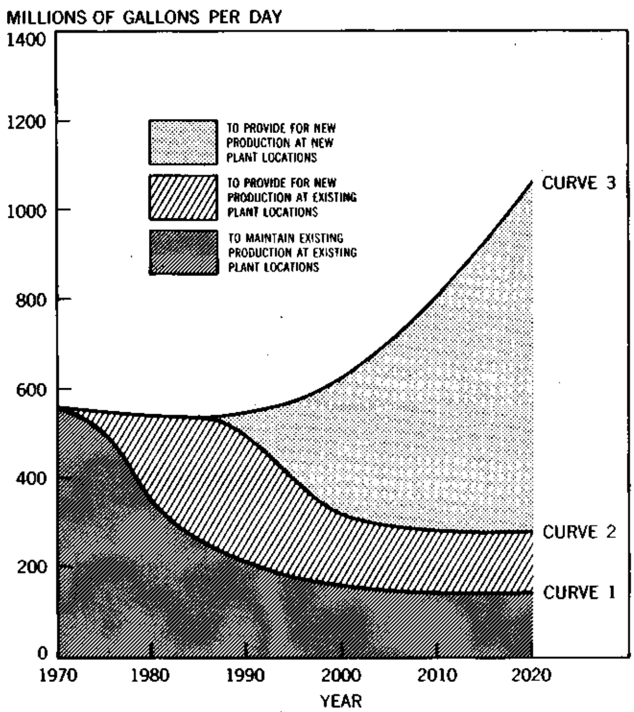


FIGURE 6–30 Total Withdrawal Demands for Manufacturing—Planning Subarea 2.3

Ground water is generally plentiful in the area, but pollution of ground water is a common local problem. Pollution of aquifers by introduction of man-made contaminants is a serious local problem. The most common pollution problem is seepage of wastes into shallow aquifers. Highly saline waters are present in parts of the area, and high iron content is common in some areas.

4.5 Lake Michigan Northeast, Planning Subarea 2.4

4.5.1 Description of Planning Subarea

4.5.1.1 Location

Planning Subarea 2.4 includes 18 counties in the northwestern part of Michigan's Lower Peninsula and three counties in the southern portion of the eastern half of the Upper Peninsula (Figure 6–31). This planning subarea is approximately 130 miles wide and 230 miles long at the widest and longest points.

4.5.1.2 Topography and Geography

Planning Subarea 2.4 comprises parts of two topographic regions, the eastern lowlands of the Upper Peninsula and the Lake border uplands in the Lower Peninsula. The eastern lowlands range in elevation from 580 to 1,000 feet above sea level, with the higher areas in western Delta County.

Low, flat plains, intermixed with swamplands and low and sand ridges, characterize most of the Upper Peninsula. The Lake border uplands topography is generally strongly rolling with elevations ranging from 580 to 1,500 feet. From Muskegon northward successive morainic ridges dominate the uplands, interspaced with outwash plains. Coastal bluffs are cut into predominantly light sandy till and reach heights of more than 400 feet above the Lake. Prominent sand dunes dominate the coastal region, rising from the flat reentrant valleys between the moraines, and often perch atop coastal bluffs. Submerged mouths of streams entering Lake Michigan form estuary lakes and adjacent swampy areas, and may be partially or completely cut off from the Lake by dune ridges. The northern extremity of the region, facing primarily on the Straits of Mackinac, resembles the Upper Peninsula with relict beach ridges and fore-dune ridges on the sloping land face, and minor outcroppings of rock near the shore.

The northern high plains form a sandy plateau, characterized by rolling plains traversed by several major stream valleys which lie well below the general upland level. The flood plains of these streams are bordered by steep cut banks. Elevations range from the level of the Lake to more than 1,700 feet above sea level.

The planning subarea is drained by the Ottawa complex, Sable complex, Muskegon River, Manistee River, Traverse complex, Les Cheneaux complex, Seul Choix-Groscap complex, Manistique River, and the Bay de Noc complex. The total drainage area is 12,647 square miles.

4.5.1.3 Climate

In general a humid continental climate dominates Planning Subarea 2.4. However, latitude differences, elevation variation, and the influence of the Great Lakes create a number of diverse localized climates in the outlined regions. Lake Michigan has a stabilizing effect on air temperature in a coastal belt averaging 15 miles wide along its leeward shore. Because of the prevailing westerly winds, winters are milder, summers cooler, and growing seasons longer along the shoreline than inland. The region experiences frequent and sometimes rapid weather changes caused by storms sweeping across the Great Lakes from the west and southwest. Extreme seasonal variation ranging from 100°F to –35°F, a mean annual temperature of 41°F, a mean growing season of approximately 130 days, and an average precipitation of 30 inches typify the region.

The Lower Peninsula also reflects the tempering influence of Lake Michigan. The growing season varies from 150 days in the coastal belt to 90 days inland. Land and sea breezes provide constant air movement, making the area attractive for summer recreation. Snow cover lasts from 100 to 120 days per year and may accumulate depths up to 120 inches in snow belts in Grand Traverse, Manistee, Charlevoix, and Antrim Counties. The tempering effects of the winter snows and large bodies of water have encouraged the expansion of fruit planting in the Lower Peninsula region.

The northern high plains lie beyond the moderating influence of the Lakes and exhibit a greater diurnal and annual range of temperature, as well as having a shorter (80- to 110-day) growing season. Rainfall ranges from 30 to 32 inches.

4.5.2 Water Resources

4.5.2.1 Surface-Water Resources

Natural water flow patterns throughout the

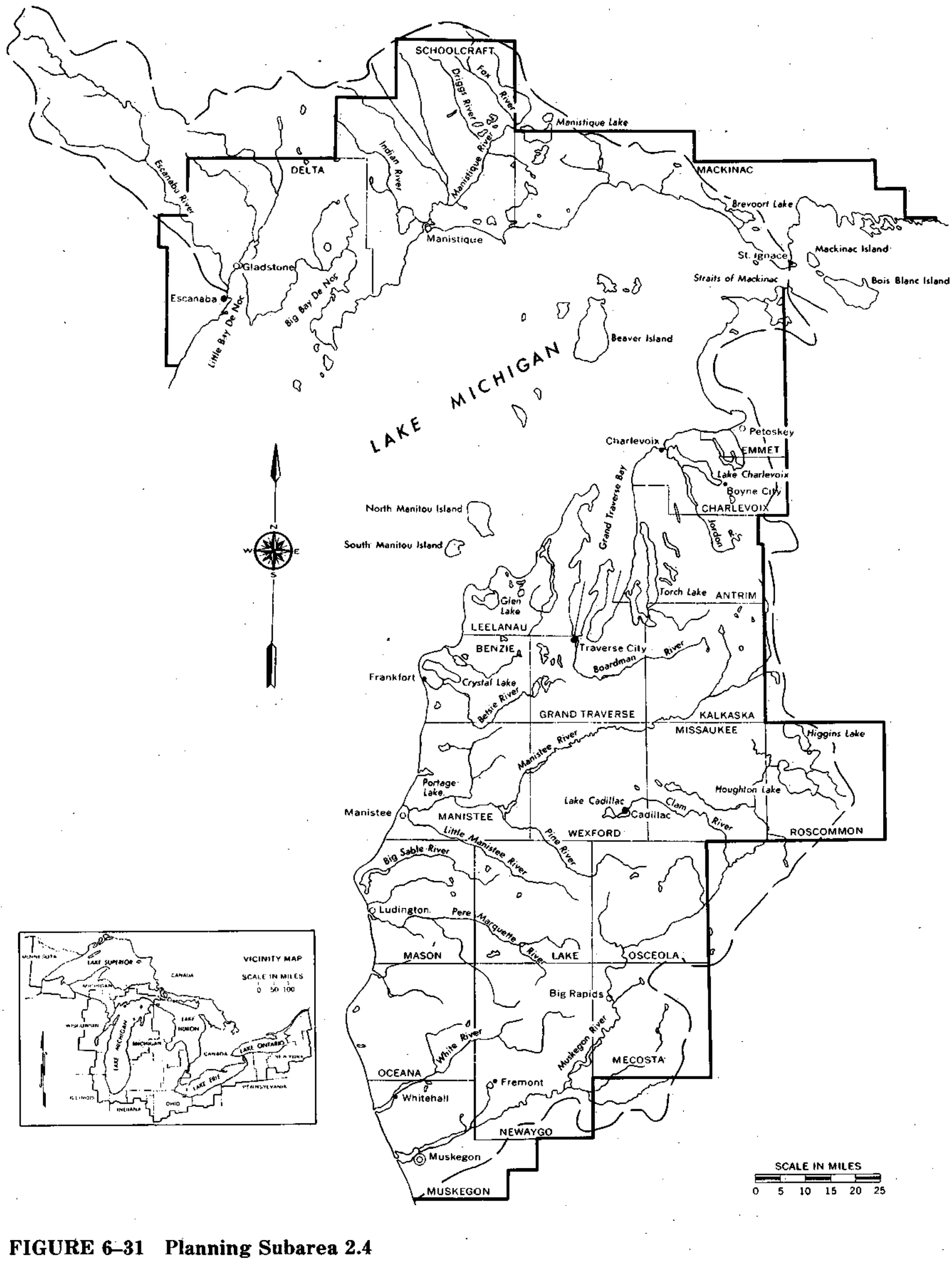


FIGURE 6–31 Planning Subarea 2.4

planning subarea reflect the combined effects of climate, topography, geology, and vegetative cover. Average annual runoff ranges from 12 to 14 inches.

Rivers in the Upper Peninsula alternate between spring highs and late summer low flows. However, major floods and droughts do occur. Streams of the Lower Peninsula and the northern high plains follow a general pattern of high flows in late March and early April to low flows in October. The average daily flows do not generally exceed twice the minimum daily discharges recorded.

Fully developed water storage areas in inland lakes and streams provide an existing storage capacity of 157,750 acre-feet. If all inland lakes and streams suitable for development as surface-water impoundments were developed, the total potential storage capacity would increase to 234,050 acre-feet.[45]

Presently developed water storage areas can produce a sustained water supply yield of 3,367 mgd. If all potential water storage areas were fully developed in Planning Subarea 2.4, impounded inland lakes and streams could produce a sustained water supply yield of 3,789 mgd.[45]

Potential capacities and yields used in this section relate to the total water resource. No attempt has been made to identify that portion of the water resource not suitable or available for use.

4.5.2.2 Ground-Water Resources

The availability of ground water in the Upper Peninsula depends upon the subsurface geology at any particular location. Glacial deposits, differing in thickness and type, account for much of the variation in yields. Wells completed in the Munising sandstone formation are found in Delta and Mackinac Counties. The Niagara series is also a primary source for many wells in these counties. The quality of available ground water is generally acceptable for most uses. It is often hard and contains objectionable amounts of iron which are susceptible to treatment if better quality is required.

Ground-water supplies in the Lower Peninsula are more abundant and more easily available than they are in the Upper Peninsula. Thick glacial drift across the area provides the Lower Peninsula with an ample supply of ground water. Most of the region's wells, which are 10 inches or more in diameter and lie in glacial deposits, will yield more than 500 gpm. Water throughout the region is of generally good quality, although it is hard and may contain iron. The Silurian and Mississippian aquifers have total dissolved solids higher than the 500 mg/l USPHS drinking water standards set for raw water. Bedrock deposits of the Paleozoic age have been tested in only a few places and have produced moderate yields.

Ground-water yield in River Basin Group 2.4 is estimated to be 4,490 mgd (based on 70 percent flow-duration data). Ground water in the Upper Peninsula portion has an estimated yield of 990 mgd, and the Lower Peninsula portion is estimated at 3,500 mgd.

4.5.3 Water-User Profile

4.5.3.1 Municipal Water Users

In 1970, 487,000 people resided in Planning Subarea 2.4, a 7.5 percent increase from 1960. No city has a population exceeding 50,000. In 1960, 44 percent of the total population was classified as urban, 56 percent as rural. Major population concentrations occur on the Lake Michigan shore, while summer vacationers and residents significantly increase the total population. Population densities averaging 37 people per square mile are lowest in the Upper Peninsula counties and those counties inland from the Lake Michigan shore in the Lower Peninsula area. Forty-three percent of the counties showed a net population decrease from 1950 to 1960. Out-migration accounted for much of this decline.

Municipal water supplies served 287,800 people, 58 percent of the population, in 1970. The average per capita income of the planning subarea is $3,300 (1970 dollars). Manufacturing, trades, and services make up more than 70 percent of total employment in the planning subarea and are the area's major industries. Employment is concentrated in the largest cities of each county. Agriculture accounts for 7 percent of the working population of the planning subarea. By 2020 the population is expected to be 841,443, of which 637,400 people are expected to be served by municipal water supplies.

4.5.3.2 Industrial Water Users

Only 487,000 people reside in the planning subarea at present, and with the concentration of population in the Muskegon-Muskegon Heights metropolitan area and a few smaller cities, the general character of the region is rural. However, there is a large and growing manufacturing sector which provides more than one-third of the total employment in the region, and which constitutes the most important economic force.

In 1967 there were 911 manufacturing plants operating in the 21-county area, and although most are small employers, each county has some manufacturing activity. The greatest number of plants are located in the Muskegon River basin, with more than 64 percent of the employment and value added by manufacture in the four lower counties of the basin. The major products are general industrial machinery, paper and paper products, basic and refined chemicals, primary and fabricated metal, furniture and fixtures, and lumber and wood products.

4.5.3.3 Rural Water Users

In 1964 Planning Subarea 2.4 had 1.9 million acres in farm. Meadow crops predominated the area. There are relatively high acreages of fruit and vegetables, heavy water users, in the area. There were more than 72,000 acres of orchards (largely sour cherries) and vines, and almost 16,000 acres of commercial vegetables. More than half of the sales of livestock and livestock products came from dairy farms, a heavy water user. Crop sales amounted to $34.6 million and livestock and livestock product sales to $38.2 million in 1964. Fifty thousand people lived on farms and 10,000 were employed on farms according to the 1960 census.

4.5.4 Present and Projected Water Withdrawal Requirements

Municipal, industrial, and rural water withdrawal requirements for Planning Subarea 2.4 are presented in Figure 6-32.

4.5.4.1 Municipal Water Use

Table 6-65 gives a summary of municipal, self-supplied industrial, and rural water use for Planning Subarea 2.4. Quantitative data pertaining to municipal water uses are shown in Table 6-66. Of the 77 central water systems operating in 1965, 15 obtained water from Lake Michigan, four drew water from inland surface waters, 57 relied upon ground water, and one system tapped both Lake Michigan and ground-water sources. Twelve new systems have been developed since 1965.

At present 492,100 people reside in Planning Subarea 2.4. A total of 58 percent, or 287,800, were served 39.1 mgd by municipal water supplies. By 2020, it is expected that 76 percent of the total population, 637,400 people, will be served 97.9 mgd by municipal facilities.

4.5.4.2 Industrial Water Use

In 1970 manufacturers withdrew 96 mgd of water to supply their plant needs, obtaining 90

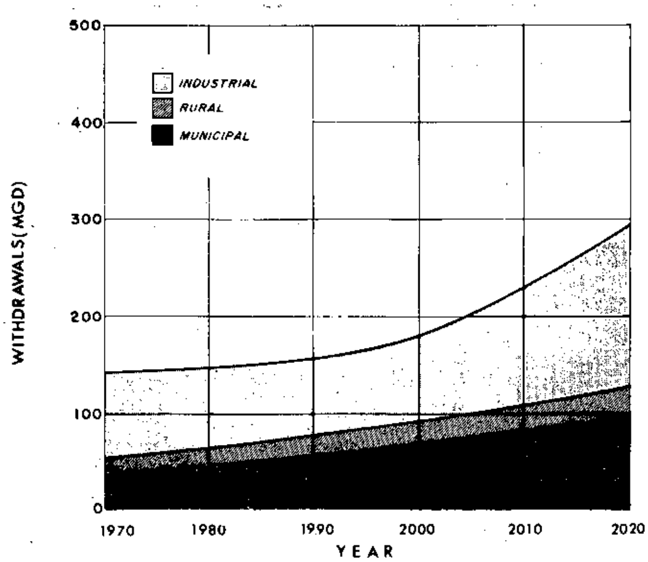


FIGURE 6-32 Municipal, Industrial, and Rural Water Withdrawal Requirements—Planning Subarea 2.4

Planning Subarea 2.4 is classified as 44 percent urban and 56 percent rural. Municipal water supplies serve 287,800 people or 58 percent of the total planning subarea population. The population served by municipal water supplies is expected to increase to 637,400 by 2020.

Adverse climate, soil conditions and drainage make agriculture a secondary industry in some parts of the planning subarea. Dairy products, beef, vegetables, fruits, and other crops play a role in the agricultural economy of the region.

Industrial activity is somewhat restricted. Mining, forestry, pulp and paper, food processing, canning and marketing are significant segments of the region's economy.

TABLE 6–65 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Planning Subarea 2.4 (mgd)

	1970				1980			
Use	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
Michigan	39.1	89.6	16.8	145.5	47.7	81.2	19.7	148.6
Total	39.1	89.6	16.8	145.5	47.7	81.2	19.7	148.6
Consumption								
Michigan	3.6	7.7	4.8	16.1	4.7	13.3	6.7	24.7
Total	3.6	7.7	4.8	16.1	4.7	13.3	6.7	24.7
1970 Capacity-Future Needs								
Michigan	58.7	89.6	16.8	165.1	8.9	--	2.9	11.8
Total	58.7	89.6	16.8	165.1	8.9	--	2.9	11.8

	2000				2020			
Use	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
Michigan	68.5	86.8	24.8	180.1	97.9	167.1	29.8	294.8
Total	68.5	86.8	24.8	180.1	97.9	167.1	29.8	294.8
Consumption								
Michigan	7.2	37.5	9.6	54.3	10.9	89.4	12.8	113.1
Total	7.2	37.5	9.6	54.3	10.9	89.4	12.8	113.1
1970 Capacity-Future Needs								
Michigan	30.8	--	8.0	38.8	63.0	77.5	13.0	153.5
Total	30.8	--	8.0	38.8	63.0	77.5	13.0	153.5

mgd from their own supply sources and only 6.4 mgd from public water supply systems. There is no information available regarding the sources of the self-supplied industrial water, but it can be assumed that inland surface-water sources and company-owned wells served the majority of establishments, and that relatively few plants withdrew directly from Lake Michigan.

Most of the water withdrawn by manufacturers was used by a small number of plants in the SIC 26, SIC 28, and SIC 33 industry groups. Approximately 50 mills and factories in those three groups accounted for almost 80 percent of all industrial water use in the region. The largest requirement was for the manufacturing establishments in SIC 28, Chemicals and Allied Products, which are estimated to have withdrawn a total of 48 mgd and recirculated the water at an industry average rate of 1.8 times. Expansion of industry output by this group is expected to increase by 1,500 percent over the next 50 years. If present water use practices were to continue, the withdrawals of water could be expected to increase by similar magnitude. However, higher recirculation rates should become more common in the industry as a result of the changing cost-benefit relationship of industrial water arising from actions taken to maintain and improve the environment.

Industry groups SIC 26, Paper and Allied Products, and SIC 33, Primary Metals Products, are also large water users in Planning Subarea 2.4. Estimated withdrawals for SIC 26 in the year 1970 are 17.6 mgd, and for SIC 33,

TABLE 6–66 Municipal Water Supply, Planning Subarea 2.4, Michigan (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Consumption
	GL		169.8	23.1	27.7	34.6	2.1
1970	IS	492.1*	25.9	3.5	4.2	5.3	0.3
	GW		92.1	12.5	15.0	18.8	1.2
	GL		208.9	29.1	34.9	43.7	2.8
1980	IS	546.8	30.8	4.3	5.1	6.4	0.5
	GW		102.8	14.3	17.2	21.5	1.4
	GL		298.8	43.9	52.7	65.8	4.6
2000	IS	671.4	37.4	5.5	6.6	8.2	0.6
	GW		130.8	19.1	22.9	28.7	2.0
	GL		439.8	67.6	81.1	101.4	7.5
2020	IS	841.7	44.6	6.8	8.2	10.2	0.8
	GW		153.0	23.5	28.2	35.2	2.6

Year	Source	Domestic and Commercial Municipal Water Supply: Gallon per capita daily	Average Demand	Consumption	Municipally Supplied Industrial Water: Average Demand	Consumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
	GL		19.3	1.9	3.8	0.2	34.6
1970	IS	113.6	2.9	0.3	0.6	0.0	5.3
	GW		10.5	1.1	2.0	0.1	18.8
	GL		24.3	2.4	4.8	0.4	6.4
1980	IS	116.6	3.6	0.4	0.7	0.1	0.8
	GW		12.0	1.2	2.3	0.2	1.7
	GL		36.7	3.6	7.2	1.0	22.2
2000	IS	122.6	4.6	0.5	0.9	0.1	2.0
	GW		16.0	1.6	3.1	0.4	6.6
	GL		56.6	5.7	11.0	1.8	48.6
2020	IS	128.6	5.7	0.6	1.1	0.2	3.4
	GW		19.7	2.0	3.8	0.6	11.0

Notes: *The water use figures for 1970 are based on the standard assumptions, with population obtained by interpolation between 1965 data and 1980 projections. This would imply a total 1970 population of 492,100, as against a preliminary 1970 Census figure of 484,090.

10.2 mgd. Increased output also has been forecast for these two industry groups. However, the growth in outputs, approximately 700 percent by the year 2020 for SIC 26 and 460 percent for SIC 33, is less dramatic than that of the chemicals industries. Recirculation and reuse of recirculated water is expected to improve over current rates in these industry groups in conjunction with water pollution control measures taken by the individual plants. As a result of those actions, total withdrawals during the early years of the planning period are forecast to drop below present levels. Then withdrawals should increase, as the opportunities for further improvements in recirculation rates diminish. Similar factors are involved in the estimates of water use for SIC 20 and the large category of other manufacturing.

Table 6–67 presents estimates and projections of five water-use parameters and the value added by manufacture for SIC two-digit industry groups and the residual other manufacturing category of industries that comprise the manufacturing sector in Planning Subarea 2.4. The total withdrawal requirements for the sector, 96 mgd in 1970, are estimated to remain relatively unchanged until the year 2000, after which the withdrawals are projected to increase sharply to 183 mgd. The table should not be interpreted as forecasts of actual withdrawal requirements for fixed years, because the water conservation actions of a single large water-using factory could seriously change the time frame.

4.5.4.3 Rural Water Use

Rural water requirements and consumption were estimated for Planning Subarea 2.4 following the methodology outlined in Subsection 1.4. Table 6–68 divides total requirements and consumption into categories of rural non-

TABLE 6–67 Estimated Manufacturing Water Use, Planning Subarea 2.4 (mgd)

	SIC 20	SIC 26	SIC 28	SIC 33	Other Mfg.	Total
1970						
Value Added (Millions 1958$)	72	31	89	57	341	590
Gross Water Required	8	60	85	21	27	201
Estimated Recirculation Ratio	1.84	3.39	1.77	2.03	1.75	--
Total Water Withdrawal	4.5	17.6	47.8	10.2	15.4	96
Estimated Self Supplied	--	--	--	--	--	90
Water Consumed	1.0	2.2	4.2	0.3	0.6	8
1980						
Value Added (Millions 1958$)	103	47	156	83	653	1042
Gross Water Required	12	89	147	29	41	318
Estimated Recirculation Ratio	2.77	6.03	3.32	3.63	2.44	--
Total Water Withdrawal	4.5	14.7	44.2	8.0	17.0	89
Estimated Self Supplied	--	--	--	--	--	81
Water Consumed	1.3	3.5	7.4	0.6	1.3	14
2000						
Value Added (Millions 1958$)	191	106	511	149	1259	2216
Gross Water Required	22	174	544	46	88	874
Estimated Recirculation Ratio	3.15	8.00	11.70	9.63	4.80	--
Total Water Withdrawal	7.1	21.8	46.5	4.8	18.3	98
Estimated Self Supplied	--	--	--	--	--	87
Water Consumed	1.9	7.0	26.9	1.0	2.6	39
2020						
Value Added (Millions 1958$)	361	218	1329	263	2975	5146
Gross Water Required	39	308	1413	70	195	2025
Estimated Recirculation Ratio	3.50	8.00	15.00	12.00	5.86	--
Total Water Withdrawal	11.2	38.5	94.2	5.8	33.3	183
Estimated Self Supplied	--	--	--	--	--	167
Water Consumed	3.5	12.2	70.0	1.3	5.4	92

TABLE 6-68 Rural Water Use Requirements and Consumption, Planning Subarea 2.4 (mgd)

	1970	1980	2000	2020
REQUIREMENTS				
Rural Farm				
Domestic	2.4	2.8	3.9	4.3
Livestock	2.7	4.6	7.3	11.1
Spray Water	0.0	0.0	0.0	0.0
Subtotal	5.1	7.4	11.3	15.4
Rural Nonfarm	11.6	12.3	13.5	14.3
Total	16.8	19.7	24.8	29.8
CONSUMPTION				
Rural Farm				
Domestic	0.6	0.7	1.0	0.6
Livestock	2.4	4.1	6.6	10.0
Spray Water	0.0	0.0	0.0	0.0
Subtotal	3.1	4.9	7.6	10.7
Rural Nonfarm	1.7	1.8	2.0	2.1
Total	4.8	6.7	9.6	12.8

farm and rural farm. Rural farm is further divided into domestic, livestock, and spray water requirements.

4.5.5 Needs, Problems, and Solutions

4.5.5.1 Municipal

Those municipal supplies in Planning Subarea 2.4 using the Great Lakes have a capacity of 34.6 mgd, the inland surface supplies have a total capacity of 5.3 mgd, and the developed ground-water capacity is 18.8 mgd. Needs for additional municipal water are presented in Table 6-65. As a result of additional population growth, municipal water supply needs are projected to be 8.9 mgd by 1980, 30.8 mgd by 2000, and 63.0 mgd by 2020. Estimates of the costs required to meet these projected needs are presented in Table 6-69.

4.5.5.2 Industrial

The quantities of water needed by industry in Planning Subarea 2.4 do not appear to be large enough to present serious problems of supply during the planning period 1970 to 2020.

4.5.5.3 Rural

Future rural water requirements will be drawn primarily from ground-water sources, although in some areas streams will be increasingly important. The location and quality of ground water will be important in channeling additional development, particularly in the location of rural nonfarm dwellings. In areas where ground water is in short supply, development should proceed only after water supplies are located. Some areas will not develop until a central supply is available.

Rural water requirements are projected to increase 77 percent between 1970 and 2020, and consumption is expected to increase 167 percent.

The planning subarea has relatively minor ground-water problems, mainly a few local low-yield or poor quality areas. Local chemical-quality problems exist in the area. The operation of brine and salt wells has caused ground-water contamination in some areas.

TABLE 6-69 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Planning Subarea 2.4 (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
Great Lakes	Capital	1.913	4.724	7.893	6.637	14.531
	Annual OMR	.095	.426	1.054	.521	1.576
	Total OMR	.953	8.522	21.098	9.476	30.574
Inland Lakes and Streams	Capital	.239	.358	.418	.598	1.016
	Annual OMR	.011	.041	.080	.053	.134
	Total OMR	.119	.834	1.609	.953	2.562
Ground Water*	Capital	.260	.749	.673	1.009	1.683
	Annual OMR	.030	.146	.310	.176	.487
	Total OMR	.300	2.929	6.212	3.229	9.442
Total	Capital	2.413	5.833	8.985	8.2456	17.231
	Annual OMR	0.137	0.614	1.446	0.752	2.198
	Total OMR	1.373	12.287	28.920	13.600	42.581

*Ground water unit cost assumptions are as follows:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells and pumping (see Figure 6-4)	33,000	27,700
total	153,000	35,300

Section 5

LAKE HURON BASIN

5.1 Summary

5.1.1 The Study Area

The United States portion of the Lake Huron basin lies within the State of Michigan and comprises approximately 14 percent of the Great Lakes drainage area (Figure 6–33). Two-thirds of the eastern half of Michigan and a small section of the Upper Peninsula drain into Lake Huron. The basin has been divided into Lake Huron North, Planning Subarea 3.1, and Lake Huron Central, Planning Subarea 3.2. The drainage area of Planning Subarea 3.1 encompasses approximately 8,100 square miles of the northeastern portion of the Lower Peninsula of Michigan and the southeastern tip of the Upper Peninsula. Planning Subarea 3.2 drains approximately 8,000 square miles of south-central Michigan, including land bordering Saginaw Bay and the periphery of Michigan's agricultural Thumb area.

5.1.2 Economic and Demographic Characteristics

The economic base of the Lake Huron basin is influenced by a variety of resources and industries. Pulp cutting, gypsum mining, and a chemical industry based on subterranean brine deposits bolster the economy of Midland, Alpena, Alcona, and Presque Isle Counties. Heavy and light manufacturing complexes are located in the three principal cities, Bay City, Saginaw, and Flint. A prospering agricultural industry in the area supplies a multitude of food products in the basin's central lowlands. A service industry consisting of restaurants, overnight accommodations, entertainment, recreation facilities, and automobile maintenance centers has grown to meet the demands of local residents and visitors.

In 1970 the resident population of the Lake Huron region was more than 1.2 million, 4 percent of the Great Lakes Region total. The distribution of the basin's population shows that the most populated counties (greater than 50,000) are clustered in the southern portion (Planning Subarea 3.2), and that each county in the northern portion has fewer than 25,000 people except for Alpena County. The basin's Standard Metropolitan Statistical Areas (SMSAs), Bay City, Flint, and Saginaw, contained 57 percent of the 1960 basin population. Since 1940 a majority of the basin counties have been gaining in population. In 1960, 63 percent of the basin residents lived in urban areas (2,500 inhabitants or more) with the remaining 37 percent in rural and rural farm areas. The resident population of the Lake Huron basin is expected to increase by 87 percent from 1970 to 2020 to more than 2.3 million.

Manufacturing, especially in the lower basin, is the major contributor to basin employment and aggregate income. In 1962 total personal income for the Lake Huron region was approximately $2.3 billion. Per capita income levels, particularly in the northern portion of the basin, have been below the national average with average per capita incomes in 1970 dollars ranging from $2,814 in Planning Subarea 3.1 to $4,190 in Planning Subarea 3.2. Agriculture, forestry, recreation trades and services, and other related industries supply approximately 20 percent of the basin's income, while manufacturing contributes nearly 80 percent.

In 1960, 356,000 people were employed in the Lake Huron basin. The manufacturing segment of the economy accounted for 41 percent of the basin's employed population.

5.1.3 Water Resources

Slightly more than one-third of the average annual rainfall (11 inches) leaves the basin as stream runoff. This annual surface-water supply combines with storage water in numerous inland lakes, streams, and subsurface deposits, as well as Lake Huron.

The Lake Huron basin has 208,000 acres of inland lakes and approximately 8,000 miles of

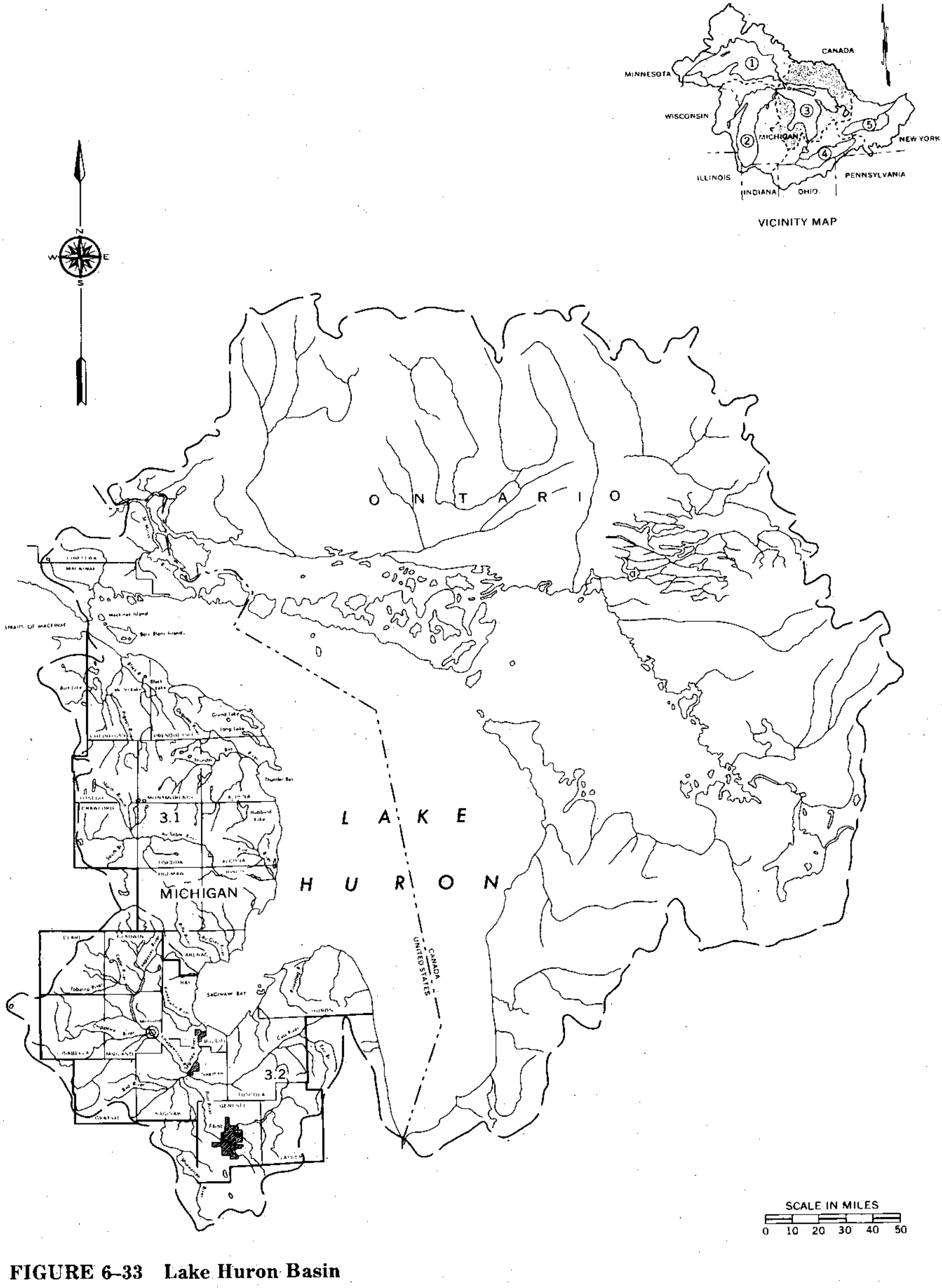


FIGURE 6–33 Lake Huron Basin

streams and rivers. The lakes vary in size from 50,000 acres to small glacial ponds measuring one-tenth of an acre. The nature of the water resource, its availability, and its quality differ from place to place. Streams in Planning Subarea 3.1 are short, with generally stable flows and small drainage areas. Water surface on inland lakes within the boundaries of Planning Subarea 3.1 exceeds 134,600 acres. Cheboygan County alone contains more than 50,350 acres of inland lake surface area. Ground-water resources decrease in availability: wells in the western morainal areas yield up to 500 gpm and sometimes less than 10 gpm in lacustrine deposits along the lakeshore. In general most water in the glacial deposits is hard, but of good chemical quality. However, local areas experience very poor quality ground water, especially where glacial deposits are directly underlain by bedrock containing highly mineralized water.

Planning Subarea 3.2 streams drain primarily agricultural land with extensive artificial drainage and also the more urbanized areas of Flint and Saginaw valley. Flows are unstable and water quality is poor due to turbidity and municipal, industrial, and agricultural waste disposal. Inland lakes are not plentiful except in the basin headwaters, and surface resources are variable but generally poor in quantity and chemical quality. Flows of the Saginaw River are altered by the raising and lowering of Saginaw Bay. Lake Huron is the second largest of the Great Lakes, with an area of 23,000 square miles and a volume of 849 cubic miles. Average discharge of Lake Huron through the St. Clair River is 190,000 cfs.

5.1.4 Present and Projected Water Withdrawal Requirements

In 1970 the Lake Huron basin total water withdrawals, 712 mgd, accounted for 4.6 percent of the total withdrawals in the entire Great Lakes Basin. This does not include the Lake Huron water withdrawn for use in Planning Subarea 4.1 to supplement water from the connecting channels (the St. Clair River, Lake St. Clair and the Detroit River), and Lake Erie.

A summary of present and projected water withdrawal requirements and needs for the municipal, industrial, and rural water-using sectors in the Lake Huron basin is presented in Table 6-70 and Figure 6-34.

Through the year 2020 the waters of Lake Huron are expected to provide 288 mgd, or 79 percent of the municipal water supply requirements in the basin. With the completion of 1,200 mgd intake tunnel near Port Huron, Michigan, the water of Lake Huron will also provide a significant portion of the 1,273 mgd withdrawal requirements projected for the Detroit Metropolitan Water Department service area in the year 2020.[13] This regional water supply system encompasses most of the major urban areas in Planning Subarea 4.1 in the Lake Erie basin. Part of this water will be sold to Flint and other customers in the Lake Huron basin. This abundant water resource is

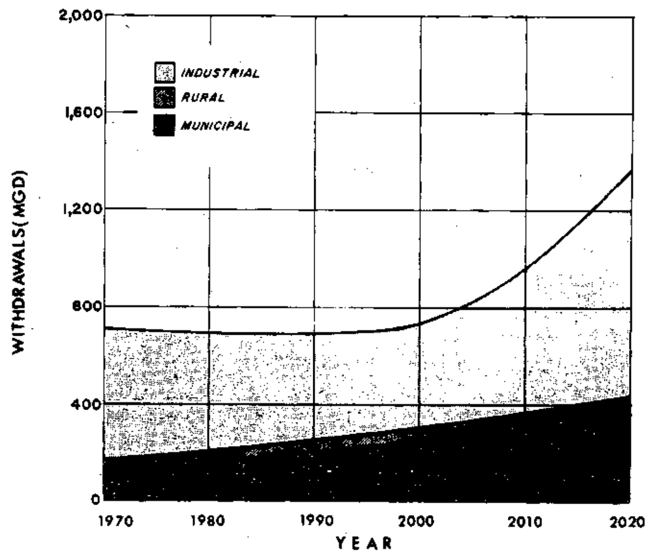


FIGURE 6-34 Municipal, Industrial, and Rural Water Withdrawal Requirements—Lake Huron Basin

In 1970 the population of the Lake Huron basin was more than 1.2 million, or 4 percent of the total in the Great Lakes Basin. The most populous regions are in the southern portion of the basin. Municipal water supplies served 765,800 people or 62 percent of the population in 1970. This is expected to increase to 1.8 million by 2020.

Production of feed grains, winter wheat, vegetable crops, and livestock are the main activities of the Saginaw basin. Only 20 percent of the northern basin is farmland, with main production centered around beef cattle, beets, and grain crops.

The Lake Huron basin supports an intense heavy industrial sector in Flint and Saginaw. Important manufacturing activities in the northern basin consist of production of cement and paper and related products.

TABLE 6–70 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Lake Huron Basin (mgd)

Use	1970				1980			
	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
3.1	7.0	25	6.8	8.8	8.8	22	9.3	40.1
3.2	125.6	515	32.5	673.1	159.6	469	38.3	666.9
Total	132.6	540	39.3	711.9	168.4	491	47.6	707.0
Consumption								
3.1	0.6	3	2.0	5.6	0.9	4	3.3	8.2
3.2	9.9	31	9.4	50.3	14.0	57	13.0	84.0
Total	10.5	34	11.4	55.9	14.9	61	16.3	92.2
1970 Capacity-Future Needs								
3.1	10.5	25	6.8	42.3	1.7	--	2.5	4.2
3.2	188.4	515	32.5	735.9	32.1	107	5.8	144.9
Total	198.9	540	39.3	778.2	33.8	107	8.3	149.1

Use	2000				2020			
	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
3.1	12.7	30	12.4	55.1	19.0	61	16.8	96.8
3.2	238.2	398	47.8	684.0	345.6	868	55.0	1268.6
Total	250.9	428	60.2	739.1	364.6	929	71.8	1365.4
Consumption								
3.1	1.4	10	4.0	15.4	2.0	15	6.3	23.3
3.2	26.9	232	17.7	276.6	43.2	648	23.0	714.2
Total	28.3	242	21.7	292.0	45.2	663	29.3	737.5
1970 Capacity-Future Needs								
3.1	5.9	5	5.6	16.5	12.6	36	10.0	58.6
3.2	115.4	349	15.3	479.7	232.4	825	22.5	1079.9
Total	121.3	354	20.9	496.2	245.0	861	32.5	1138.5

considered to be unlimited as a source of water supply for the time period of this study, and more than adequate to meet the water supply requirements projected for the municipal water-using sector of the Lake Huron basin and the Detroit Metropolitan regional water supply system. Needs do not exist in the availability of the water resource, but in the development and proper management of the water of Lake Huron.

Estimates of the costs to be incurred in developing, operating and maintaining municipal water supply facilities are shown in Table 6–71. Over the 50-year period of this study, it is estimated that $107 million will be required for capital investment in municipal water supply facilities and $210 million will be required for total OMR expenditures in the Lake Huron basin.

Lake Huron is suitable for domestic water

TABLE 6–71 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Lake Huron Basin (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
	Capital	8.641	22.215	31.335	30.856	62.192
Great Lakes	Annual OMR	.430	1.968	4.636	2.398	7.035
	Total OMR	4.306	39.365	92.737	43.671	136.409
	Capital	.762	2.053	2.940	2.816	5.757
Ground Water*	Annual OMR	.128	.601	1.440	.729	2.170
	Total OMR	1.281	12.029	28.817	13.310	42.127
Long Distance	Capital	5.000	14.500	19.500	19.500	39.000
Transport of	Annual OMR	0.000	0.660	0.660	0.660	1.320
Great Lakes	Total OMR	0.000	13.20	13.20	13.20	26.40
	Capital	14.399	38.755	53.760	53.156	106.914
Total	Annual OMR	0.575	3.308	6.917	3.881	10.799
	Total OMR	5.745	66.134	138.336	71.888	210.225

*Ground water unit cost assumptions are as follows:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells and pumping (see Figure 6-4)	35,600	44,700
total	155,600	52,300

supply in all periods to the year 2020. Although some problems may be experienced, the water quality standards program for these interstate waters demands that these waters be a suitable source of municipal water supply and includes plans and timetables for implementation.

5.1.5 Acknowledgments

Figures on average municipal water demands and population served are based on 1965 data from the Michigan Department of Public Health. The Michigan Department of Public Health had direct information about quantities of water supplied by municipalities to industry in 1965. For future years, quantities supplied to industry were assumed to vary in direct proportion to the quantities in domestic and commercial uses. This assumption is considered reasonable because of the character of the industries seeking water from municipal sources.

Data concerning industrial and rural water supplies were furnished by the Bureau of Domestic Commerce, U.S. Department of Commerce; and the Economic Research Service, U.S. Department of Agriculture, respectively.

5.2 Lake Huron North, Planning Subarea 3.1

5.2.1 Description of Planning Subarea

5.2.1.1 Location

Planning Subarea 3.1, composed of 11 counties located in the northeastern quarter of Michigan's Lower Peninsula, presents an abundance of natural resources for a variety of uses (Figure 6–35). The region is bounded by Lake Huron to the north and east, the Saginaw and Kawkawlin basins to the south, and the Muskegon, Manistee, and Traverse basins to the west. The planning subarea has a length of more than 70 miles from east to west and extends more than 110 miles from north to south.

5.2.1.2 Topography and Geography

The oldest bedrock formations in Planning Subarea 3.1 stretch across the northern one-third of the region. Formed during the Devonian era, they consist primarily of limestone. Outcrops occur in Alpena, Cheboygan, and Presque Isle Counties. A wide band of undifferentiated bedrock composed of gray-blue limestone and calcareous shale lies across Cheboygan and Presque Isle Counties. Shale formations outcrop in Alpena, Presque Isle, and Cheboygan Counties. The Michigan formation, composed of shales, sandstone, beds of gypsum, and some dolomitic limestone, outcrops in Iosco and Ogemaw Counties. Sandstones are common bedrock types in the southwest section. Glacial drift covers most of the area except where bedrock outcroppings occur.

Moraines, consisting of boulders, gravels, sand, silt, and clay, cover most of the region, except for lakebed formations of clay and sands which stretch from 5 to 20 miles inland along the lakeshore. Separating the moraines are areas of outwash plains and till plains consisting of sand and gravels.

Physiographically, the planning subarea is exemplified by rather flat to rolling terrain with elevations from 600 to almost 1,000 feet above sea level. In the northwestern portion, hilly, sandy morainal uplands predominate. Elevations range to 1,400 feet in this section. The northern high plains are generally characterized by ridges and plateau blocks with smooth crests of 1,200 to 1,400 feet; steep or broken slopes are also found in its morainal system. Mixed hills, plains, and swamps typify the Ogemaw-Alpena upland. Marshlands are common in Cheboygan, Presque Isle, Otsego, and Montmorency Counties. The Cheboygan lowland contains flat, lakebed benches and plains less than 200 feet above Lake Huron, partly stony land over limestone bedrock, and detached hills and ridges. Flat, sandy plains characterize the Midland-Arenac subdivision.

The drainage area includes the Cheboygan River basin, the Presque Isle complex, the Thunder Bay River basin, the Alcona complex, the Au Sable River basin, and the Rifle-Au Gres complex. The hydrologic area of the planning subarea is 8,137 square miles.

5.2.1.3 Climate

Planning Subarea 3.1 has a humid continental climate with frequent and sometimes rapid weather changes caused by storms sweeping across the Great Lakes Region from the west and southwest. Because of latitude differences, the northern extremities of the region experience cooler temperatures than the southern counties. Cool breezes from Lake Huron make the shoreline attractive for summer vacationists. Seasonal temperature variations can be extreme across the region. Mean annual precipitation ranges from 26 to 30 inches with an average of 28 inches. Precipitation is evenly distributed over the year, but with a slightly greater portion during the growing season. Droughts occur occasionally, but are not usually of long duration. Snowfall depths range from 50 to 120 inches, increasing from southeast to northwest across the planning subarea.

Mean annual growing seasons vary from nearly 130 days along the shoreline and in the southern counties to 90 days in the interior uplands. The minimum and maximum average temperature ranges for January and July are 10°F to 38°F and 52°F to 82°F, respectively.

5.2.2 Water Resources

5.2.2.1 Surface-Water Resources

Planning Subarea 3.1 has an abundant supply of surface-water resources. Although streams in the planning subarea are not generally long or steep in slope, they combine to drain more than 8,100 square miles. The Au Sable River drains the largest area and averages slightly more than 900 cfs near Mio in Oscoda County. The North Branch of the Thunder Bay River has a highly variable flow derived almost entirely from direct surface runoff. Approximately one-third of the total precipitation, averaging 11 inches annually, leaves as stream runoff.

Inland lakes are plentiful in the area. Surface area of inland lakes exceeds 134,650 acres. Cheboygan County alone contains more than 50,350 acres. Other counties with significant inland water-surface acreage include Presque Isle, 15,500; Alpena, 13,370; Alcona, 13,000; Montmorency, 12,100; and Iosco, 10,990. Arenac County contains the least surface-water acreage in inland lakes, 325 acres.

Fully developed water storage areas in the planning subarea's inland lakes and streams provide an existing storage capacity of 110,125 acre-feet. If all inland lakes and streams in Planning Subarea 3.1 suitable for develop-

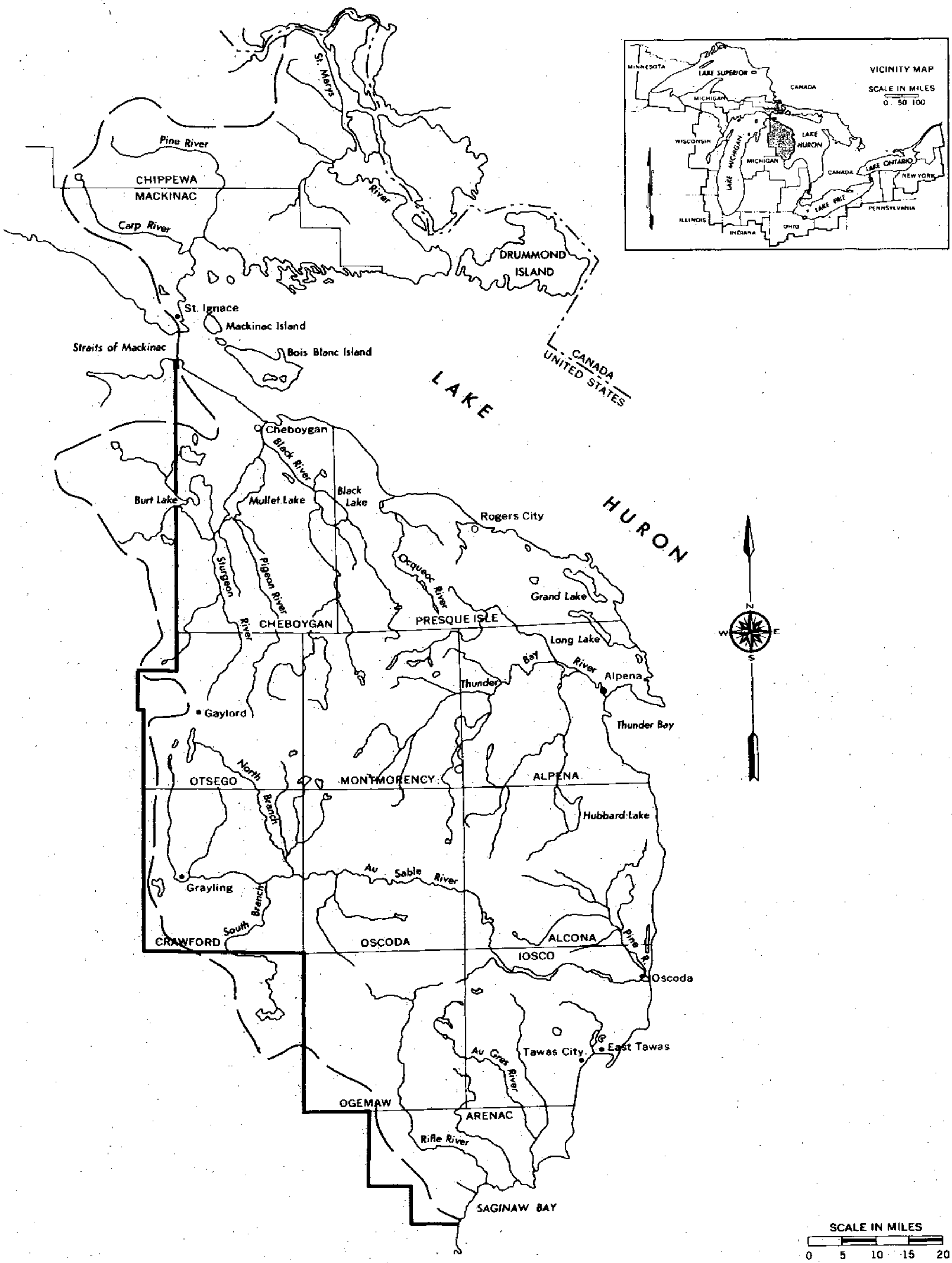


FIGURE 6–35 Planning Subarea 3.1

ment as surface-water impoundments were developed, the total potential storage capacity would increase to 116,125 acre-feet.[45]

Presently developed water storage areas can produce a sustained water supply yield of 3,141 mgd. If all potential water storage areas were fully developed in Planning Subarea 3.1, impounded inland lakes and streams could produce a sustained water supply yield of 3,490 mgd.[45]

Potential capacities and yields used in this section relate to the total water resource. No attempt has been made to identify that portion of the water resource not suitable or available for use.

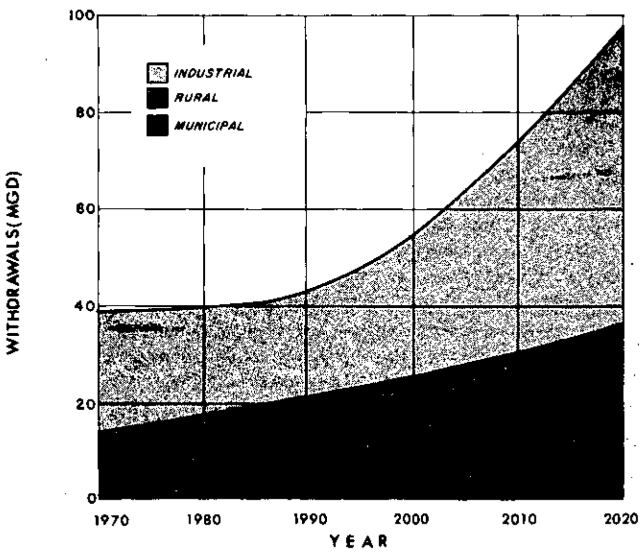


FIGURE 6-36 Municipal, Industrial, and Rural Water Withdrawal Requirements—Planning Subarea 3.1

Planning Subarea 3.1 is sparsely populated. The average population density is 17 people per square mile. Municipal water supplies served 57,800 people or 41 percent of the population in 1970. This is expected to reach 137,000 by 2020.

In 1964 slightly more than 20 percent of the region was devoted to farms. Farms are less frequent in the northern half of the planning subarea than in the southern half. Main farm production is in beef and dairy operations and meadow crops.

The area is not considered a major manufacturing area in the State, but it does play a role in the economy. Important manufacturing activities include production of cement, paper and paper products, and miscellaneous metal products.

5.2.2.2 Ground-Water Resources

Throughout the northern one-third of the planning subarea, wells in limestone bedrock strata yield from 10 to 100 gpm. Wells in shales, dominating most of the central portion, produce less than 10 gpm, and sandstone and limestone deposits underlying the southern sections yield from 100 to 500 gpm. Ground water from bedrock is of good chemical quality, except for a narrow region stretching along the Lake Huron shore from south of Presque Isle County. Wells in this area yield supplies generally too highly mineralized for domestic or public supplies.

Utilizing 70 percent flow duration data from Appendix 3, *Geology and Ground Water*, it is estimated that the potential maximum sustained yield of Planning Subarea 3.1 ground-water resources is 1,945 mgd.[21]

Most of the communities obtaining supplies from ground-water sources rely on glacial deposits. In general, water availability from glacial deposits increases inland from the Lake from less than 10 gpm to more than 500 gpm. Fine-grained sands, clays, and silts of the lake plains area often make the development of ground-water supply difficult. Thick glacial deposits composed largely of sands cover much of the western portion and wells typically produce over 500 gpm. Most water in the glacial deposits is hard, but of good chemical quality. However, in localized areas water is of very poor quality, especially in areas where the glacial deposits are directly underlain by bedrock containing highly mineralized water.

5.2.3 Water-User Profile

5.2.3.1 Municipal Water Users

In 1970 the resident population of Planning Subarea 3.1 was 140,200, an increase of 15 percent over the 1960 total. Alpena, Cheboygan, Iosco, and Presque Isle Counties had the highest population levels, while counties inland generally had populations of less than 9,000 people. According to the 1960 census, only Alpena, Cheboygan, Otsego, and Presque Isle Counties supported an urban population. This total reached more than 27,000, 23 percent of the total resident population. Population densities in 1960 were low, Alpena County having the highest with 51 people per square mile, and Oscoda County the lowest with six people per square mile. Average population density of the planning subarea was 17.2 people per square mile.

In addition to the thousands of vacationing tourists who come to the region, approximately 20,710 seasonal vacation homes are located in the region. The highest concentration of these homes is in counties adjacent to Lake Huron and in counties with large numbers of inland lakes. Iosco, Montmorency, Cheboygan, and Ogemaw Counties are among the counties with the highest levels of seasonal homes.

Municipal water supplies serve 57,800 people, 41 percent of the population of the planning subarea. The estimated annual average per capita income is $2,800 (1970$). The majority of the population is employed in trades and services (41 percent), developed largely to meet the demands of the tourist trade. By 2020 the population of this area is expected to be 266,959, of which 137,000 people will be served by municipal water supplies.

5.2.3.2 Industrial Water Users

In 1967 there were 290 manufacturing establishments in the planning subarea, and only 54 of those employed more than 20 people each. The manufacturing sector is composed mainly of small enterprises, the majority of which are engaged in lumber and wood products manufacture. Pulp and paper products are manufactured in Cheboygan and Alpena Counties, and primary metal products are manufactured in small and medium size plants in several locations in the planning subarea. Total manufacturing employment was 7,600 people in 1967 and the estimated value added by manufacture was $116 million in constant 1958 dollars. Both of these figures represent increases of approximately 50 percent over the year 1963.

5.2.3.3 Rural Water Users

In 1964 Planning Subarea 3.1 had 833,000 acres of land in farm. Meadow crops have the largest acreage of all crops. Specialty crops, which are heavy water users, are not significant in this area. Dairy farming, which is a heavy water user, is relatively important in the area with more than half of the receipts from livestock and livestock products coming from this source. Crop sales amounted to $6.5 million and livestock and livestock product sales $15.7 million in 1964. There were 19,000 people living on farms, and 3,000 people employed on farms according to the 1960 census.

5.2.4 Present and Projected Water Withdrawal Requirements

5.2.4.1 Municipal Water Use

Aside from providing a tremendous recreational resource, the planning subarea water resource also fills domestic, industrial, and agricultural water needs. Most communities receiving their water supply from municipal systems depend upon ground water as their source of supply. The communities of Alpena, Alabaster, and East Tawas depend upon Lake Huron for water supply. Water for residential uses dominates demands from municipal sources. Individual wells provide most of the population with an ample water supply.

Total water withdrawals are expected to increase from 39 mgd in 1970 to 97 mgd by 2020 (Figure 6–36 and Table 6–72). Municipal water withdrawals show the greatest increase. However, self-supplied industrial withdrawals at 61 mgd in 2020 remain the largest single quantity.

Municipal water supply data are shown in Table 6–73. Of the 23 central water systems operating in 1965, eight used water from Lake Michigan and 15 relied upon ground water. Six new water supply systems have been developed since 1965. At present, municipal water supplies serve 7.0 mgd to 41 percent of the population or 57,800 people in Planning Subarea 3.1. Projections indicate that this will increase to 137,000 people receiving 19.0 mgd by the year 2020.

5.2.4.2 Industrial Water Use

Total water withdrawals by all manufacturers averaged 25 mgd in 1970 and by the year 2020 are projected to reach 65 mgd. These are derived from estimates of annual requirements based on the projected employment and employee productivity information from Appendix 19, *Economic and Demographic Studies*. It was assumed that all plants would operate year-round on a six-day work week for derivation of the daily requirements (Table 6–74).

TABLE 6–72 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Planning Subarea 3.1 (mgd)

Use	1970 mun.	1970 ind.	1970 rural	1970 total	1980 mun.	1980 ind.	1980 rural	1980 total
Withdrawal Requirements								
Michigan	7.0	25	6.8	39	8.8	22	9.3	40
Total	7.0	25	6.8	39	8.8	22	9.3	40
Consumption								
Michigan	0.6	3	2.0	6	0.9	4	3.3	8
Total	0.6	3	2.0	6	0.9	4	3.3	8
1970 Capacity-Future Needs								
Michigan	10.5	25	6.8	42	1.7	--	2.5	4.2
Total	10.5	25	6.8	42	1.7	--	2.5	4.2

Use	2000 mun.	2000 ind.	2000 rural	2000 total	2020 mun.	2020 ind.	2020 rural	2020 total
Withdrawal Requirements								
Michigan	12.7	30	12.4	55	19.0	61	16.8	97
Total	12.7	30	12.4	55	19.0	61	16.8	97
Consumption								
Michigan	1.4	10	4.0	15	2.0	15	6.3	23
Total	1.4	10	4.0	15	2.0	15	6.3	23
1970 Capacity-Future Needs								
Michigan	5.9	5	5.6	17	12.6	36	10.0	59
Total	5.9	5	5.6	17	12.6	36	10.0	59

5.2.4.3 Rural Water Use

Rural water requirements and consumption were estimated for Planning Subarea 3.1 following the methodology outlined in Subsection 1.4. Table 6–75 divides total requirements and consumption into categories of rural nonfarm and rural farm. Rural farm is further divided into domestic, livestock, and spray water requirements.

5.2.5 Needs, Problems, and Solutions

5.2.5.1 Municipal

At present, developed municipal water supply facilities have a rated capacity of 10.5 mgd consisting of 5.0 mgd drawn from Lake Huron and 5.5 mgd withdrawn from ground-water resources. Needs were estimated according to

TABLE 6–73 Municipal Water Supply, Planning Subarea 3.1, Michigan (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Con-sumption
1970	GL	140.2	27.8	3.4	4.0	5.0	0.3
	GW		30.1	3.6	4.4	5.5	0.3
1980	GL	164.3	35.0	4.4	5.3	6.6	0.5
	GW		35.0	4.4	5.3	6.6	0.4
2000	GL	208.7	49.0	6.4	7.7	9.6	0.7
	GW		48.0	6.3	7.6	9.5	0.7
2020	GL	267.0	69.0	9.6	11.5	14.4	1.1
	GW		68.0	9.4	11.3	14.1	0.9

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Con-sumption	Municipally Supplied Industrial Water: Average Demand	Con-sumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
1970	GL	107.8	3.0	0.3	0.4	0.0	5.0
	GW		3.2	0.3	0.4	0.0	5.5
1980	GL	110.8	3.9	0.4	0.5	0.1	1.0
	GW		3.9	0.4	0.5	0.0	0.7
2000	GL	116.8	5.7	0.6	0.7	0.1	3.2
	GW		5.6	0.6	0.7	0.1	2.7
2020	GL	122.8	8.5	0.9	1.1	0.2	6.6
	GW		8.4	0.8	1.0	0.1	6.0

TABLE 6–74 Estimated Manufacturing Water Use, Planning Subarea 3.1 (mgd)

	1970	1980	2000	2020
Value Added (Millions 1958)	116	176	389	871
Gross Water Required	80	118	240	491
Total Water Withdrawal	25	23	31	63
Estimated Self-Supplied	25	22	30	61
Water Consumed	3	4	10	16

the methodology of this appendix and are shown in Table 6–72 for this planning subarea. It is estimated that only 1.7 mgd will be needed by 1980 as a result of additional growth. A total of 12.6 mgd will have to be developed in order to meet the needs by 2020. Estimates of the costs incurred in the development of water supply facilities are presented in Table 6–76.

TABLE 6–75 Rural Water Use Requirements and Consumption, Planning Subarea 3.1 (mgd)

	1970	1980	2000	2020
REQUIREMENTS				
Rural Farm				
Domestic	0.9	0.8	0.7	0.7
Livestock	1.2	2.4	2.7	4.9
Spray Water	0.0	0.0	0.0	0.0
Subtotal	2.1	3.3	3.4	5.6
Rural Nonfarm	4.7	6.1	9.0	11.2
Total	6.8	9.3	12.4	16.8
CONSUMPTION				
Rural Farm				
Domestic	0.2	0.2	0.2	0.2
Livestock	1.1	2.2	2.5	4.4
Spray Water	0.0	0.0	0.0	0.0
Subtotal	1.3	2.4	2.6	4.6
Rural Nonfarm	0.7	0.9	1.3	1.7
Total	2.0	3.3	4.0	6.3

TABLE 6-76 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Planning Subarea 3.1 (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
	Capital	.299	.657	1.016	.956	1.973
Great Lakes	Annual OMR	.014	.062	.146	.077	.223
	Total OMR	.149	1.251	2.920	1.400	4.321
	Capital	.109	.314	.518	.423	.942
Ground Water*	Annual OMR	.014	.072	.186	.087	.273
	Total OMR	.149	1.455	3.723	1.605	5.328
	Capital	0.409	0.972	1.535	1.381	2.915
Total	Annual OMR	0.030	0.136	0.332	0.165	0.498
	Total OMR	0.300	2.707	6.644	3.006	9.650

*Ground water unit cost assumptions are as follows:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells & pumping (See Figure 6-4)	37,000	35,200
total	157,000	42,800

5.2.5.2 Industrial

The quantity of water available for industrial use appears to be of sufficient quality and quantity for use during the period of the time under study. There are no needs projected for self-supplied industrial water users.

5.2.5.3 Rural

Future rural water requirements will be drawn primarily from ground-water sources, although in some areas streams will be increasingly important. The location and quality of ground water will be important in channeling additional development, particularly in the location of rural nonfarm dwellings. In areas where ground water is in short supply, development should proceed only after water supplies are located. Some areas will not develop until a central supply is available.

Rural water requirements are projected to increase 146 percent between 1970 and 2020, and consumption is expected to increase 212 percent.

Major ground-water problems are low yields in a large part of the planning subarea and the presence of highly mineralized water. Although quality is generally good, the water is often hard and high in iron content.

5.3 Lake Huron Central, Planning Subarea 3.2

5.3.1 Description of Planning Subarea

5.3.1.1 Location

Planning Subarea 3.2, comprising 11 counties, is located in the central and western portion of Michigan's Lower Peninsula (Figure 6-37). The region is bounded to the north and east by Lake Huron, to the south by the Shiawassee River basin, and to the west by the Cedar River, Tobacco River, Chippewa River, Pine River, and Bad River basins. The planning subarea is approximately 90 miles in width, and 120 miles in length from north to south.

5.3.1.2 Topography and Geography

Planning Subarea 3.2 lies within the Central Lowland physiographic province. Glaciation produced the present topography. The area is characterized by its hilly glacial moraines in the western and southern areas which contrast with the flat glacial lake plains in the east. Several hills reach altitudes of 1,300 feet, whereas the plains are 600 feet above sea level.

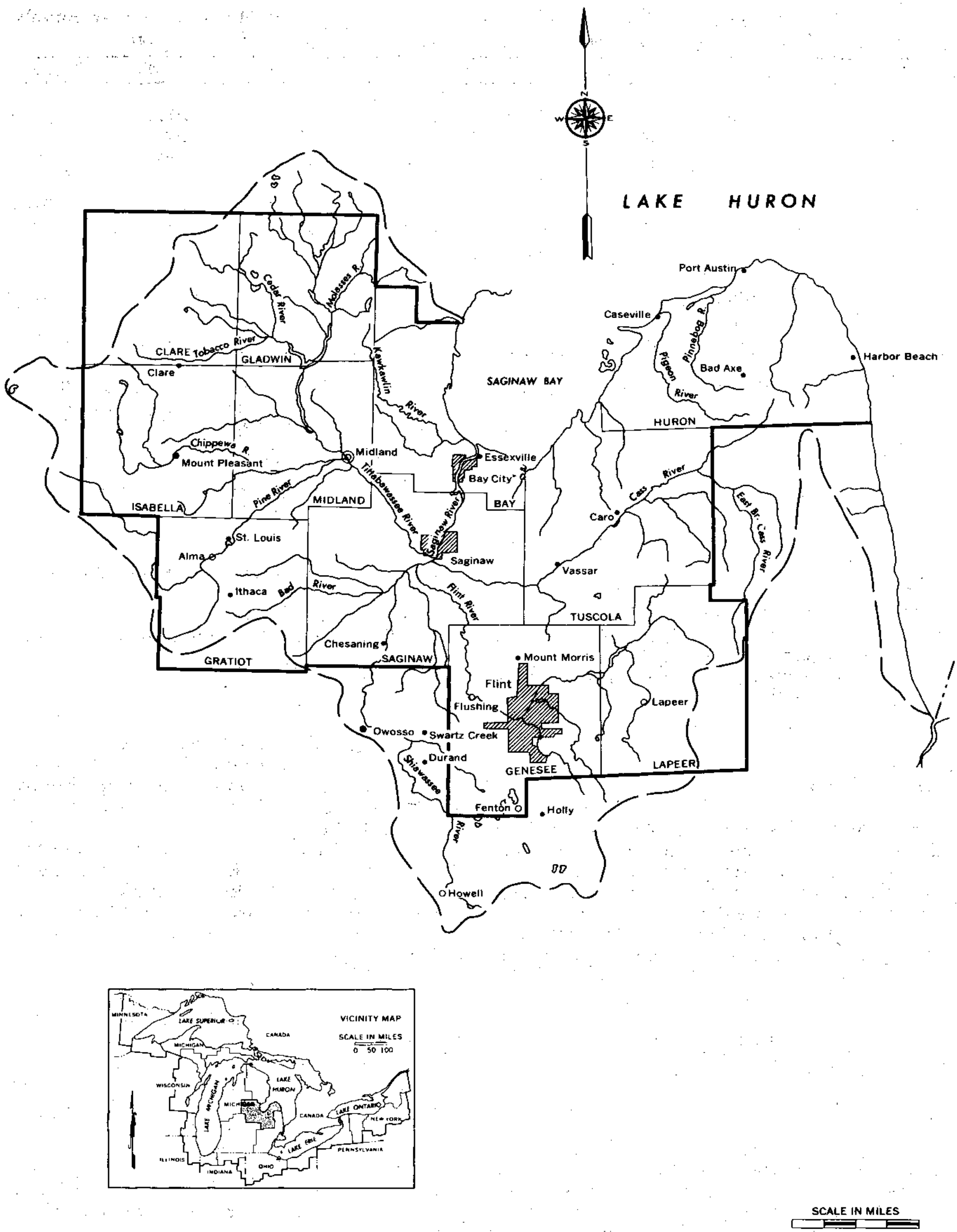


FIGURE 6–37 Planning Subarea 3.2

Most of the planning subarea is covered with thick glacial sediments, but in the eastern part, the glacial deposits are thin and bedrock is exposed in places. Glacial deposits 850 feet thick are reported in the hilly morainal northwestern area and are composed largely of silty and clayey sediments. Till plain, moraine, and outwash deposits are less common.

The bedrock underlying the planning subarea consists of Paleozoic sedimentary carbonates, shales, and sandstones which form the northeastern part of the Michigan structural basin. The older consolidated rocks form the northeastern rim of the structural basin, and the younger rocks lie in the middle. This type of bedrock has been important in the formation of major physiographic features. Where the bedrock directly underlying the glacial drift consists of relatively resistant carbonates and sandstones, erosion has formed escarpments and hilly topography. On the other hand, where shales are present, they have been easily eroded by various erosional processes and now underlie the lake bottoms and other low areas.

Major drainage basins of Planning Subarea 3.2 are the Saginaw, Tittabawassee, Flint, Shiawassee and Cass River basins. These river basins combine to form a drainage area of 8,046 square miles.

5.3.1.3 Climate

The Saginaw basin has a moderate climate, typical of the lower Great Lakes region. The climate is somewhat modified by the influence of the Lakes which nearly surround Michigan.

Mean annual temperature varies over the basin from 45°F to 47°F. Mean annual precipitation is slightly less than 30 inches. Average annual snowfall is 40 inches with the heaviest snowfall occurring in January. Growing season varies from 120 days in the north to 148 days in the south.

5.3.2 Water Resources

5.3.2.1 Surface-Water Resources

Although the City of Flint has developed the potential of the Flint River to a considerable degree, the surface waters of the Flint basin constitute a limited source of water supply. Smaller communities depend on ground water. This basin is relatively close to potable supplies in Lake Huron and Saginaw Bay. Rainfall is slightly heavier during the summer, but 60 percent of the runoff occurs during the first four months of the year. A similar rainfall-runoff pattern has been observed in the Tittabawassee and the Shiawassee basin.

Fully developed water storage areas in the planning subarea's inland lakes and streams provide an existing storage capacity of 36,220 acre-feet. If all inland lakes and streams suitable for development as surface-water impoundments were developed, the total potential storage capacity would increase to 984,450 acre-feet.[45]

Presently developed water storage areas can produce a sustained water supply yield of 247 mgd. If all potential water storage areas were fully developed in Planning Subarea 3.2, impounded inland lakes and streams could produce a sustained water supply yield of 2,123 mgd.[45]

Potential capacities and yields used in this section relate to the total water resource. No attempt has been made to identify that portion of the water resource not suitable or available for use.

5.3.2.2 Ground-Water Resources

Ground-water resources throughout the Saginaw basin vary in both quantity and quality. In the eastern lowland area of the Tittabawassee basin, fresh ground-water supplies are often difficult to obtain. Permeable beds of sand or gravel within the glacial drift are scarce, and saline or mineralized water occurs in the bedrock formations. In the western upland area it is easier to obtain satisfactory ground-water supplies because of the increased thickness of the glacial drift.

In the Flint basin water supplies from the Saginaw formation are generally brackish, but fresh water occurs locally. Bedrock channels filled with coarse material are widely scattered throughout the area and serve as good aquifers. Although the Davison area is a famous flowing well area, in the deployed moraines area salt is usually found below 200 feet. The Marshall sandstone of the interlobate area is a good aquifer. However, the shale of the southeast and northeast corners of Lapeer County is somewhat saline. All of the aquifers in the region have higher total dissolved solids than the 500 mg/l USPHS standard for drinking water supplies.

The quantity and quality of ground water in the Shiawassee basin varies because of the difference in thickness and composition of the glacial drift. The northern part is covered by a flat, poorly drained glacial lake plain consisting of dense clays and fine sands. In general, only small capacity wells are obtainable. Depth of rock wells varies, depending upon the thickness of glacial drift and permeability of the rock aquifer. The southern part of the basin is covered by moraines, till plains, outwash, and channel deposits offering fair to excellent possibilities for the development of domestic and municipal supplies. In this part of the basin water generally has better chemical quality, and salinity problems are not as numerous as in the northern portion.

Ground-water yield (based on 70 percent flow-duration data) in River Basin Group 3.2 is estimated to be 1,270 mgd.[21]

5.3.3 Water-User Profile

5.3.3.1 Municipal Water Users

There are three SMSAs in Planning Subarea 3.2: Flint, Saginaw, and Bay City. In 1970 the population was 1.1 million, and the population density averaged 134.6 people per square mile. The average per capita income is estimated to be $4,190 (1970$).

The economy of the region is focused on the intense heavy manufacturing areas of Flint and Saginaw. Most of the manufacturing activity is concentrated in the urban areas of Genesee, Saginaw, and Bay Counties. Midland County is the center of one of the largest chemical industries in the United States. For the most part population is centered in these four counties. Most of the other counties in the basin are dependent on resource-based activities, such as the prime croplands in the Thumb (Huron and Tuscola Counties) and in the central counties of Gratiot and Isabella.

In 1970 municipal water supplies served 708,000 people, which represented 65 percent of the population. The population is forecast to be 2.0 million by 2020, of which 1.7 million people should be served by municipal water supplies.

5.3.3.2 Industrial Water Users

Manufacturing is the major economic sector in Planning Subarea 3.2, providing nearly 42 percent of all employment in 1970 and producing goods whose value exceeded $7 billion. More than 1,000 manufacturing establishments are located in this eleven-county, east-central Michigan region along the shores of Saginaw Bay and Lake Huron. Most plants are small in terms of employment and production, but there are also very large establishments and industrial complexes engaged in the production of transportation equipment and parts, chemicals and allied products, machinery, primary metals, and fabricated metal products. Genesee, Saginaw, Bay and Midland Counties are important manufacturing centers which together provide 86 percent of the manufacturing employment and account for nearly 95 percent of the value added by manufacture in the planning subarea.

The growth and vigor of the region's manufacturing sector resulted in an increase of more than 23 percent in employment between 1963 and 1967 and an increase in value of product of more than 40 percent during the same period. Projections of manufacturing sector growth, provided by OBERS, suggest the expansion of industry group SIC 28, Chemicals and Allied Products, from an estimated constant 1958-dollar value added by manufacture of $600 million in 1970 to more than $11 billion in year 2020. This will have major significance for water resources planning because of the large self-supplied water withdrawals associated with these industries. Expanded output by the large undefined category of manufacturers signified as other manufacturing in Table 6–79 from an estimated $1.5 billion value added to $12.7 billion during the same period is equally important. This group includes the many small and large manufacturers who normally obtain water supply from municipal systems. It also includes large plants in the transportation industries with water demands that require large supplemental self-operated plant systems.

5.3.3.3 Rural Water Users

In 1964 Planning Subarea 3.2 contained 2.8 million acres of land in farm. This area contains very productive cropland with field beans, corn, wheat, oats, meadow, sugar beets, and soybeans forming the major crops of the area. There were more than 15,000 acres of commercial vegetables and 12,000 acres of potatoes, heavy water users, in the area in 1964. Dairy farming, also a heavy water user, grossed more than half the sales of livestock and livestock products in the area. Crop sales were valued at more than $104 million and livestock and livestock product sales at more than $81 million in 1964. There were 97,000 people living on farms and 17,000 people employed on farms according to the 1960 census.

5.3.4 Present and Projected Water Withdrawal Requirements

5.3.4.1 Municipal Water Use

Water withdrawals in Planning Subarea 3.2 totaled 673 mgd in 1970 (Figure 6–38 and Table 6–77). Total demand for water withdrawals will continue to rise, with central distribution systems providing an increasing share of the total water supply. Municipal withdrawals amounted to 18 percent of the total in 1970 and are expected to increase to 25 percent, 35 percent, and 27 percent of total withdrawals in 1980, 2000, and 2020, respectively.

One of the most important uses of Lake Huron water is for public water supply. Central distribution systems served a 1970 population of nearly 511,000 (46 percent of the population) with nearly 91 mgd from the Great Lakes. Municipal supplies using either ground-water or inland surface-water sources supplied 35 mgd to nearly 198,000 people in the area. Table 6–78 contains results of the munic-

TABLE 6–77 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Planning Subarea 3.2 (mgd)

	1970				1980			
Use	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
Michigan	125.6	515	32.5	673	159.6	469	38.3	667
Total	125.6	515	32.5	673	159.6	469	38.3	667
Consumption								
Michigan	9.9	31	9.4	50	14.0	57	13.0	84
Total	9.9	31	9.4	50	14.0	57	13.0	84
1970 Capacity Future Needs								
Michigan	188.4	515	32.5	737	32.1	107	5.8	145
Total	188.4	515	32.5	737	32.1	107	5.8	145

	2000				2020			
Use	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
Michigan	238.2	398	47.8	684	345.6	868	55.0	1269
Total	238.2	398	47.8	684	345.6	868	55.0	1269
Consumption								
Michigan	26.9	232	17.7	277	43.2	625	23.0	714
Total	26.9	236	17.7	277	43.2	625	23.0	714
1970 Capacity-Future Needs								
Michigan	115.4	349	15.3	480	232.4	825	23.5	1080
Total	115.4	349	15.3	480	232.4	825	23.5	1080

ipal water supply analysis pertaining to Planning Subarea 3.2.

By 2020 municipal water supplies are expected to serve 345.6 mgd to more than 1.6 million persons, accounting for 80 percent of the planning subarea's projected population.

Of the 99 central water systems operating in 1965, 33 obtained water from Great Lakes sources. Many of these systems were served by the large Saginaw-Midland system drawing from Lake Huron at White Stone Point at the head of Saginaw Bay, while some supplies use water from the main body of Lake Huron. Flint and Flushing purchased treated water from the Detroit system which uses the Detroit River as a source. Soon Detroit will be

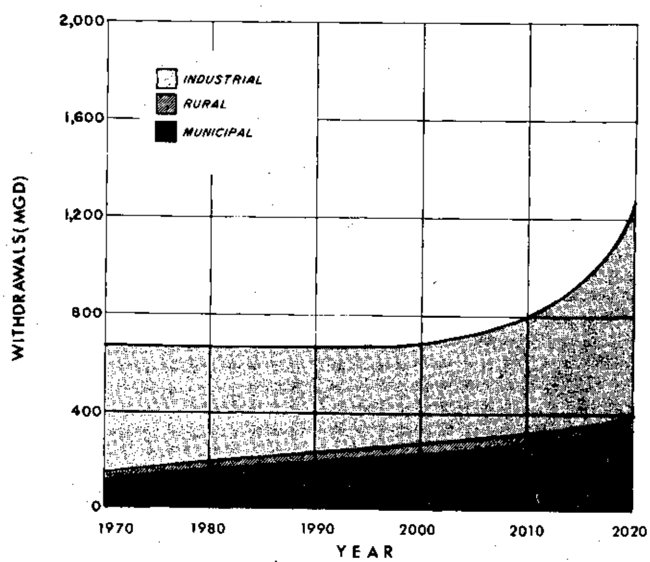


FIGURE 6–38 Municipal, Industrial, and Rural Water Withdrawal Requirements—Planning Subarea 3.2

Planning Subarea 3.2 is sparsely populated with 1.1 million people residing in the region in 1970. Municipal water supplies served 65 percent of the population or 708,000 people in 1970, and this is projected to be 1.66 million by the year 2020.

Production of feed grains, winter wheat, sugar beets, vegetable crops, and livestock are the main elements of agricultural industry in the Saginaw basin. Irrigation plays a minor role in the total water use in the planning subarea.

The economy of the region is focused on the intense heavy manufacturing activity in Flint and Saginaw, concentrated in the urban areas of Genesee, Saginaw, and Bay Counties. Most of the water used for industrial purposes is for processing and cooling.

drawing on Lake Huron north of Port Huron for a substantial amount of water. One of the municipal systems obtained its water from inland surface waters, 64 relied upon ground water, and one system tapped both inland surface- and ground-water sources. Ten new systems have been developed since 1965.

5.3.4.2 Industrial Water Use

Water use by manufacturers in Planning Subarea 3.2 is almost five times as great as the domestic and commercial use supplied by municipal systems. In 1970 manufacturers required an average 567 mgd, supplied from their own sources, in addition to the 52 mgd they obtained from public water supplies. A large portion of the self-supplied industrial water is accounted for by withdrawals of approximately 300 mgd from the Tittabawassee River by the chemicals industry complex at Midland, Michigan, and unknown quantities from Lake Huron. Other rivers and streams also serve as supply sources for manufacturers, as do company-owned wells. In general, well water supplies are not expected to be important as a source for new manufacturing supplies because of the limited yields of aquifers and the frequent occurrence of poor quality water.

Table 6–79 presents the base year estimates and projections of five water-use parameters and constant dollar estimates of value added by manufacture for five of the major water-using SIC two-digit industry groups and the residual other manufacturing group that comprise the sector. The value-added parameter is derived from OBERS projections and is included to serve as an indicator of the rates of growth of the industry groups. The water-use estimates represent the needs of all establishments without differentiation between small and large users. The large water-using plants (those withdrawing 20 million gallons per year or more) are relatively few in number, but the impact of their water use is huge. Less than 40 establishments in the region accounted for more than 95 percent of all industrial withdrawals.

In addition to the concentration of water use among relatively few plants, there is a concentration of water use by one SIC industry group. Water requirements of industries in SIC 28 dominate throughout the planning period (Table 6–79). Approximately 80 percent of water withdrawals for the SIC 28 group were used for cooling and condensing on a

TABLE 6–78 Municipal Water Supply, Planning Subarea 3.2, Michigan (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Con-sumption
1970	GL	1,103.2	510.5	90.6	108.7	135.8	7.2
	IS		7.8	1.4	1.7	2.1	0.1
	GW		189.7	33.6	40.4	50.5	2.7
1980	GL	1,246.8	637.6	119.5	143.4	179.3	10.5
	IS		5.0	1.0	1.1	1.4	0.1
	GW		209.0	39.1	46.9	58.7	3.4
2000	GL	1,600.5	942.3	186.3	223.5	279.4	20.9
	IS		7.0	1.4	1.7	2.1	0.2
	GW		256.0	50.5	60.6	75.7	5.7
2020	GL	2,057.	1,337.2	277.9	333.4	416.8	34.7
	IS		8.0	1.7	2.1	2.6	0.2
	GW		317.0	66.0	79.2	99.0	8.3

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Con-sumption	Municipally Supplied Industrial Water: Average Demand	Con-sumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
1970	GL	103.9	53.1	5.3	37.5	1.9	135.8
	IS		0.8	0.1	0.6	0.0	2.1
	GW		19.7	2.0	13.9	0.7	50.5
1980	GL	109.8	70.0	7.0	49.5	3.5	27.9
	IS		0.6	0.1	0.4	0.0	
	GW		22.9	2.3	16.2	1.1	4.2
2000	GL	115.8	109.2	10.9	77.1	10.1	100.0
	IS		0.8	0.1	0.6	0.1	
	GW		29.6	3.0	20.9	2.7	15.4
2020	GL	121.8	162.8	16.3	115.1	18.4	201.4
	IS		1.0	0.1	0.7	0.1	
	GW		38.7	3.9	27.3	4.4	31.0

TABLE 6–79 Estimated Manufacturing Water Use, Planning Subarea 3.2 (mgd)

	SIC 20	SIC 26	SIC 28	SIC 29	SIC 33	Other Mfg.	Total
1970							
Value Added							
(Millions 1958$)	97	10	602	34	137	1,508	2,388
Gross Water Required	11	5	534	118	55	91	815
Recirculation Ratio	1.84	3.39	1.21	3.02	2.03	1.75	--
Total Water Withdrawal	6.1	1.6	441	39.1	26.9	52.2	567
Self Supplied	--	--	--	--	--	--	515
Water Consumed	1.3	--	26.7	1.9	1.0	2.6	33.5
1980							
Value Added							
(Millions 1958$)	130	18	1,152	47	170	2,364	3,881
Gross Water Required	24	8	1,077	182	65	145	1,501
Recirculation Ratio	2.77	6.03	2.57	5.61	3.63	2.44	--
Total Water Wathdrawal	5.8	1.3	419	32.4	17.9	59.3	535
Self Supplied	--	--	--	--	--	--	469
Water Consumed	1.6	0.3	51.5	3.2	1.3	4.2	62.1
2000							
Value Added							
(Millions 1958$)	213	44	4,180	116	251	5,439	10,243
Gross Water Required	24	18	4,400	584	77	351	5,454
Recirculation Ratio	3.15	8.00	11.70	19.61	9.63	4.80	--
Total Water Withdrawal	7.7	2.2	376	29.8	8.0	73.1	497
Self Supplied	--	--	--	--	--	--	398
Water Consumed	2.2	0.6	220	10.6	1.6	9.6	245
2020							
Value Added							
(Millions 1958$)	358	97	11,253	282	319	12,670	24,979
Gross Water Required	39	36	11,855	1,349	89	834	14,202
Recirculation Ratio	3.50	8.00	15.00	23.92	12.00	5.86	--
Total Water Withdrawal	11.2	4.5	790	56.4	7.4	142.3	1,011
Self Supplied	--	--	--	--	--	--	868
Water Consumed	3.5	1.3	593	25.3	1.6	22.8	648

once-through basis in 1970. The average recirculation rate for all water used is estimated to have been 1.21. Dramatic reductions in withdrawal requirements can be achieved by the cooling and recirculation of cooling water to offset the demand for increases in withdrawals. In this study improvements are projected to occur following an interest rate curve to achieve an average rate of 11.7 by the year 2000, and 15.0 by 2020. Projections do not attempt to predict sudden and large changes, but deal instead with overall trends and effects.

Other manufacturing represents a large assortment of small and large industrial establishments in varied manufacturing activities, whose sum total growth in manufacturing output is forecast to exceed 800 percent between 1970 and 2020. The potential for improvement in water management in the many different manufacturing activities of this group is immensely varied. A close study of the group was not within the scope of this study, and the net changes in recirculation rates have been projected conservatively by extension of past trends. It is probable that greater improvement will be achieved.

SIC 29, Petroleum and Coal Products, and SIC 33, Primary Metals Products, are significant users of water at present, accounting for 39 mgd and 27 mgd withdrawals, respectively. SIC 29 is forecast to expand production by more than 800 percent during the planning period, with similar increases in gross water requirements. This industry group presently recirculates at an estimated rate of 3.0 which is projected to improve to 23.9 by year 2020, requiring that total withdrawals by the group increase to 56 mgd. For SIC 33 the projected growth rate is 230 percent, but because of improvements in recirculation and reuse of water, the withdrawals by the group are forecast to decline to 7.5 mgd by the year 2020.

Total manufacturing sector withdrawals, as a result of changing practices in water use, are projected in Table 6–79 to decline slightly to 500 mgd in the year 2000, after which the demand increases sharply, reaching 1,000 mgd in year 2020. The rapid increase in withdrawals is expected to occur as improvements in recirculation rates become less feasible as an alternative to meeting water requirements of the rapidly expanding sector.

5.3.4.3 Rural Water Use

Rural water requirements and consumption were estimated for Planning Subarea 3.2 following the methodology outlined in Subsection 1.4. Table 6–80 divides total requirements and consumption into categories of rural nonfarm and rural farm. Rural farm is further divided into domestic, livestock, and spray water requirements.

5.3.5 Needs, Problems, and Solutions

5.3.5.1 Municipal

At present developed municipal water supply facilities have a rated capacity of 188.4 mgd in Planning Subarea 3.2, including 135.8 mgd withdrawn from Lake Huron, 2.1 mgd withdrawn from inland lakes and streams, and 50.5 mgd withdrawn from ground-water sources. Needs are projected on the basis of a water-use coefficient and additional population growth, and are presented in Tables 6–77 and 6–78.

Development of 32.1 mgd of water supply facilities will be required to meet the projected needs by 1980. Of this total need 27.9 mgd is expected to be withdrawn from Lake Huron. By 2020 the need is projected to be 232.4 mgd, of which 201.4 mgd will be withdrawn from Lake Huron. The water supply from Lake Huron is considered unlimited and is more than adequate to meet the projected water supply needs.

TABLE 6–80 Rural Water Use Requirements and Consumption, Planning Subarea 3.2 (mgd)

	1970	1980	2000	2020
REQUIREMENTS				
Rural Farm				
Domestic	5.1	6.6	6.2	6.8
Livestock	5.3	8.7	13.1	18.1
Spray Water	0.1	0.1	0.1	0.1
Subtotal	10.5	15.3	19.5	25.0
Rural Nonfarm	22.1	23.0	28.3	30.0
Total	32.5	38.3	47.8	55.0
CONSUMPTION				
Rural Farm				
Domestic	1.3	1.6	1.6	1.7
Livestock	4.7	7.8	11.8	16.7
Spray Water	0.1	0.1	0.1	0.1
Subtotal	6.1	9.5	13.5	18.5
Rural Nonfarm	3.3	3.4	4.2	4.5
Total	9.4	13.0	17.7	23.0

Estimates of the costs incurred in the development of municipal water supply facilities are presented in Table 6–81.

The programmed construction of parts of a new pipeline paralleling an existing pipeline in this planning subarea necessitates an alternative computation method for estimating expenditures during the 1970 to 1980 period. The actual calculation was made to the year 2000 with a portion of the dollars assigned to the 1980 date. This was done to allow for the probable installation of portions of a larger pipeline that will not realize full capacity until completed.

5.3.5.2 Industrial

Although water must be supplied to meet the needs of new and expanded production facilities, the total withdrawal needs for manufacturing are not expected to increase until after the year 2000. If all new production were to occur at existing manufacturing plant locations, then it might be possible to supply the new water need with water conserved by recirculation without developing new sources. However, new production is most likely to occur at new plants as well as old, and new supplies will have to be developed even though total withdrawals do not increase. Knowledge of the probable locations of new manufacturing facilities would enable identification of the new industrial supply needs and problems.

Figure 6–39 illustrates the hypothetical change in water supply needs at old and new manufacturing locations. In preparing this set of curves, it was assumed that the first 100

TABLE 6–81 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Planning Subarea 3.2 (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
Great Lakes	Capital	8.342	21.557	30.318	29.900	60.218
	Annual OMR	.415	1.905	4.490	2.321	6.812
	Total OMR	4.157	38.114	89.817	42.271	132.088
Ground Water*	Capital	.647	1.727	2.405	2.374	4.780
	Annual OMR	.129	.605	1.433	.735	2.169
	Total OMR	1.297	12.112	28.675	13.410	42.085
Long Distance Transport of Great Lakes	Capital	5.000	14,500	19.500	19.500	39.000
	Annual OMR	0.000	0.660	0.660	0.660	1.320
	Total OMR	0.000	13.200	13.200	13.200	26.400
Total	Capital	13.990	37.783	52.225	51.775	103.999
	Annual OMR	0.545	3.172	6.585	3.716	10.301
	Total OMR	5.455	63.427	131.692	68.882	200.575

*Ground water unit cost assumptions are as follows:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells & pumping (see Figure 6-4)	34,200	54,200
Total	154,200	61,800

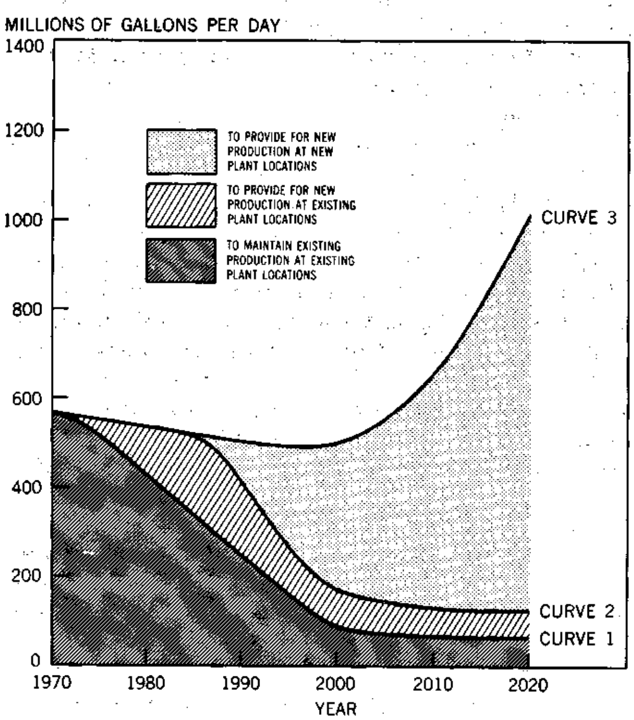


FIGURE 6–39 Total Withdrawal Demands for Manufacturing—Planning Subarea 3.2

percent increase in value added by manufacture would occur at existing plant locations, and that all further increases in production would occur at new locations. Curve 1 represents the demand to maintain existing production levels at existing plants. Curve 2 represents the demand to maintain existing production and to maintain the supply for the first 100 percent increase in production. Curve 3 represents the demand for all manufacturing production. The area between Curves 2 and 3 represents the withdrawal demand at new locations. Under these circumstances the new supply demand for manufacturing is estimated to be 135 mgd by 1980, 330 mgd by 2000, and 880 mgd by 2020.

5.3.5.3 Rural

Future rural water requirements will be drawn primarily from ground-water sources, although in some areas streams will be increasingly important. The location and quality of ground water will be important in channeling additional development, particularly in the location of rural nonfarm dwellings. In areas where ground water is in short supply, development should proceed only after water supplies are located. Some areas will not develop until a central supply is available.

Rural water requirements are projected to increase 69 percent between 1970 and 2020, and consumption is expected to increase 140 percent.

Ground-water supplies are generally sparse throughout the planning subarea, and there is a definite water quality problem. Saline water is often found at depths less than 100 feet. In general poor water can be expected in the central basin area. Development of large supplies of water in this area requires the use of Lake Huron water or water from inland streams and lakes.

Section 6

LAKE ERIE BASIN

6.1 Summary

6.1.1 The Study Area

The Lake Erie basin is located in the south-central portion of the Great Lakes, draining more than 21,460 square miles of United States land in Michigan, Ohio, Indiana, Pennsylvania, and New York (Figure 6–40). The basin extends from the south-central Michigan Thumb region near Port Huron, south through Ohio, and east along Lake Erie through Pennsylvania to a point near Niagara Falls in northwestern New York State. Following the axis of the Lake, the basin, lying within the United States and Canada, is approximately 400 miles long and 200 miles wide at its widest point in the western section. The study area is divided into four planning subareas, described as Lake Erie Northwest, Planning Subarea 4.1; Lake Erie Southwest, Planning Subarea 4.2; Lake Erie Central, Planning Subarea 4.3; and Lake Erie East, Planning Subarea 4.4.

6.1.2 Economic and Demographic Characteristics

On a hydrologic basis, the Lake Erie basin is the most populous of the five Great Lakes basins, with a 1960 population estimated at 9.8 million. In contrast the Lake Erie plan area (county boundaries) in 1970 had a total resident population of 11.4 million. Population distribution analysis reveals the major concentration of people in Wayne County in Michigan, Cuyahoga County in Ohio, and Erie County in New York. The resident population of the Lake Erie basin is expected to increase by 86 percent by the year 2020 to 21.2 million.

The U.S. Bureau of Census has designated 10 Standard Metropolitan Statistical Areas within the Lake Erie basin. The urbanized areas of the SMSAs comprise approximately 10 percent of the total land area of the basin. Approximately 80 percent of the basin population in 1960 lived in these areas. The Lake Erie region has been one of the fastest growing regions in the Great Lakes.

The Lake Erie basin is characterized by a diversified economy which relies upon light and heavy industry, manufacturing, agriculture, and tourism and recreation for support. Industrial activity is concentrated in the highly populated metropolitan areas located near the lakeshore. The chief products are automobiles, fabricated metal, primary metals, rubber, food, petroleum, chemicals, and paper. Total value added by manufacture in the region is estimated at more than $17 billion annually.

Despite a trend of decreasing acreage of actual agricultural production, agricultural sales in the Lake Erie basin reached $733 million in 1964. Agricultural production in the western portion of the basin is characterized by dairy products, vegetables, fruits, and field crops, as well as livestock and livestock products. The central and eastern sections are smaller in area with higher urban concentrations and generate nursery and greenhouse products, vegetables, and specialty crops such as grapes, pears, and sweet cherries.

Tourism and recreation add hundreds of millions of dollars to the basin's economy each year. The largest enterprises are in Sandusky, Ohio, and Erie, Pennsylvania.

The Lake Erie island area resort towns along the Lake combined with State and regional parks add to the attraction of the region. One of the most serious detriments to recreational growth is degraded environmental conditions in the basin water and land resource systems.

The availability of the Lakes and the St. Lawrence Seaway for waterborne commerce makes the Lake Erie basin a major distribution center for both raw materials and finished products. The basin has 11 major U.S. ports: Detroit, Toledo, Sandusky, Huron, Lorain, Cleveland, Fairport, Ashtabula, Conneaut, Erie, and Buffalo. Coal and iron ore are the largest volume commodities, but foreign package trade is also large in tonnage. Lake

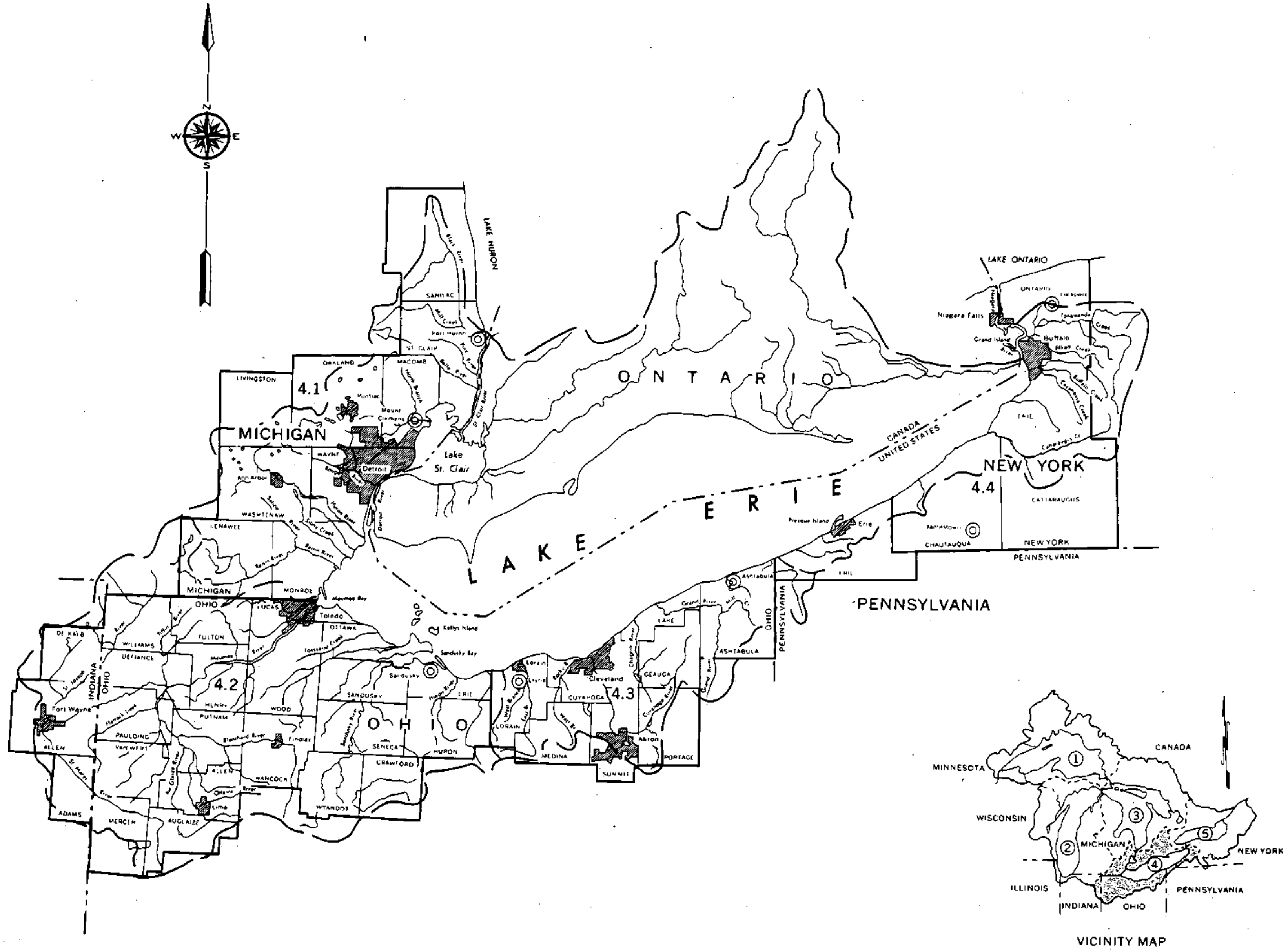


FIGURE 6-40 Lake Erie Basin

Erie accounts for 13 percent of the annual ton-miles of shipping out of a total of more than 100 billion on the Great Lakes. In 1968 total traffic on Lake Erie reached 143.2 million tons, the highest of any Lake or connecting channel in the Great Lakes system.

In 1960 approximately 3.8 million persons (39 percent of the population) found employment in agriculture, forestry, fisheries, mining, manufacturing, trades and services, and other occupations in the Lake Erie region. Manufacturing, trade, and services are the major employers in the region.

Total personal income generated in the region in 1962 exceeded $26.2 billion, 39 percent of the total in the Great Lakes Region. Per capita income levels have been higher than the rest of the nation. Planning Subarea 4.1 (the Detroit area) and Planning Subarea 4.3 (the Cleveland area) have led the Lake Erie region with per capita incomes of $4,653 and $4,612, respectively. In terms of 1970 dollars the average per capita income for the Lake Erie basin was $4,432 in 1970.

6.1.3 Water Resources

The availability and quality of surface and subsurface water resources in the basin is a reflection of natural and man-made factors bearing upon those resources. Approximately one-third of the water that falls as precipitation in the basin runs off annually. Glacial and bedrock features control the drainage patterns of streams in the Lake Erie basin. Drainage is irregular and deflected in the western portion of the basin by morainal features. Streams in the east are short and flow directly to Lake Erie as they drain from the Niagara and Portage Escarpments.

With the exception of Planning Subarea 4.1 in the western portion, there are few inland lakes and ponds in the Lake Erie basin. Artificial impoundments, particularly in Ohio, are found frequently throughout the basin. A 1966 inventory listed 1,473 inland lakes and artificial impoundments with 89,650 acres of surface-water area in the Lake Erie basin. The estimated total surface area of rivers and embayments in the Lake Erie basin is 197,600 acres.

Lakes St. Clair and Erie are major water resources in the basin. Lake St. Clair is a very shallow lake with a total surface area of 430 square miles (162 square miles in the U.S.) and a volume at low water datum of 1 cubic mile. Lake Erie is the fourth in the chain of five Great Lakes, and has become infamous for its advanced eutrophic condition. Lake Erie is the shallowest and has the least volume of the five Great Lakes. There are two diversions of water out of Lake Erie, the Welland Canal (7,000 cfs average) and the New York State Barge Canal (700 cfs average). The Niagara River, Lake Erie's natural outlet, discharges an average of 202,000 cfs from Lake Erie.

Basin streams and lakes reflect poor natural drainage conditions, high dissolved solid concentrations, and low quality water in most stream reaches due to municipal, industrial, and agricultural waste disposal practices. Lake Erie has phosphorous concentrations six times higher than that contained in the other Lakes. Low dissolved oxygen concentrations and high algae growths are characteristic of most surface-water resources in the Lake Erie basin. Taste and odor irregularities, due to excessive algal concentrations in the surface water, are a problem for Toledo and Cleveland in the western basin of Lake Erie.

The Lake Erie basin has the least overall ground-water potential of the Great Lakes basins. Glacial drift provides excellent aquifers in selected areas of Michigan, New York, and Ohio. Carbonate aquifers are plentiful in western Ohio and northern New York areas. Areas of limited ground-water potential are found in the lake plains along the southern shore of Lake Erie east of Sandusky and in the upland areas of Pennsylvania and New York. Here, conjunctive use of surface water and ground water is a necessity to provide adequate water. The total estimated ground-water potential of the Lake Erie basin is 1,945 mgd.

Chemical quality of the ground water has been a limiting factor in ground-water development in the Lake Erie basin. However, most poor quality water can be treated to improve its quality, so the use of ground water becomes an economic factor. Water from the surficial sand and gravel aquifers is good to fair in quality. Iron is usually present and the water can be hard and contain appreciable dissolved solids. Bedrock aquifers consistently yield hard to very hard water with dissolved solids often over the recommended limit of 1,000 mg/l. Salt water is usually a local problem, but overall salinity tends to increase with depth. Iron and sulfate contents may be relatively high in localized areas and increase treatment costs.

6.1.4 Present and Projected Water Withdrawal Requirements

In 1970 the Lake Erie basin total water withdrawals, 5,769 mgd, accounted for 37 percent of the withdrawals for the entire Great Lakes Basin. A summary of present and projected water withdrawal requirements and needs for the municipal, industrial, and rural water-using sectors is presented in Table 6-82 and Figure 6-41.

The waters of Lake Huron, Lake Erie, and

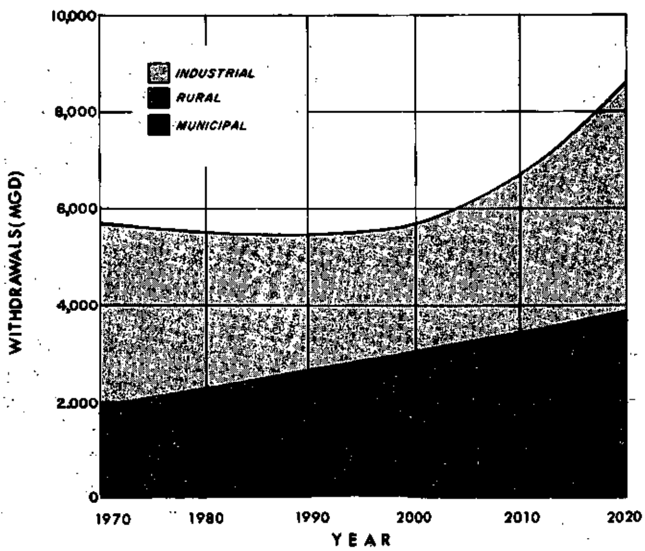


FIGURE 6-41 Municipal, Industrial, and Rural Water Withdrawal Requirements—Lake Erie Basin

The 1970 population of the Lake Erie basin, the most populous in the Great Lakes Basin, was 11.6 million people. The major concentration of people is along the southern shore of Lake Erie. Municipal water supplies served 10.0 million people or 86 percent of the total basin population in 1970. This is projected to be 19.6 million by 2020.

Agricultural production in the western portion of the basin is characterized by dairy products, vegetables, fruits, field crops, livestock and livestock products. The central and eastern regions produce vegetables, nursery products, and specialty crops.

Industrial activity is concentrated in the highly populated urban areas near the lakeshore, since it relies on an abundant water supply and waterborne commerce. Chief manufacturing activities are automobile, primary metals, rubber, food, petroleum, chemical, and paper production.

connecting channels are expected to provide approximately 85 percent, or 3,197 mgd, of the municipal water supply requirements projected to the year 2020, totaling 3,762 mgd. Inland lakes and streams and ground-water resources are expected to supply 11 percent and 4 percent, respectively, of the municipal water supply requirements by 2020. As discussed in a previous section, the waters of Lake Huron will provide most of the municipal water supply requirements in Planning Subarea 4.1 through the Detroit Metropolitan Water Department regional supply system. By 2020 the system is expected to supply through interbasin transfer almost 1,100 mgd or 30 percent of the total Lake Erie basin municipal requirement.[13]

The water supply available from Lake Erie is considered unlimited for the time period of this study and is more than adequate for the water-use requirements projected for the municipal water-using sector of the basin. Needs in the availability of the water resource do not exist in the Lake Erie basin, but rather in the development of water supplies and proper management of the water quality of the Lake.

Estimates of the costs incurred in developing, operating, and maintaining municipal water supply facilities are shown in Table 6-83. During the 50-year period of this study it is estimated that $972 million will be required for capital investment in municipal water supply facilities and that $1,572 million will be required for total OMR expenditures in the Lake Erie basin.

Lake Erie is suitable for domestic water supply in all periods to the year 2020. Although some problems may be experienced, the water quality standards program for these interstate waters calls for making these waters suitable for municipal water supply. The program includes plans for implementation and timetables for making this possible.

6.1.5 Acknowledgments

Municipal water supply data came from the Ohio Department of Health files as supplied by local community officials for Planning Subareas 4.2 and 4.3.[50] Figures on average municipal water demands and population served are based on 1965 data from the Michigan Department of Public Health for Planning Subarea 4.1.[29] Water supply data for the base year (1970) was obtained from draft reports prepared by contract consultants for each New York county in Planning Subarea 4.4.

TABLE 6–82 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Lake Erie Basin (mgd)

Use	1970				1980			
	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
4.1	738.9	1297	49.4	2085.3	891.7	900	54.2	1845.9
4.2	185.9	318	42.4	546.3	236.6	347	51.1	634.7
4.3	516.9	1306	24.7	1847.6	610.2	1171	26.3	1807.5
4.4	327.2	946	16.6	1289.8	365.9	854	16.4	1236.3
Total	1768.9	3867	133.1	5769.0	2104.4	3272	148.0	5524.4
Consumption								
4.1	60.8	135.0	11.9	207.7	79.6	173.7	13.5	266.8
4.2	18.5	36.0	15.3	69.8	25.5	60.0	21.0	106.5
4.3	52.0	85.3	5.8	143.1	82.0	117.1	5.9	205.0
4.4	30.0	82.0	6.4	118.4	34.8	115.0	7.1	156.9
Total	161.3	338.3	39.4	539.0	221.9	465.8	47.5	735.2
1970 Capacity-Future Needs								
4.1	1295.0	1297	49.4	2641.4	165.3	30.8	4.8	200.9
4.2	441.7	318	42.4	802.1	23.4	58.0	8.7	90.1
4.3	800.7	1306	24.7	2131.4	79.5	153.0	1.6	234.1
4.4	490.8	946	16.6	1453.4	39.1	114.0	---	153.1
Total	3028.2	3867	133.1	7028.3	307.3	355.8	15.1	678.2

Use	2000				2020			
	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
4.1	1236.0	589	63.3	1888.3	1710.0	1092	67.7	2869.7
4.2	335.4	333	64.1	732.5	454.5	594	76.3	1124.8
4.3	800.3	1103	31.0	1934.3	1037.0	1946	33.4	3016.4
4.4	453.6	670	23.5	1147.1	560.9	1010	31.6	1602.5
Total	2825.3	2695	181.9	5702.2	3762.4	4642	209.0	8613.4
Consumption								
4.1	136.6	372.7	15.6	524.9	207.8	744	17.3	969.1
4.2	42.5	140.0	28.4	210.9	62.5	312	37.4	411.9
4.3	101.0	338.1	6.9	446.0	140.1	781	7.9	929.0
4.4	48.2	232.0	8.8	289.0	58.9	475	10.9	544.8
Total	328.3	1082.8	59.7	1470.8	469.3	2312	73.5	2854.8
1970 Capacity-Future Needs								
4.1	553.4	401	13.9	968.3	1094.0	923	18.3	2035.3
4.2	116.2	238	21.7	375.9	260.8	523	33.9	817.7
4.3	247.7	836	6.3	1090.0	494.8	1730	8.7	2233.5
4.4	137.7	454	6.9	598.6	260.0	849	15.0	1124.0
Total	1055.0	1929	48.8	3032.8	2109.6	4025	75.9	6210.5

TABLE 6-83 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Lake Erie Basin (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
Great Lakes	Capital	89.102	202.034	267.754	291.136	558.890
	Annual OMR	4.440	18.948	42.359	23.388	65.747
	Total OMR	44.402	378.966	847.184	423.368	1270.552
Inland Lakes and Streams	Capital	.657	16.923	41.022	17.581	58.604
	Annual OMR	.032	.908	3.796	.941	4.738
	Total OMR	.327	18.178	75.930	18.505	94.436
Ground Water*	Capital	1.278	2.748	3.528	4.027	7.555
	Annual OMR	.095	.396	.865	.492	1.357
	Total OMR	.955	7.931	17.312	8.886	26.199
Long Distance Transport of Great Lakes	Capital	164.500	88.000	95.000	252.500	347.500
	Annual OMR	5.600	3.000	3.200	8.600	11.800
	Total OMR	56.000	60.000	64.000	116.000	180.000
Total	Capital	255.541	309.702	407.298	565.242	972.539
	Annual OMR	10.168	23.259	50.240	33.426	83.667
	Total OMR	101.430	465.167	1004.806	566.844	1571.657

*Ground water unit cost assumptions are as follows:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells & pumping (see Figure 6-4)	27,000	14,367
total	147,000	21,967

Data concerning industrial water supplies were furnished by the Bureau of Domestic Commerce, U.S. Department of Commerce. The Economic Research Service, U.S. Department of Agriculture, provided data on rural water supplies.

6.2 Lake Erie Northwest, Planning Subarea 4.1

6.2.1 Description of Planning Subarea

6.2.1.1 Location

Planning Subarea 4.1 is composed of nine counties located in the central portion of the Great Lakes Basin in the southeastern corner of Michigan's Lower Peninsula (Figure 6-42). The region is bounded to the north by the Saginaw River basin and small tributaries to Lake Huron, to the west by the Grand River basin, and to the south by the Maumee River basin and the Ohio State line. To the east, the region lies at the edge of Lake St. Clair, the St. Clair River, the Detroit River, and Lake Erie. The total drainage area is 145 miles long with an average width of 40 miles.

6.2.1.2 Topography and Geography

In the western half or upstream portions of the major tributaries, a moderately rolling to rugged terrain is interspersed locally with relatively flat areas. Elevations generally range from 800 to 1,000 feet, with areas in Oakland, Washtenaw, and Lenawee Counties at elevations exceeding 1,000 feet above sea level. Numerous inland lakes, interconnected by marshy lands and small streams, are found in the area. The lower lake bed portion of the region is predominantly level, generally without any naturally formed lakes, and is marked by a series of fragmentary ancestral lake beach ridges. Elevations in the lake bed area

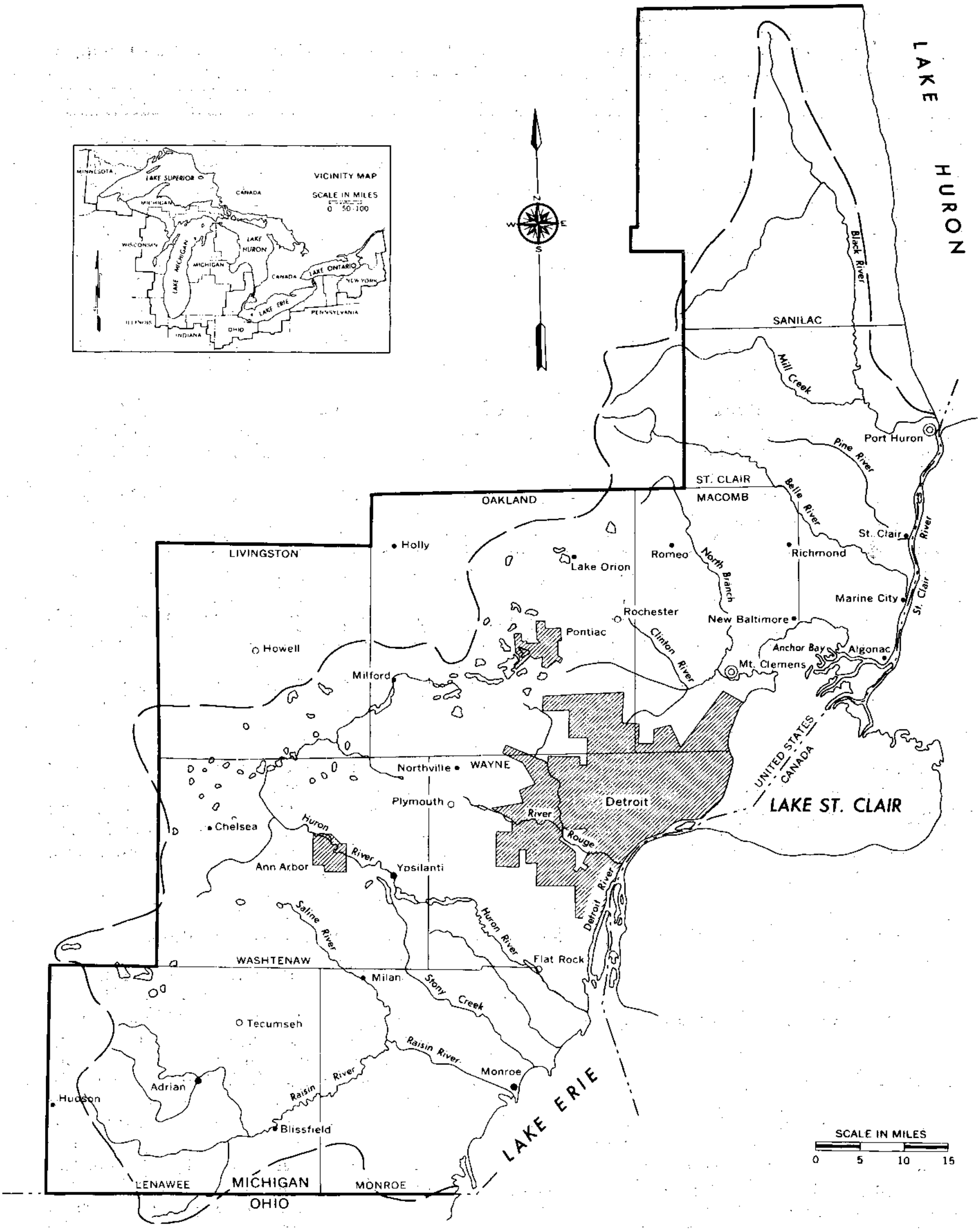


FIGURE 6–42 Planning Subarea 4.1

increase from less than 600 feet near the Lakes Erie-Huron shores to nearly 800 feet inland.

Limestone, sandstone, and shale deposits dominate subsurface formations in the western portion of the region, while shale and limestone become more prevalent in Macomb, Wayne, southern Washtenaw, and northern Lenawee Counties. Dolomite and sandstone dominate subsurface formations in Monroe County. The surface geology of southeastern Michigan is the result of deposition of border moraines from the Lakes Erie-Huron lobe and the Saginaw lobe during the Wisconsin glacial period, and from the ponding of glacial melt waters. A mixture of sand, silt, clay, and glacial drift characterize the rolling land in the western half of the area. Predominant formations are moraines of clay, sand, and gravel; outwash plains, primarily of sand, gravel, and clay; and till plains or ground moraines of interbedded sands and gravel. Depths vary, but glacial drift averages 100 to 300 feet in thickness in the region.

In the eastern half the level land is a former lake plain consisting of water-worked glacial drift. The region is characterized by former glacial-lake bottoms, beaches, and level stretches along the shoreline of Lake Huron, the St. Clair River, Lake St. Clair, the Detroit River, and the western edge of Lake Erie. These shorelines are mainly composed of clay, silt, and sand, with waterlaid moraines of clay, or clay with sand, gravel, and boulders. Glacial drift is very thin in Monroe County, where there are numerous bedrock outcrops, but it becomes thicker to the north and west, reaching 250 and 300 feet at many points in the area.

Planning Subarea 4.1 has a total drainage area of 5,205 square miles. It includes seven major drainage systems: the Black River, Pine River, Belle River, Clinton River, River Rouge, Huron River, and Raisin River. These principal tributaries drain the region and flow in a southeasterly direction, averaging from 30 to 50 miles in length, and fall approximately 400 feet from the headwaters to their outlets.

6.2.1.3 Climate

Planning Subarea 4.1 has a humid continental climate and lies in the pathway of storms that sweep across the Great Lakes area from the west and southwest. Although the climate is moderated by the stabilizing influence of the Great Lakes, it is characterized by frequent and sometimes rapid weather changes. These are caused by the passage of such storms, by extreme seasonal temperature variation, and a fairly even annual distribution of precipitation. Average yearly temperatures vary from 47°F at Port Huron to 50°F at Monroe, with extremes ranging from 108°F in the summer to −26°F in the winter. Averaging 31 inches annually, precipitation is usually ample for the growth and development of vegetation. Sixty percent of the precipitation usually falls during the six-month period from April through September. Total annual snowfall averages vary from 42 inches at Port Huron to 29 inches at Monroe. Depths generally increase with distance from the lakes and with increasing latitude. The growing season averages 180 days in Detroit, but it is three weeks shorter in the northern portions of the area.

6.2.2 Water Resources

6.2.2.1 Surface-Water Resources

Drainage patterns of the streams in the planning subarea reflect topographic glacial features. Glacial moraines predominantly control drainage in the western half of the basin. After leaving the peripheral morained areas, the streams traverse irregular till plains, are deflected by intermediate moraines, and enter upon the level glacial lake bed. Average stream discharges do not exceed 700 cfs. The average annual runoff is 10 inches per year in this area.

The natural and artificial lakes in southeastern Michigan constitute one of the region's major water resource assets. Most of the 3,651 inland lakes are located in the morainic hills and outwash which comprise the western half of the region. Oakland County leads the region with 1,534 lakes with a total surface area of 22,669 acres. A little more than 1,000 miles of inland lake shoreline are found in this area, 90 percent of which is in private ownership.

Area streams and lakes have poor natural drainage conditions, high dissolved solid concentrations, and low quality water in most stream reaches due to municipal, industrial, and agricultural waste disposal practices.

Fully developed water storage areas in the planning subarea's inland lakes and streams provide an existing storage capacity of 12,000 acre-feet. If all inland lakes and streams in Planning Subarea 4.1 considered suitable for development as surface-water impoundments were developed, the total potential storage capacity would increase to 971,235 acre-feet.[45]

Presently developed water storage areas can produce a sustained water supply yield of 212 mgd. If all potential water storage areas were fully developed in Planning Subarea 4.1, impounded inland lakes and streams could produce a sustained water supply yield of 1,167 mgd.[45]

Potential capacities and yields in this section relate to the total water resource. No attempt has been made to identify that portion of the water resource suitable or available for use.

6.2.2.2 Ground-Water Resources

Ground-water resources are poor to moderate as one travels from east to west over the basin. In general, bedrock formations underlying the large lake plain area consist of shales, sandstones, and limestones from which little water can be obtained. Water obtained from bedrock sources usually has a high mineral content and is unsuitable for ordinary use. Sandstone formations produce moderate yields in parts of Washtenaw, Livingston, and Sanilac Counties.

Most water for domestic supplies comes from glacial deposits. These deposits are thinnest on the lake plain and thicken to the west and northwest. The large lake plain area, composed mainly of lake clay, is unfavorable for the development of large ground-water supplies. In the western and northwestern portion of the region where outwash deposits are thick, wells will yield more than 500 gpm. Generally water from glacial deposits is hard, but of good chemical quality. Objectionable amounts of mineralization occur locally where glacial deposits directly overlie bedrock containing highly mineralized water.

Ground-water yield in River Basin Group 4.1 is estimated to be 600 mgd (based on 70 percent flow-duration data).[21]

6.2.3 Water-User Profile

6.2.3.1 Municipal Water Users

In 1970, approximately 56 percent of Michigan's total population resided in Planning Subarea 4.1. Of the nearly five million people in the planning subarea, approximately 87 percent obtained their water supply through central distribution systems. Since 1960 the area population total has increased 17 percent, with urban expansion accounting for most of the increase. Wayne County contains more than 2.8 million people with a population density of nearly 4,700 persons per square mile (the highest density in Michigan). Urban expansion continues to spread in all directions from the Detroit urban center. By 2020 the population of Planning Subarea 4.1 is expected to double to 9.5 million people. It is expected that 8.9 million people, 91 percent of the population, will be served by municipal water supplies in 2020. Average annual per capita income in the southeastern Michigan area is estimated at approximately $4,700 per year (1970$). Manufacturing activities in the planning subarea account for the employment of 39 percent of the resident working population.

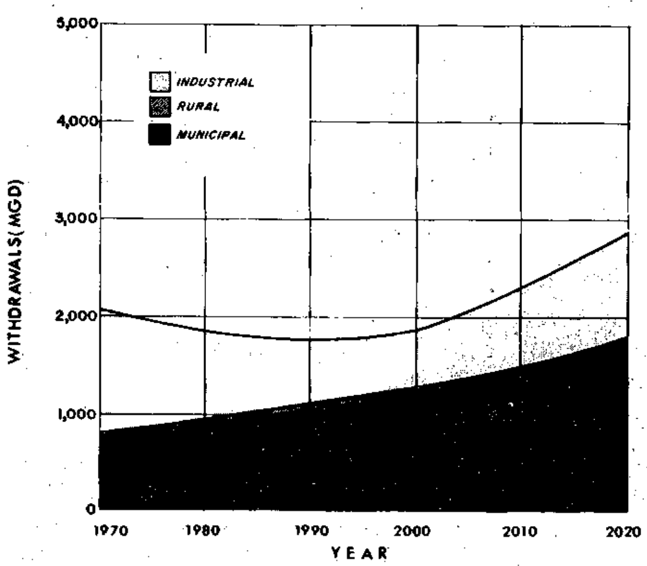


FIGURE 6–43 Municipal, Industrial, and Rural Water Withdrawal Requirements—Planning Subarea 4.1

Planning Subarea 4.1 is one of the more heavily populated, with a total population of 5.0 million people in 1970. Municipal water supplies served 80 percent or 4.0 million people in 1970, and by 2020 this is expected to increase to 8.6 million.

Vegetable and fruit production are important in this nearly urbanized area. Dairy products are also important.

Manufacturing is concentrated in urban Wayne and Oakland Counties, and particularly in Detroit. The chemical and paper industries have the greatest water-use projections, with increases of 100 percent and 400 percent respectively from 1970 to 2020.

6.2.3.2 Industrial Water Users

The nine counties of southeastern Michigan which comprise Planning Subarea 4.1 are a mixture of heavily industrialized counties in the Detroit urban area, and essentially rural counties in the southern, western, and extreme northern parts of the region. In the Detroit metropolitan area, Wayne, Oakland, and Macomb Counties support manufacturing sectors that provide 89 percent of the manufacturing employment of the planning subarea, and that account for more than 88 percent of the region's value added by manufacture. In 1967 there were more than 800 manufacturing establishments scattered through all counties, but heaviest concentration was found in the three counties named above, in which 7,100 individual factories were located. The value added by manufacture in all the counties totalled $9.6 billion in 1967, and the manufacturing employment of more than 650,000 people accounted for 39 percent of total employment in the region.

The manufacturing sector has been growing steadily during recent years, with more factories being established, more factories growing to larger size, and more employment being provided. Much of the employment is found in motor vehicle manufacture and related industries, but the growth of employment in other industries is occurring at a more rapid rate, and most new employment in recent years has been in industries not directly related to motor vehicle manufacture. These trends will probably continue as the region's economy becomes less dependent on the automotive industries, and more broadly based in its manufacturing activities.

6.2.3.3 Rural Water Users

In 1964 Planning Subarea 4.1 contained 2.3 million acres of land in farm. Major crops consisted of corn, wheat, oats, soybeans and meadow. The area also grew more than 28,000 acres of commercial vegetables and more than 10,000 acres of orchards and vines, heavy water users. Dairy farming, also a heavy water user, contributed more than half of the receipts of livestock and livestock products coming from this source. More than $68 million were derived from crop sales and more than $82 million from livestock and livestock product sales in 1964. There were 78,000 persons living on farms, and 21,000 employed on farms, according to the 1960 census.

6.2.4 Present and Projected Water Withdrawal Requirements

Table 6–84 presents a summary of municipal, self-supplied industrial and rural water use for Planning Subarea 4.1.

6.2.4.1 Municipal Water Use

The major regional water supplier is the City of Detroit, which currently draws its water from the Detroit River. In 1966 the Detroit Department of Water Supply pumped 207 billion gallons for an estimated 3.47 million people. As the regional system continues to grow, service is anticipated to extend to many points throughout Planning Subarea 4.1. Of the 240 central water systems operating in the planning subarea in 1965, 93 systems obtained water from Lake Huron, the St. Clair River, Lake St. Clair, the Detroit River, and Lake Erie, seven systems drew water from inland surface waters, and 138 systems relied upon ground water. Two systems tapped both inland surface- and ground-water sources. In the mid-1960s municipal water use exceeded 650 mgd. More than 50 percent of the total went to users located in minor basins draining directly into the Great Lakes and their connecting channels. More than 90 percent of the water used by municipalities is from the Great Lakes and connecting channels.

The population served by municipal water supply in Planning Subarea 4.1 was 4.4 million in 1970. The population served is expected to increase to 8.9 million by 2020. In 1970, 91.4 percent of the population used water withdrawn from the Great Lakes, 2.7 percent from inland surface waters, and 5.9 percent from ground-water sources. These percentages are expected to change to 97.4 percent, 0.3 percent, and 2.3 percent respectively by 2020.

The 1970 average daily municipal withdrawal in Planning Subarea 4.1 from the Great Lakes and connecting channels was estimated to be 675 mgd (Table 6–85). The projected figure for 2020 is 1,666 mgd, a total increase of almost one billion gallons daily.

Water consumption in domestic and commercial use should continue to be 10 percent of withdrawals. Consumption of water supplied by municipalities to industry follows the rates calculated by the U.S. Bureau of Domestic Commerce for other manufacturing for a given year. In this area, the rate will rise from 5 percent in 1970 to 16 percent in 2020.

Use of inland lakes and streams and ground

TABLE 6–84. Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Planning Subarea 4.1 (mgd)

Use	1970				1980			
	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
Michigan	738.5	1297	49.4	2085	891.7	900	54.3	1846
Total	738.5	1297	49.4	2085	891.7	900	54.3	1846
Consumption								
Michigan	60.8	135	11.9	208	79.6	173.7	13.5	266.8
Total	60.8	135	11.9	208	79.6	173.7	13.5	266.8
1970 Capacity-Future Needs								
Michigan	1295	1297	49.4	2642	165.3	30.8	4.8	201
Total	1295	1297	49.4	2642	165.3	30.8	4.8	201

Use	2000				2020			
	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
Michigan	1236	589	63.3	1889	1710	1092	67.7	2870
Total	1236	589	63.3	1889	1710	1092	67.7	2870
Consumption								
Michigan	136.6	372.7	15.6	525	207.8	744	17.3	969.1
Total	136.6	372.7	15.6	525	207.8	744	17.3	969.1
1970 Capacity-Future Needs								
Michigan	553.4	401	13.9	968	1094	923	18.3	2035
Total	553.4	401	13.9	968	1094	923	18.3	2035

water in southeastern Michigan for municipal water supply is expected to decrease as more cities switch sources in favor of Great Lakes water. Total withdrawal requirements from these sources are expected to decrease from 63.5 mgd in 1970 to 44.4 mgd in 2020. The Detroit Metropolitan Water Department is currently constructing a 1,200 mgd intake in Lake Huron as a regional water supply system for many southeastern Michigan communities.[13]

6.2.4.2 Industrial Water Use

At present manufacturing water withdrawals are approximately double the withdrawals for domestic and commercial uses. Total withdrawals for all manufacturing are estimated to have been 1.56 billion gallons per day in 1970, of which 265 mgd or 17 percent was obtained from municipal water supply systems. This ratio of municipally supplied industrial water is quite high in comparison to the national ratio of less than 10 percent, and the overall Great Lakes Basin ratio of 11 percent.

Two factors may account for these differences. First, the category of industries that is included under other manufacturing accounts for the greatest share of value added by manufacture (Table 6–86). Although other manufacturing includes large water-using establishments such as the automotive industry, the category is composed mainly of industries with small water requirements, which are more economically satisfied by purchase from municipal systems. Second, the concentration

TABLE 6–85 Municipal Water Supply, Planning Subarea 4.1, Michigan (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Con-sumption
1970	GL		4018.3	675.4	810.4	1013.1	55.5
	IS	5033.0	118.7	19.9	23.9	29.9	1.7
	GW		259.4	43.6	52.3	65.4	3.6
1980	GL		4802.6	829.3	995.1	1244.0	74.0
	IS	5799.2	110.0	18.7	22.5	28.1	1.4
	GW		250.0	43.7	52.4	65.4	3.9
2000	GL		6509.8	1185.6	1422.8	1778.5	131.1
	IS	7426.4	30.0	5.0	5.9	7.4	0.5
	GW		250.0	45.8	54.9	68.6	5.0
2020	GL		8703.0	1665.7	1998.7	2498.5	202.4
	IS	9569.6	30.0	5.1	6.2	7.7	0.6
	GW		200.0	39.3	47.2	59.0	4.8

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Con-sumption	Municipally Supplied Industrial Water: Average Demand	Con-sumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
1970	GL		433.6	43.4	241.8	12.1	1200.0
	IS	107.9	12.8	1.3	7.1	0.4	29.9
	GW		28.0	2.8	15.6	0.8	65.4
1980	GL		532.4	53.3	296.9	20.7	165.3
	IS	110.9	12.0	1.2	6.7	0.2	-
	GW		28.1	2.8	15.6	1.1	-
2000	GL		761.2	76.1	424.4	55.0	553.4
	IS	116.9	3.2	0.3	1.8	0.2	-
	GW		29.4	2.9	16.4	2.1	-
2020	GL		1069.4	106.9	596.3	95.5	1093.9
	IS	122.9	3.3	0.3	1.8	0.3	-
	GW		25.2	22.5	14.1	2.3	-

Notes: The source capacity is determined to be somewhat greater than estimated maximum day to bring the latter figure into better agreement with known capacities.

TABLE 6–86 Estimated Manufacturing Water Use, Planning Subarea 4.1 (mgd)

	SIC 20	SIC 26	SIC 28	SIC 29	SIC 33	Other Mfg.	Total
1970							
Value Added							
(Millions 1958$)	435	85	581	78	810	6696	8685
Gross Water Required	48	166	511	266	1204	438	2633
Recirculation Ratio	1.84	3.39	1.77	3.02	1.40	1.75	--
Total Water Withdrawal	26	49	289	88	860	250	1562
Self Supplied	--	--	--	--	--	--	1297
Water Consumed	5.11	6.7	26	4.5	93.2	13	148
1980							
Value Added							
(Millions 1958$)	590	124	1018	98	999	9816	12645
Gross Water Required	72	235	956	381	1379	649	3672
Recirculation Ratio	2.77	6.03	3.32	5.61	2.59	2.44	--
Total Water Withdrawal	26	39	288	68	532	266	1219
Self Supplied	--	--	--	--	--	--	900
Water Consumed	6.7	9.3	48	6.7	106	19	196
2000							
Value Added							
(Millions 1958$)	1006	799	3230	215	1464	20287	27000
Gross Water Required	117	1320	3428	1079	1820	1402	9166
Recirculation Ratio	3.15	8.00	11.7	19.61	9.63	4.80	--
Total Water Withdrawal	37	165	293	55	189	292	1031
Self Supplied	--	--	--	--	--	--	590
Water Consumed	11	52	170	20	138	39	430
2020							
Value Added							
(Millions 1958$)	1778	1413	8387	433	2228	43210	57449
Gross Water Required	193	2000	8910	2080	2400	3035	16618
Recirculation Ratio	3.50	8.00	15.0	23.92	12.0	5.86	--
Total Water Withdrawal	55	250	594	87	200	518	1704
Self Supplied	--	--	--	--	--	--	1092
Water Consumed	18	80	442	39	179	84	842

of industries in Wayne, Oakland, and Macomb Counties have relatively limited frontage on Lake St. Clair and the Detroit River, and the lack of sizeable inland surface sources provides few locations for the development of large individual industrial supplies. These circumstances will continue to influence industrial water supply development, and it is expected that municipal water systems will provide even larger shares of the industrial water requirements of the future.

Lake St. Clair and the Detroit River are the principal sources of self-supplied industrial water in the Detroit metropolitan area, Lake Erie is a major source in the southeastern counties, and Lake Huron and the St. Clair River provide the major source in the northeast. Surface streams such as the Raisin, Huron, and Rouge Rivers are also used for industrial supplies, but there is no information available about the quantities obtained from any of the sources. Information is not available on well-water supplies used by industries. However, because of the relatively poor yields of ground-water aquifers in this planning subarea, it is believed that industry-operated wells provided only a very small part of the total industrial water used.

Table 6–86 presents the base year estimates and projections of five water-use parameters and constant dollar estimates of value added by manufacture for the five major water-using SIC two-digit industry groups and the residual manufacturing groups that comprise the manufacturing sector. The value-added parameter is derived from OBERS projections and is included in the table as an indicator of the rates of growth of the industry groups and sector. It is also a key element in the water use projection methodology. The water-use estimates represent the needs of all establishments without differentiating between small and large water users. The large water-using establishments (those withdrawing 20 million gallons per year or more) are relatively few in number and probably do not exceed 300 factories, but the impact of their water requirements is huge. It is estimated that the 300 large water-using establishments account for more than 97 percent of the total withdrawal needs of the manufacturing sector.

In addition to the concentration of water use among these 300 plants, there is a further concentration of water use within particular industry groups. The largest water withdrawals in 1970 were found in SIC 33, the Primary Metals industry group, followed by SIC 28, Chemicals and Allied Products (Table 6–86). Manufacturing establishments in these two groups accounted for 1,149 mgd of the estimated total manufacturing withdrawals of 1,562 mgd.

These withdrawals of water enabled manufacturers to meet their larger gross water requirement of 2,633 mgd in 1970 by recirculation and reuse of water at various rates within their plants. There are differences in present day estimated recirculation rates between the various industry groupings (Table 6–86). Although their gross water needs are larger than any of the other industry groups, the recirculation rates of SIC 28 and SIC 33 are the lowest. For these two industry groups in particular and all industries in general, reasonable improvements in recirculation rates can bring about dramatic reductions in the quantities of water that need to be supplied. Improved recirculation rates have been forecast for the manufacturing industries in the manner discussed in the projection methodology outlined in Section 1 of this appendix.

For the total manufacturing sector the value added by manufacture is projected to increase from $8,685 million (1958$) to $57,450 million (1958$) from 1970 to 2020. The gross water needed to meet the manufacturing requirements of 2020 is 16,600 mgd, an increase of 630 percent over the gross water requirements of 1970. Without improvements in recirculation rates and other water management practices, the withdrawal requirements would increase correspondingly to more than 8,000 mgd. However, improvements in the recirculation rates should cause a slight decrease in total manufacturing withdrawals to the year 2000 after which the withdrawals will increase to 1,700 mgd by the year 2020.

Two industry groups, SIC 28 and 33, and the broad industry grouping under other manufacturing are most influential in the changing withdrawal requirements. SIC 28 has been forecast by OBERS to expand its production rapidly during the planning period for a net production increase of more than 1,400 percent. Although the industry group should improve its recirculation rate from 1.77 in 1970 to 15.0 in 2020, this improvement does not keep pace with the growth in production. The net result is an increase in the water withdrawal demands for SIC 28.

On the other hand, SIC 33 is projected to expand production more slowly. The improvements in recirculation by this industry group from 1.40 to 12.0 should meet increasing water needs for the added production. The net result for SIC 33 is a decrease in water withdrawal demands.

Other manufacturing represents a large assortment of small and large industries whose sum total growth during the planning period should exceed 640 percent. The potential for improvements in water reuse by these industries is not as great as for the SIC two-digit industries. Therefore, its withdrawal requirements will grow from 250 mgd in 1970 to 518 mgd in year 2020, and municipal systems can be expected to increase the quantity of their service to this sector. However, a close study of this residual industry group was not within the scope of this study, and therefore the recirculation rate improvements were forecast conservatively. It is possible that greater improvement will be achieved.

Table 6–86 shows that consumption of water by manufacturing in the planning subarea will increase to approximately 850 mgd. To put this figure into perspective, it may be recalled that the total present day domestic and commercial withdrawal requirements for the planning subarea are only 475 mgd. Three industry groups will account for 705 mgd of the water consumption: SIC 28, 442 mgd; SIC 33, 179 mgd; and other manufacturing, 84 mgd.

6.2.4.3 Rural Water Use

Rural water requirements and consumption were estimated for Planning Subarea 4.1 following the methodology outlined in Subsection 1.4. Table 6–87 divides total requirements and consumption into categories of rural nonfarm and rural farm. Rural farm is further divided into domestic, livestock, and spray water requirements.

6.2.5 Needs, Problems, and Solutions

6.2.5.1 Municipal

Table 6–85 shows the projected need for additional water supply capacity in Planning Subarea 4.1 to be 1,094 mgd in 2020. This capacity will be used to supply water needed for additional growth. All needs should be met by withdrawals from the Great Lakes and their connecting channels.

If all potential water storage areas were fully developed, inland lakes and streams in Planning Subarea 4.1 could produce a sustained yield of 1,167 mgd.[45] Ground-water aquifers in this area can produce 600 mgd.[21] The quantity of the water resource available in Planning Subarea 4.1 is adequate to meet the projected future requirements, but the management and proper development of the water resource is necessary.

The estimated costs for new construction are presented in Table 6–88. All estimates are adjusted to January 1970 price levels. The costs include transmission of the water supply and water treatment, but not intraurban distribution.

Published information on the Detroit Metropolitan Water Department program for southeastern Michigan presents dimensions and approximate locations of proposed large transmission mains through the year 2000.[13] These proposals for transmission lines were used along with the $10,560 unit-cost figure presented in Subsection 1.2.2 of this appendix to estimate costs for construction to the year 2000 in Planning Subarea 4.1. Judgment was used in extrapolating a result for the period of 2000 to 2020.

The cost estimates in Table 6–88 are related

TABLE 6–87 Rural Water Use Requirements and Consumption, Planning Subarea 4.1 (mgd)

	1970	1980	2000	2020
REQUIREMENTS				
Rural Farm				
Domestic	4.1	3.3	2.4	2.5
Livestock	5.4	6.6	7.8	9.1
Spray Water	0.1	0.1	0.1	0.1
Subtotal	9.6	10.0	10.3	11.6
Rural Nonfarm	39.6	44.2	53.0	56.1
Total	49.3	54.2	63.3	67.7
CONSUMPTION				
Rural Farm				
Domestic	1.0	0.8	0.6	0.6
Livestock	4.9	5.9	7.0	8.2
Spray Water	0.1	0.1	0.1	0.1
Subtotal	6.0	6.8	7.7	8.8
Rural Nonfarm	5.9	6.6	8.0	8.4
Total	11.9	13.5	15.6	17.3

TABLE 6–88 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Planning Subarea 4.1 (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
Great Lakes	Capital	49.424	116.041	161.609	165.466	327.076
	Annual OMR	2.462	10.708	24.544	13.171	37.716
	Total OMR	24.629	214.172	490.895	238.802	729.697
Long Distance Transport of Great Lakes	Capital	164.506	88.000	95.000	252.500	347.500
	Annual OMR	5.600	3.000	3.200	8.600	11.800
	Total OMR	56.000	60.000	64.000	116.000	180.000
Total	Capital	213.925	204.042	256.610	417.967	674.576
	Annual OMR	8.063	13.709	27.745	21.772	49.516
	Total OMR	80.63	274.173	554.895	354.802	909.700

*Ground water unit cost assumptions are as follows:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells & pumping	--	--
total	120,000	7,600

to additional population growth. No attempt has been made to subtract costs of meeting needs which are within the scope of ongoing programs.

The City of Detroit is engaged in a $110 million construction program that will result in 400 mgd additional treatment facilities (already completed) and an intake in Lake Huron with a design capacity of 1,200 mgd.

In regard to intake capacity, the ongoing program will satisfy projected needs beyond the time period of this study. The 400 mgd of treatment capacity will be entirely additional to present capacity.

6.2.5.2 Industrial

Water withdrawals by manufacturers in Planning Subarea 4.1 are estimated to be 1,562 mgd in 1970. Although manufacturing production will continue to grow, the increasing gross water demand to meet the expanding output will be more than matched by the increasing reuse and recirculation of water in the manufacturing plants. As a result total water withdrawals are expected to decline to 1,000 mgd by the late 1980s. As maximum feasible recirculation rates are approached in 1990, the withdrawal demand will start to increase sharply to a total sector demand of 1,700 mgd by the year 2020.

For the total manufacturing sector, output measured in value added by manufacture is projected to increase from $8.685 billion in 1970 to $57.449 billion in 2020. If it is assumed that existing manufacturing plants can enlarge their capacities at present locations by 100 percent to double the present value added by manufacture, then $40 billion of manufacturing activity will occur at new plants in new locations for which new water supplies must be developed.

Figure 6–44 illustrates the changing characteristics of the industrial water demand during the 50-year planning period. In the preparation of this chart the effects of improving recirculation practices by the major water-using industries, the increases in manufacturing output, and the basic assumption that existing plants will double their outputs during the first stages of the 50-year period are taken into account. Curve 1 represents the withdrawal demand to maintain 1970 production levels at existing plants. Curve 2 represents the withdrawal demand to maintain 1970 levels assuming that the first 100 percent increase in production will occur at existing plants. Curve 3 represents the total withdrawal demand for old and new production. The area between Curves 2 and 3 represents the withdrawal requirements for new production at new locations. By the year 2000, 370 mgd of industrial water will be required at locations where plants do not presently exist, and by the year 2020 the demand at new locations will be 1,180 mgd.

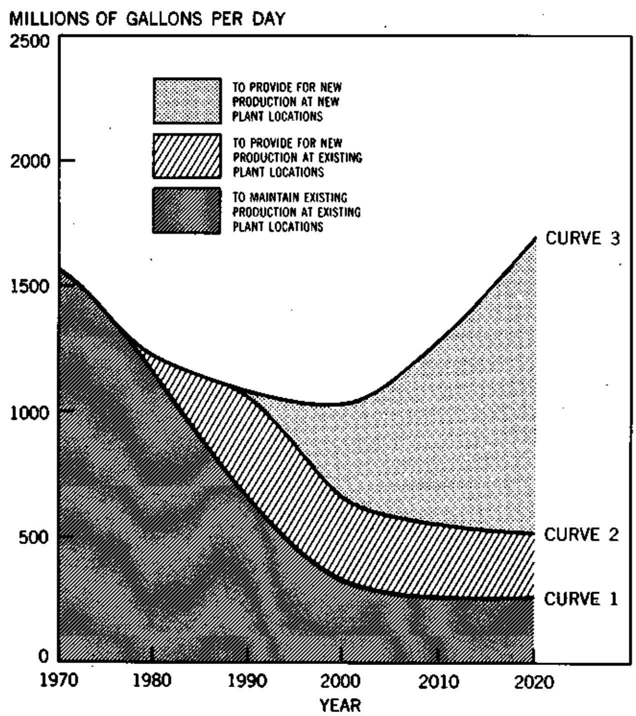


FIGURE 6–44 Total Withdrawal Demands for Manufacturing—Planning Subarea 4.1

The fulfillment of new withdrawal needs will be affected by other planning goals such as land use, environmental quality, subregional economic development, the availability of the water supply, and facilities for its return to the resource base. Undoubtedly, much of the new industrial development will occur in inland counties if sufficient water supply is available. Inland dispersal of new industries and management of the water resource can be best achieved by the enlargement of municipal systems and the development of regional supply systems to provide industrial water through the development of local sources and the transfer of large quantities from Lake Huron, Lake Erie, and the interconnecting river-lake system.

6.2.5.3 Rural

Future rural water requirements will be drawn primarily from ground-water sources, although in some areas streams will be increasingly important. The location and quality of ground water will be important in channeling additional development, particularly the location of rural nonfarm dwellings. In areas where ground water is in short supply, development should proceed only after water supplies are located. Some areas will not develop until a central supply is available.

Rural water requirements are projected to increase 37 percent between 1970 and 2020, and consumption is expected to increase 45 percent.

Ground-water supplies for rural areas are being depleted by the demands of the metropolitan areas in this planning subarea. The chemical quality of the ground water is likely to be poor in much of the area because of the presence of saline bedrock water. High chloride and sulfate content is common. Little or no regional ground-water information is available for planning purposes.

6.3 Lake Erie Southwest, Planning Subarea 4.2

6.3.1 Description of Planning Subarea

6.3.1.1 Location

Three counties in northeastern Indiana and 20 counties in northwestern Ohio combine to form this planning subarea. Planning Subarea 4.2 is 150 miles long and varies in width from 90 miles at the Indiana-Ohio border to 25 miles at both ends of the region (Figure 6–45).

6.3.1.2 Topography and Geography

Elevations range from nearly 980 feet in the northwestern extremities of the planning subarea to 580 feet at the Lake Erie shore. The land is very flat to undulating with very little local relief in most areas. The land gently slopes to the north and east so that drainage generally follows topographic features.

Repeated glacial advances left till and outwash over much of the planning subarea. In addition, former lakes left lacustrine deposits. The till plains are characterized by several broken moraines deposited at the retreating edges of glaciers. The lake plains are characterized by ancient shoreline deposit composed of sand and gravel and shallow lake-bottom silts and clays. Relief adjacent to major streams is generally 20 to 40 feet.

Planning Subarea 4.2 is drained by the Maumee, Toussaint-Portage, Sandusky, and Huron-Vermilion River basins. The total drainage area is 9,950 square miles.

6.3.1.3 Climate

Planning Subarea 4.2 has a humid, continental climate with warm summers and mildly cold winters. The mean annual temperature is approximately 51°F, with recorded temperature extremes of −30°F and 100°F. The frost-free season averages 170 days, with slightly longer seasons in the Lake Erie shoreline counties. Average annual precipitation ranges from 32 inches to 36 inches, with the highest level farthest inland. Snowfall averages 30 inches per year and ranges from a high of 32 inches near the lakeshore to 24 inches inland.

6.3.2 Water Resources

6.3.2.1 Surface-Water Resources

Streamflow in this planning subarea reflects a variety of factors. Because of the flat topography, streams characteristically follow slow-moving courses. Glacial moraines have forced streams like the Blanchard and the St. Marys to flow east to west across the planning subarea before confluence with the general north to south drainage trend. Average annual runoff is 10 inches in the basin.

Inland lakes are not plentiful in Planning Subarea 4.2. The largest lake is Lake St. Marys. The topography makes upground reservoirs feasible where water supplies are needed. Lake Erie serves the water supply and recreational needs of the shoreline counties, while inland streams and lakes supply the interior of the planning subarea.

Streams and lakes in the area reflect poor natural drainage conditions with dissolved solid concentrations and low quality water in most stream reaches due to municipal, industrial and agricultural waste disposal practices.

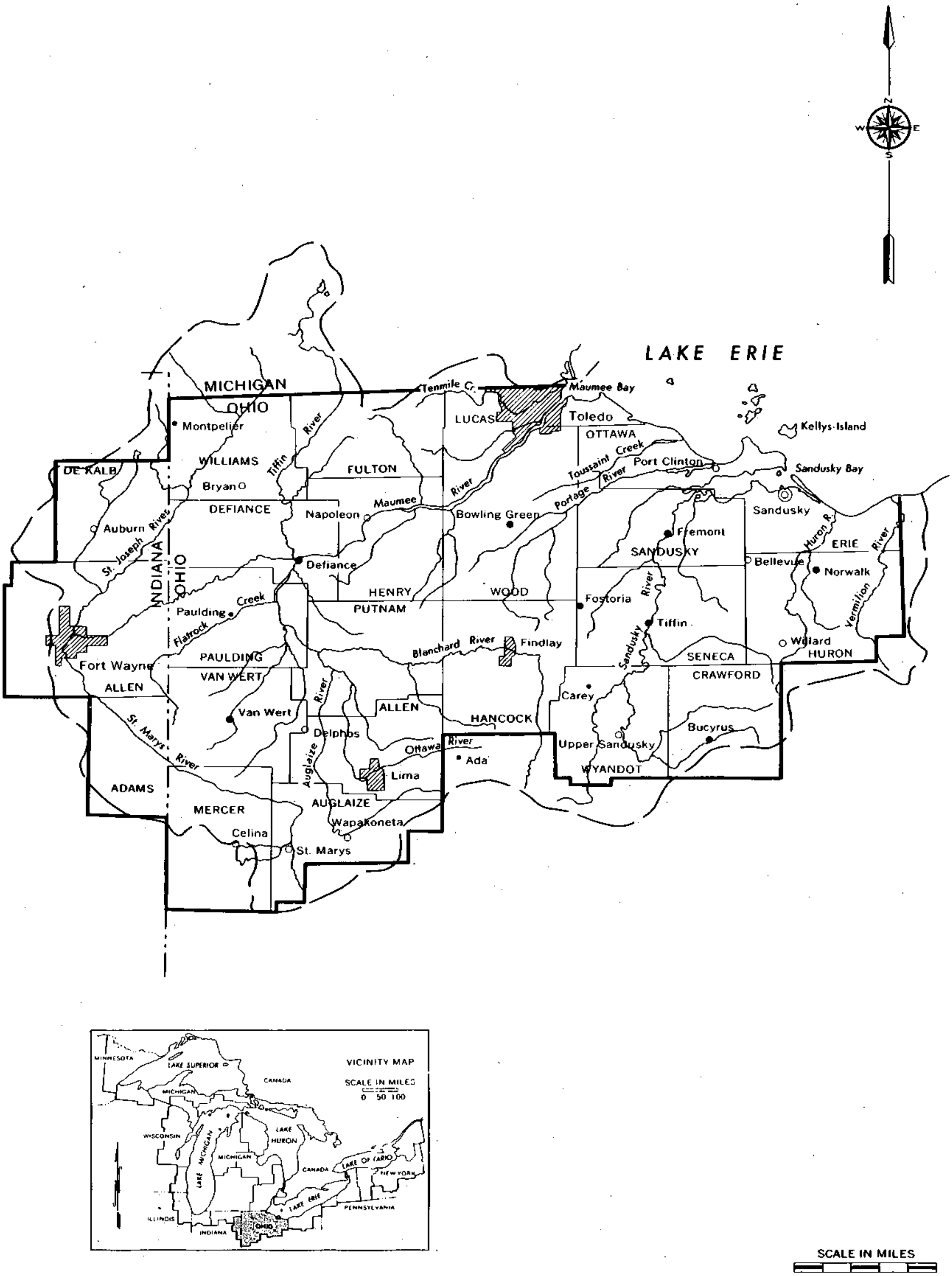


FIGURE 6–45 Planning Subarea 4.2

Fully developed water storage areas in the planning subarea's inland lakes and streams provide an existing storage capacity of 139,975 acre-feet. If all inland lakes and streams suitable for development as surface-water impoundments were developed, the total potential storage capacity would increase to 236,000 acre-feet.[45]

Presently developed water storage areas can produce a sustained water supply yield of 516 mgd. If all potential water storage areas were fully developed in Planning Subarea 4.2, impounded inland lakes and streams could produce a sustained water supply yield of 2,423 mgd.[45]

Potential capacities and yields used in this section relate to the total water resource. No attempt has been made to identify that portion of the water resource not suitable or available for use.

6.3.2.2 Ground-Water Resources

The sources of ground water in Planning Subarea 4.2 include consolidated bedrock and unconsolidated glacial deposits. Mississippian and Upper Devonian rocks, which cover a large portion of the region, offer little or no ground water because they consist primarily of shale. Occasional sandstones provide domestic and farm supplies, but they usually produce less than 25 gpm. Lower Devonian limestone and dolomites contain dependable water sources for farm, domestic, and limited industrial supplies. This water is unusually hard, ranging from 350 mg/l to 700 mg/l, and requires treatment in most cases. In several aquifers the raw water source exceeds the 500 mg/l USPHS standard for total dissolved solids. Hydrogen sulfide is a problem in many limestone and dolomite areas. The community of Bellevue at one time contaminated ground water in parts of Sandusky, Erie, and Huron Counties by pumping domestic sewage wastes into porous limestone formations.

Glacial material consisting primarily of sands and outwash gravel commonly associated with kames and moraines yields moderate supplies of ground water. Wells in preglacial valleys that filled with outwash and fractured limestones may produce 300 gpm.

Ground-water yield in River Basin Group 4.2 is estimated to be 635 mgd (based on 70 percent flow-duration data).[21]

The glaciated till encountered in the eastern basins does not produce the quantities of ground water obtainable in the limestone formations of the western basins. Excess iron is a common constituent of ground-water supplies in the planning subarea.

6.3.3 Water-User Profile

6.3.3.1 Municipal Water Users

In 1970 the population of Planning Subarea 4.2 exceeded 1.6 million, 65 percent of which was classified as urban in 1960. Highest population concentrations occur in the major urban centers of Toledo, Lima, Fort Wayne, and Sandusky, and in the counties adjacent to Lake Erie. Small rural communities dot the entire planning subarea. Average population density was 162.7 people per square mile in 1970. By 2020 the population of this area is projected to exceed 3.1 million people. At present municipal water supplies serve 1.2 million people, 73 percent of the population. It is projected that 2.7 million people will be served by 2020. The estimated annual average per capita income in 1970 was $4,227 (1970$). Manufacturing, trades, services, and agriculture account for most of the economic value of the planning subarea.

6.3.3.2 Industrial Water Users

Manufacturing industries provide approximately 35 percent of the total employment in Planning Subarea 4.2. Most of the manufacturing activities are concentrated around Toledo, Sandusky, Lima, and Findlay, Ohio, and Fort Wayne, Indiana. Although many of the counties are predominantly rural in character, manufacturing plants are located in all counties and contribute significantly to employment and the general economy. In 1967 there were 2,711 manufacturing plants in the planning subarea, 15 fewer than in 1963. However, the number of establishments employing 20 or more persons grew from 1,011 plants in 1963 to 1,117 in 1967. Total employment increased by more than 18 percent and the value added by manufacture grew from $2.5 billion to $3.4 billion during the same period.

Fort Wayne, Indiana, at the confluence of the St. Marys and St. Joseph Rivers, is a major manufacturing city at the approximate center of the three-county Indiana portion of Planning Subarea 4.2. In 1967 there were 494 manufacturing establishments in the Indiana portion, some 383 of which are found in the Fort

Wayne SMSA. In 1967 the 494 plants provided employment for 51,000 people and produced goods with a value of shipments of $1.75 billion. Major industries in the area are food processing, nonferrous metal rolling and drawing, fabricated metal products, and machinery manufacture.

In the 20 counties of Ohio that comprise the remainder of the planning subarea, the Cities of Toledo, Lima, Findlay, and Sandusky are major manufacturing centers producing nearly one-third of the total manufactured goods of the planning subarea. However, the manufacturing sector in each county is enlarging in output and employment. In the Toledo metropolitan area the major industries are food processing, paper products, chemicals, petroleum refining, primary metals, fabricated metals, machinery, electrical machinery, and transportation equipment. The total value of shipments from the Toledo area in 1967 was $2.76 billion. Similar manufacturing activities are found in the other cities and counties of the planning subarea. The area is noted especially for its production of high quality machinery which is manufactured in 10 of the 20 counties and sold in markets worldwide.

6.3.3.3 Rural Water Users

In 1964 Planning Subarea 4.2 contained nearly 5.5 million acres of land in farm. The two major crops in the area were corn and soybeans, each occupying more than a million acres in 1964. Other important crops included wheat, oats, and meadow crops. More than 36,000 acres of vegetable crops, largely tomatoes, a heavy water user, were grown in the area. Dairy farming, also a heavy water user, contributed more than $46 million out of the $187.7 million receipts from livestock and livestock products. Crop sales totaled more than $204 million in 1964. According to the 1960 census, 168,000 people lived on farms and 35,000 worked on farms.

6.3.4 Present and Projected Water Withdrawal Requirements

6.3.4.1 Municipal Water Use

The major portion of water for Planning Subarea 4.2 for industrial and municipal use is supplied by Lake Erie and the Maumee, Toussaint, Huron, Sandusky, and Portage Rivers. As shown in Figure 6-46 and Table 6-89, counties in the planning subarea required more than 500 mgd in 1970 to satisfy the water supply requirement, of which approximately 318 mgd, 58 percent, were for industrial water supply. Of the 186 mgd municipal water withdrawals in 1970, approximately 100 mgd, 54 percent, were required by Toledo and Fort Wayne.

For municipal use approximately equal amounts were supplied from inland streams, lakes, and Lake Erie. Of the total 186 mgd in 1970, approximately 51 percent came from Lake Erie, 13 percent from ground water, and

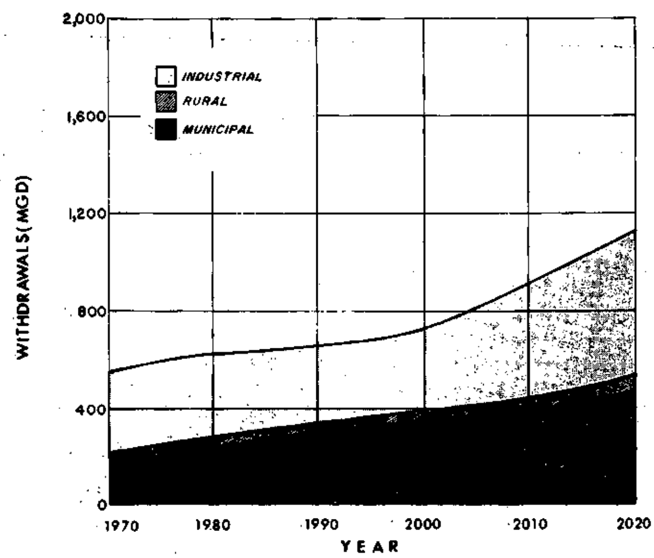


FIGURE 6-46 Municipal, Industrial, and Rural Water Withdrawal Requirements—Planning Subarea 4.2

More than half of the population of 1.7 million people residing in Planning Subarea 4.2 in 1970 was classified as urban. Municipal water supplies served 73 percent of the population, or 1.2 million people in 1970. This is expected to increase to 2.7 million by 2020.

This planning subarea is one of the basin's most productive agricultural regions. Corn, wheat, oats, soybeans, and tomatoes lead the crop list, along with fruits and truck crops along the shore of Lake Erie. Agriculture employs 6 percent of the working force.

Major industrial centers occur largely along the shore of Lake Erie, but smaller complexes are located in the interior. Important industrial activity is centered in transportation goods, primary and fabricated metals, glass products, petroleum, and paper and printing.

TABLE 6-89 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Planning Subarea 4.2 (mgd)

Use	1970 mun.	1970 ind.	1970 rural	1970 total	1980 mun.	1980 ind.	1980 rural	1980 total
Withdrawal Requirements								
Indiana	29.2	13	5.9	48	41.4	13	7.1	62
Ohio	156.7	305	36.5	498	195.2	334	44.0	573
Total	185.9	318	42.4	546	236.6	347	51.1	635
Consumption								
Indiana	3.0	1.9	2.1	7.0	4.5	2.5	2.9	9.9
Ohio	15.5	34.1	13.2	62.8	21.0	57.5	18.1	96.6
Total	18.5	36	15.3	70	25.5	60	21.0	107
1970 Capacity-Future Needs								
Indiana	68.5	19	5.9	93	2.0	8	1.2	11
Ohio	373.2	299	36.5	709	21.4	50	7.5	79
Total	441.7	318	42.4	802	23.4	58	8.7	90

Use	2000 mun.	2000 ind.	2000 rural	2000 total	2020 mun.	2020 ind.	2020 rural	2020 total
Withdrawal Requirements								
Indiana	72.2	10	8.9	91	109.9	13	10.6	134
Ohio	263.2	323	55.2	641	344.6	581	65.7	991
Total	335.4	333	64.1	732	454.5	594	76.3	1125
Consumption								
Indiana	9.2	8	4.0	21	15.3	7	5.2	28
Ohio	33.3	132	24.4	190	47.2	305	32.2	384
Total	42.5	140	28.4	211	62.5	312	37.4	412
1970 Capacity-Future Needs								
Indiana	22.9	33	3.0	59	71.8	73	4.7	150
Ohio	93.3	205	18.7	317	189.0	450	29.2	668
Total	116.2	238	21.7	376	260.8	523	33.9	818

the remaining 36 percent from inland streams and lakes. As growth continues, Lake Erie will continue to be a very important source, but the majority of future water demands will be met by a system of reservoirs in the inland areas. This proposed reservoir complex will cause inland lakes and streams to become the dominant source in the planning subarea, supplying approximately 233 mgd or 51 percent of municipal water supply by 2020. Ground water will continue to supply the least, with its relative share dropping to 8 percent in the year 2020.

Approximately 87 percent or 162 mgd of the municipal water supply is withdrawn from surface waters and requires purification treatment including coagulation, sedimentation, rapid sand filtration, and disinfection. The remaining ground-water supplies are disinfected and receive some type of major corrective treatment such as softening or iron removal. A few ground-water sources are high in iron, sulfates, and hydrogen sulfide, especially in the Maumee River basin. These sources will probably be replaced by future surface-water sources. Water is hard in limestone areas, but treatable. Some individual communities not providing treatment for hard water are planning to do so in the future.

Developed source quantities are generally adequate in the area at present with a few small communities needing expansion of ground-water sources to meet their requirements.

The total municipal supply average demand requirements are expected to increase to 237 mgd by 1980, to 355 mgd by 2000, and to 455 mgd by 2020 (Tables 6-90, 6-91, 6-92). The av-

TABLE 6-90 Municipal Water Supply, Planning Subarea 4.2, Indiana and Ohio (mgd)

				Total Municipal Water Supply			
Year	Source	Total Population (thousands)	Population Served (thousands)	Average Demand	Maximum Month	Maximum Day	Consumption
1970	GL	1686.7	527.5	94.2	114.5	144.9	9.4
	IS		519.5	67.6	87.3	106.2	6.7
	GW		179.1	24.1	28.2	37.4	2.4
1980	GL	1963.4	628.0	112.4	136.6	172.9	12.0
	IS		690.8	98.4	126.9	154.9	10.8
	GW		184.1	25.8	30.1	40.2	2.7
2000	GL	2473.8	804.0	144.2	175.1	221.4	17.8
	IS		1012.3	161.2	208.3	256.0	21.1
	GW		196.9	30.0	35.2	46.6	3.6
2020	GL	3116.2	1019.5	183.0	222.3	280.8	24.3
	IS		1393.8	233.1	302.0	372.4	33.2
	GW		242.3	38.4	45.0	59.3	5.0

		Domestic and Commercial Municipal Water Supply			Municipally Supplied Industrial Water		Source Capacity (1970) & Needs (1980, 2000, 2020)
Year	Source	Gallons per capita daily	Average Demand	Consumption	Average Demand	Consumption	
1970	GL	109	70.0	7.0	24.2	2.4	196.8
	IS		44.9	4.5	22.6	2.2	175.9
	GW		18.3	1.8	5.8	0.6	69.0
1980	GL	116	83.8	8.4	28.6	3.6	21.4
	IS		65.5	6.6	32.9	4.2	-
	GW		20.2	2.0	5.6	0.7	2.0
2000	GL	119	107.8	10.8	36.4	7.0	59.3
	IS		108.7	11.0	52.5	10.1	49.6
	GW		23.4	2.3	6.6	1.3	7.3
2020	GL	122	136.8	13.7	46.2	10.6	105.5
	IS		157.5	15.8	75.6	17.4	140.5
	GW		29.9	3.0	8.5	2.0	14.8

Notes: 54.3 mgd additional inland lake and stream source capacity is programmed for development by 1980.

erage day in the maximum month of total municipal water usage per year is expected to increase from 230 mgd in 1970 to 294 mgd in 1980, 419 mgd in 2000, and 569 mgd in 2020. The maximum day of water usage can be expected to almost triple by 2020 to 713 mgd.

It is assumed that 10 to 15 percent of the municipal water use will be consumptive use and will not be available for reuse. The consumptive water use can be expected to amount to roughly 25.5 mgd in 1980, 42.5 mgd in 2000, and 62.5 mgd in 2020.

Diversion of water from one basin to another in this area is not expected to exceed 7

TABLE 6–91 Municipal Water Supply, Planning Subarea 4.2, Ohio (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Consumption
	GL		527.5	94.2	114.5	144.9	9.4
1970	IS	1350.1	325.0	43.9	56.0	63.5	4.3
	GW		142.9	18.6	21.6	29.1	1.8
	GL		628.0	112.4	136.6	172.9	12.0
1980	IS	1559.8	439.7	64.6	82.2	93.9	7.1
	GW		137.5	18.2	21.0	28.8	1.9
	GL		804.0	144.2	175.1	221.4	17.8
2000	IS	1912.5	628.2	101.2	129.1	148.0	13.5
	GW		125.6	17.8	20.6	28.3	2.0
	GL		1019.5	183.0	222.3	280.8	24.3
2020	IS	2340.3	828.6	141.9	181.5	207.9	20.6
	GW		137.5	19.7	22.6	31.3	2.3

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Consumption	Municipally Supplied Industrial Water: Average Demand	Consumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
	GL		70.0	7.0	24.2	2.4	196.8
1970	IS	113	28.2	2.8	15.6	1.5	127.9
	GW		14.6	1.4	4.0	0.4	48.5
	GL		83.8	8.4	28.6	3.6	21.4
1980	IS	117	41.7	4.2	22.9	2.9	-
	GW		15.7	1.5	3.1	0.4	-
	GL		107.8	10.8	36.4	7.0	59.3
2000	IS	122	66.5	6.8	34.7	6.7	34.0
	GW		15.2	1.5	2.6	0.5	-
	GL		136.8	13.7	46.2	10.6	105.5
2020	IS	125	93.4	9.4	48.5	11.2	83.5
	GW		17.3	1.7	2.4	0.6	-

Notes: 30.3 mgd additional inland lake and stream source capacity is programmed for development by 1980.

TABLE 6–92 Municipal Water Supply, Planning Subarea 4.2, Indiana (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Consumption
1970	IS	336.6	194.5	23.7	31.3	42.7	2.4
	GW		36.2	5.5	6.6	8.3	0.6
1980	IS	403.6	251.1	33.8	44.7	61.0	3.7
	GW		46.6	7.6	9.1	11.4	0.8
2000	IS	561.3	384.1	60.0	79.2	108.0	7.6
	GW		71.3	12.2	14.6	18.3	1.6
2020	IS	775.9	565.2	91.2	120.5	164.5	12.6
	GW		104.8	18.7	22.4	28.0	2.7

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Consumption	Municipally Supplied Industrial Water: Average Demand	Consumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
1970	IS	85.8	16.7	1.7	7.0	0.7	48.0
	GW	103.1	3.7	0.4	1.8	0.2	20.5
1980	IS	94.8	23.8	2.4	10.0	1.3	-
	GW	108.9	5.1	0.5	2.5	0.3	2.0
2000	IS	109.8	42.2	4.2	17.8	3.4	15.6
	GW	114.5	8.2	0.8	4.0	0.8	7.3
2020	IS	115.4	64.1	6.4	27.1	6.2	57.0
	GW	120.4	12.6	1.3	6.1	1.4	14.8

Notes: 24 mgd additional inland lake and stream source capacity is programmed for development by 1980.

mgd within the next 50 years. This diversion would be out of the Maumee River basin and into the Toussaint-Portage complex.

6.3.4.2 Industrial Water Use

Total withdrawals for all manufacturing are estimated to have been approximately 370 mgd in 1970. Of this total, 320 mgd were self-supplied and slightly more than 50 mgd were obtained from municipal systems. Manufacturing water withdrawals, at present, are the largest water demands in the planning subarea and are three times greater than the quantities withdrawn for domestic and commercial uses. The water withdrawal demands for manufacturing will increase throughout the planning period with demands estimated to be 414 mgd by 1980, 429 mgd by 2000, and 724 mgd by 2020. These steadily increasing withdrawal requirements reflect the rapid growth forecast for the SIC 28 industry group whose production has been forecast to nearly double every 10 years, and the growth of the large group of manufacturing industries categorized as other manufacturing (Table 6–93), which is forecast to increase by more than

TABLE 6–93 Estimated Manufacturing Water Use, Planning Subarea 4.2 (mgd)

	SIC 20	SIC 26	SIC 28	SIC 29	SIC 33	Other Mfg.	Total
1970							
Value Added							
(Millions 1958$)	328	100	152	140	310	2379	3409
Gross Water Required	42	18	113	658	220	143	1194
Recirculation Ratio	2.36	3.74	2.01	4.95	2.18	2.43	--
Total Water Withdrawal	18	4.8	56	133	101	59	371
Self Supplied	--	--	--	--	--	--	318
Water Consumed	2.2	0.6	3.2	22	8	5.8	42
1980							
Value Added							
(Millions 1958$)	427	152	323	204	432	3678	5216
Gross Water Required	54	27	255	1074	306	222	1941
Recirculation Ratio	2.77	6.03	3.64	7.84	2.82	3.05	--
Total Water Withdrawal	20	4.5	70	137	109	73	414
Self Supplied	--	--	--	--	--	--	344
Water Consumed	2.6	1.0	7.0	37	12	9.3	69
2000							
Value Added							
(Millions 1958$)	683	320	1255	466	757	8278	11759
Gross Water Required	72	50	1110	2350	537	525	4645
Recirculation Ratio	3.15	8.00	11.70	19.61	7.06	4.80	--
Total Water Withdrawal	23	2.6	95	120	76	109	429
Self-Supplied	--	--	--	--	--	--	333
Water Consumed	3.5	1.6	31	83	18	21	158
2020							
Value Added							
(Millions 1958$)	1158	655	3389	962	1336	18760	26260
Gross Water Required	126	880	3000	4260	947	1200	10400
Recirculation Ratio	3.50	8.00	15.00	23.92	12.00	5.86	--
Total Water Withdrawal	36	11	200	193	79	205	724
Self-Supplied	--	--	--	--	--	--	594
Water Consumed	5.8	2.9	883	169	34	47	342

790 percent by the year 2020. Although water conservation practices by these manufacturers are expected to improve considerably, the rapid growth rates will require more water than can be conserved by reuse and recirculation in the plants. As a consequence, the demand for new water inputs to these manufacturers will continue to increase.

In Toledo, Sandusky, and other locations along the shore of Lake Erie, industries obtain a substantial part of their supply through their own intakes in Lake Erie. However, the inland plants must rely on the rivers and wells because there are no major intakes in Lake Erie for delivery of industrial water to inland locations. Among the inland sources, the Maumee River and its tributaries are major sources of industrial water supply, but the Toussaint, Portage, Sandusky and Huron Rivers also supply water to industry. Wells are estimated to provide less than 2 percent of the total industrial water at present.

Table 6–93 presents the base-year estimates and projections of five water-use parameters and constant dollar estimates of value added by manufacture for the five major water-using SIC two-digit industry groups and the residual manufacturing groups that comprise the manufacturing sector. The water-use estimates represent the needs of all establishments without differentiating between small or large water users. The large water-using establishments (those that withdrew 20 million gallons per year or more) are relatively few in number and probably do not exceed 85 factories, but the impact of their water requirements is tremendous. It is estimated that these 85 large water-using establishments account for more than 95 percent of the total withdrawal needs of the entire manufacturing sector in the planning subarea.

In addition to the concentration of water use among these 85 plants, there is a further concentration of water use within particular industry groups. The largest water withdrawals in 1970 were found in SIC 29, Petroleum and Coal Products, SIC 33, Primary Metals, and SIC 28, Chemicals and Allied Products (Table 6–93). Manufacturing plants in these three industry groups accounted for 290 mgd of the estimated total manufacturing sector withdrawals of 371 mgd. By the year 2020 the withdrawals of industries in SIC 28 and SIC 29 will together exceed the total manufacturing sector withdrawals of the present day. In Table 6–94 average recirculation rates are shown for industry groupings. The impact of water conservation through reuse is evident in the SIC 29 industry group. Without recirculation and reuse of water, the withdrawal demand for this industry alone would have been 658 mgd instead of 133 mgd in 1970. Improvements in recirculation of water by that industry group and others can bring about dramatic reductions in the quantities of water that need to be supplied to meet production requirements. Improved recirculation practices have been forecast for the manufacturing industries in the planning subarea in the manner discussed in the section on methodology.

The distribution of the industrial water withdrawal demands between the industrial sectors of the Indiana counties and the Ohio counties is presented in Table 6–94. These estimates were derived by proportioning demand on the basis of the ratio of value added by manufacture in each State section to the value added in the total planning subarea, as reported in the 1967 Census of Manufacturers. Because there are no large water-using establishments in the SIC 28 and 29 industry groups in the Indiana counties, the demands of those industries were assigned to the Ohio portion. SIC 33 industry group establishments are located in each State portion, but the very large water-using establishments are in Ohio. Approximately 80 percent of the SIC 33 water demand is in Ohio. The remaining 20 percent was distributed between the two States by ratio of values added by manufacture, as were the total demands for SIC 20 and 26 and other manufacturing. An identical method was used to obtain the State consumption figures on total water supply for all users (Table 8–94).

6.3.4.3 Rural Water Use

Rural water requirements and consumption were estimated for Planning Subarea 4.2 following the methodology outlined in Subsection 1.4. Table 6–95 divides total requirements and consumption into categories of rural nonfarm and rural farm. Rural farm is further divided into domestic, livestock, and spray water requirements.

6.3.5 Needs, Problems, and Solutions

6.3.5.1 Municipal

The presently developed quantity of municipal water supply sources is not adequate to meet all projected future requirements. The

TABLE 6–94 Estimated Total Manufacturing Water Withdrawals by State, Planning Subarea 4.2 (mgd)

State	1970	1980	2000	2020
Ohio	349	389	397	678
Indiana	22	25	32	46
Total	371	414	429	724

TABLE 6–95 Rural Water Use Requirements and Consumption, Planning Subarea 4.2 (mgd)

	1970	1980	2000	2020
REQUIREMENTS				
Rural Farm				
Domestic	8.8	9.8	8.8	9.4
Livestock	10.6	16.2	23.5	33.1
Spray Water	0.2	0.2	0.2	0.2
Subtotal	19.6	26.3	32.6	42.7
Rural Nonfarm	22.9	24.8	31.5	33.6
Total	42.4	51.1	64.1	76.3
CONSUMPTION				
Rural Farm				
Domestic	2.2	2.5	2.2	2.4
Livestock	9.5	14.6	21.2	29.7
Spray Water	0.2	0.2	0.2	0.2
Subtotal	11.9	17.3	23.6	32.3
Rural Nonfarm	3.4	3.7	4.7	5.0
Total	15.3	21.0	28.4	37.4

quantity of the water resource available is adequate to meet the projected future requirements, but the resource should be developed better.

Water supply needs for the time periods 1980, 2000, and 2020 are shown in Table 6–89. The current capacity of existing sources is shown for 1970. A cushion of excess capacity is assumed necessary. Development to provide at least an additional 23 mgd by 1980, 93 mgd by 2000, and 145 mgd by 2020 is needed. Approximately 50 percent of this need is projected as additional development of inland lake and stream sources, and 41 percent as Great Lakes sources development.

Estimated costs for new construction and associated operations are listed in Table 6–96. All estimates are adjusted to January 1970 price levels. The estimated costs include conveyance of the raw water supply and water treatment but not surface-water storage and urban distribution.

The Northwest Ohio State Water Plan, which will be described later, provides for development of an additional 140 mgd of water available for municipal use in the Ohio portion of Planning Subarea 4.2, with 30.3 mgd available by 1980. This will leave an additional need for new construction of 79.3 mgd by 2020.[47]

An additional 24 mgd of inland lake and stream source capacity is programmed for development in the Indiana portion of Planning Subarea 4.2. The remaining new construction needs are for 71.8 mgd by 2020.

Some of the capacity of this new construction will be used to replace existing facilities that have become obsolete. It will not all be used for additional water use.

Inland lakes and streams in Planning Subarea 4.2 potentially can yield more than 2,400 mgd if fully developed. Lake Erie is suitable for water supply uses and may be considered capable of supplying an unlimited quantity. It has also been estimated that 635 mgd of sustained yield are available from underground aquifers. The water resource in Planning Subarea 4.2 can meet all projected water uses and needs.

In the Ohio portion of Planning Subarea 4.2, consisting of 20 counties, four river basins, and 123 individual community sources, the Northwest Ohio State Water Plan presents a water-resource development plan for the area.[25]

The objective of the State Water Plan is to provide an adequate quantity of clean water for all the people for all uses. The approach is on a regional water management basis and

TABLE 6–96 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Planning Subarea 4.2 (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
Great Lakes	Capital	6.398	11.332	13.813	17.730	31.544
	Annual OMR	.318	1.202	2.455	1.521	3.976
	Total OMR	3.188	24.048	49.110	27.237	76.347
Inland Lakes and Streams	Capital	.000	14.830	27.179	14.830	42.009
	Annual OMR	.000	.739	2.832	.739	3.571
	Total OMR	.000	14.780	56.649	14.780	71.430
Ground Water*	Capital	.290	.768	1.087	1.058	2.146
	Annual OMR	.025	.116	.276	.141	.417
	Total OMR	.250	2.325	5.525	2.575	8.100
Total	Capital	6.689	26.931	42.081	33.620	75.701
	Annual OMR	0.344	2.057	5.564	2.401	7.967
	Total OMR	3.189	41.155	111.285	44.593	155.879

*Ground water unit cost assumptions are as follows:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells and pumping (see Figure 6-4)	25,000	17,400
Total	145,000	25,000

includes recreation, streamflow regulation, water quality control, agricultural water supply, flood control, and domestic and industrial water supply.

The Northwest Ohio State Water Plan in Planning Subarea 4.2 indicates that municipal water supply use in 1965 was 154 mgd, and that this use would more than triple by 2020. The plan provides for the construction of 35 multiple purpose upground reservoirs to serve 34 communities, 30 water intakes to serve 30 communities adjacent to streams, three intakes and pipelines to Lake Erie, and the drilling of 89 test wells to locate underground water supplies.

Water is relatively abundant in the area, but shortages exist in individual communities. Lake Erie is the largest single source of water. The main problems are management and paying the cost of the development.

The Northwest Ohio State Water Plan appears to be the best solution to the water supply needs in the Ohio portion of Planning Subarea 4.2.

In some cases it might be necessary for a proposed development in one watershed to supply a need in another watershed. Limited, further Level B study is warranted as a supplement to the existing Northwest Ohio State Water Plan.

6.3.5.2 Industrial

The total withdrawal demands by manufacturing industries in Planning Subarea 4.2 should increase 15 percent by the year 2000 and be about 100 percent larger than base year demands by the year 2020. Although the increasing demand would not appear to overtax the water resource base, there are problems of water supply for industries that will arise in meeting the water demands of new manufacturing facilities.

For the total manufacturing sector, output measured in value added by manufacture is forecast to increase from $3.409 billion in 1970 to $26.260 billion in 2020. If it is assumed that the existing plants can enlarge their operations at present locations by 100 percent, then some $20 billion of manufacturing activity, for which new water supplies must be developed, will be occuring at new locations. Figure 6–47 illustrates the changing characteristics of the industrial water demand during the 50-year planning period. In the preparation of this chart, the effects of improved recirculation practices by the SIC two-digit industries, the

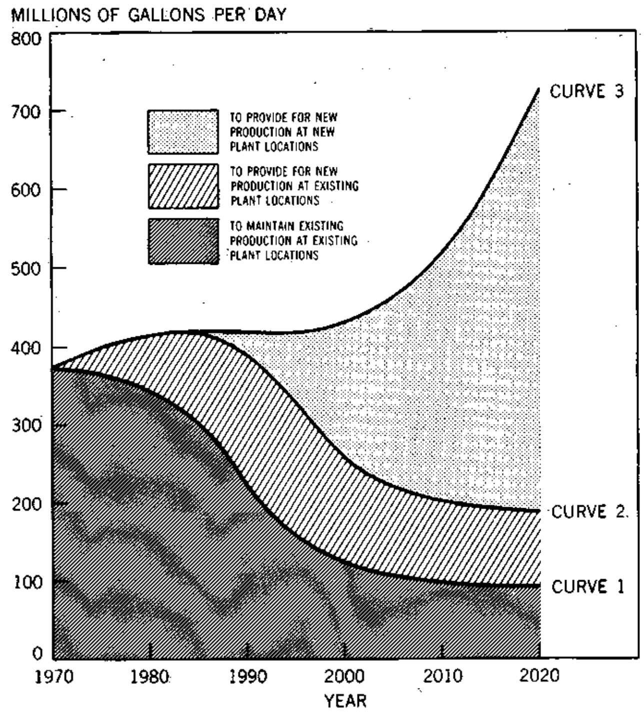


FIGURE 6–47 Total Withdrawal Demands for Manufacturing—Planning Subarea 4.2

increases in manufacturing output, and the basic assumption that existing plants will double their outputs during the first stages of the 50-year period are taken into account for development of the curves. Curve 1 represents the withdrawal demand to maintain 1970 production levels at existing plants. Curve 2 represents the withdrawal demand to maintain 1970 levels, assuming that the first 100 percent increase in production will occur at existing plants. Curve 3 represents total withdrawal demand for old and new production. The area between Curves 2 and 3 represents the withdrawal requirements for new production at new locations. By the year 2000, 180 mgd of industrial water will be required at locations where plants do not presently exist, and by the year 2020, the demand at new locations will be 535 mgd.

The problems associated with meeting those new withdrawal needs will be influenced by other planning goals such as land use, environmental quality, subregional economic development, the availability of the water supply, and facilities for its return to the resource base. Much of the new industrial development will occur in the inland counties if a sufficient water supply is available. The inland dispersal of new industries and the management of the water resource can best be achieved by the enlargement of municipal systems and the development of regional supply systems to provide the industrial water through the development of local sources and the transfer of large quantities from Lake Erie and upland reservoirs.

6.3.5.3 Rural

Future rural water requirements will be drawn primarily from ground-water sources, although in some areas streams will be increasingly important. The location and quality of ground water will be important in channeling additional development, particularly in the location of rural nonfarm dwellings. In areas where ground water is in short supply, development should proceed only after water supplies are located. Some areas will not develop until a central supply is available.

Rural water requirements are projected to increase 80 percent between 1970 and 2020, and consumption is expected to increase 44 percent during the same period.

Ground-water supplies in Planning Subarea 4.2 are fairly adequate in quantity, with the exception of a few areas. Water quality is a more critical problem. Throughout much of the area, water from carbonate-rock aquifers is very hard and highly mineralized. The dissolved solids content of some ground water is considerably above the limit recommended by the U.S. Public Health Service for drinking water. Iron is often present in high concentrations, as is hydrogen sulfide in localized areas.

6.4 Lake Erie Central, Planning Subarea 4.3

6.4.1 Description of Planning Subarea

6.4.1.1 Location

Eight northeastern Ohio counties make up this area, which lies on the south central shore of Lake Erie (Figure 6–48). The area is 110 miles long and 60 miles wide at the widest point.

6.4.1.2 Topography and Geography

Sedimentary bedrock, composed largely of limestone with overlying sandstone and shales, underlies the area. The sediments slope gently from west to east across the planning subarea. Erosion has cut deep valleys into the less resistant limestones, leaving elevated sandstone deposits. The Wisconsin glacier moved slowly across the entire planning subarea, depositing glacial till and outwash deposits and smoothing the bedrock outcrops to create a flat to rolling topography across the region. Elevations in the glaciated plateau generally range from 1,000 to 1,200 feet with some higher local areas in Geauga County. The lake plain area represents former lake shorelines. The very flat elevations in the lake plains are generally from 580 to 680 feet above sea level. A major feature known as the Portage Escarpment runs the length of the boundary between the lake plains and the plateau from Cleveland to the Pennsylvania border.

Five drainage basins combine to form a total drainage area of 3,640 square miles. These drainage basins are the Black-Rocky complex, the Cuyahoga River basin, the Chagrin complex, the Grand River basin, and the Ashtabula-Conneaut complex.

6.4.1.3 Climate

Planning Subarea 4.3 has a continental climate. Lake Erie has some moderating effects on the lakeshore counties. Average annual precipitation ranges from 33 to 43 inches, and is generally evenly distributed throughout the year. Rainfall increases from the shoreline inland and from southwest to northeast. Spring brings the most abundant rainfall, and snowfall depths reach up to 60 inches in Lake and Geauga Counties. The average frost-free period runs from 200 days along the Lake Erie shore to 150 days in inland counties. The basin as a whole has a mean annual temperature of 50°F with recorded extremes of −30°F and 100°F.

6.4.2 Water Resources

6.4.2.1 Surface-Water Resources

The streams of Planning Subarea 4.3 are typically short (100 miles or less) with low average discharges and low gradients. Average annual runoff varies from 11 to 18 inches across the region. Major problems in rural areas are siltation and the accumulation of

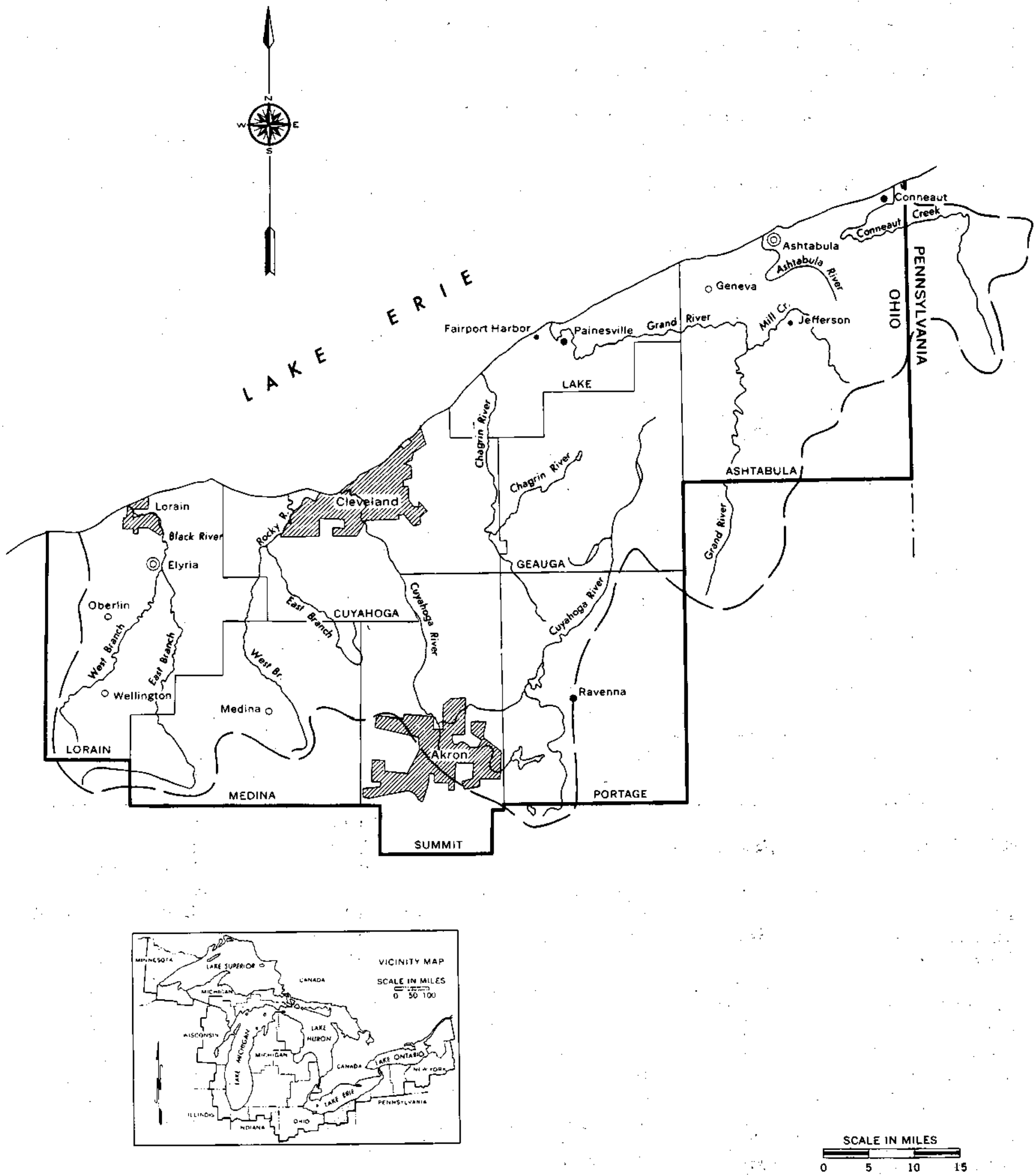


FIGURE 6-48 Planning Subarea 4.3

assorted pollutants in streams that ultimately reach Lake Erie. Additional degradation of the water resource results from industrial and municipal waste discharges. Deterioration of water quality is most severe near Lake Erie at the mouths of streams in the planning subarea.

Area streams and lakes reflect poor natural drainage conditions with dissolved solid concentrations and low quality water in most stream reaches due to municipal, industrial, and agricultural waste disposal practices.

Inland lakes and ponds are few (191) in the planning subarea drainage basins. Portage, Geauga, and Summit Counties contain most of the lakes in the planning subarea, which total 9,500 acres.

Fully developed water storage areas in inland lakes and streams provide an existing storage capacity of 32,070 acre-feet. If all inland lakes and streams suitable for development as surface-water impoundments were developed, the total potential storage capacity would increase to 2.34 million acre-feet.[45]

Presently developed water storage areas can produce a sustained water supply yield of 199 mgd. If all potential water storage areas were fully developed, impounded inland lakes and streams could produce a sustained water supply yield of 1,494 mgd.[45]

Potential capacities and yields used in this section relate to the total water resource. No attempt has been made to identify that portion of the water resource not suitable or available for use.

6.4.2.2 Ground-Water Resources

Availability of ground water varies across Planning Subarea 4.3. In general sandstones and sand and gravel deposits produce the largest quantities, while shale bedrock covered with clay or deposits of clay and silt produce little or no ground water. Those areas of least abundance are found in the till plain area along Lake Erie. The lower reaches of all drainage basins produce little ground water. Exceptions to this are the deposits near Cleveland and Garfield Heights which have produced up to 100 gpm. Inland areas in the upper reaches of the planning subarea drainage systems generally yield from 5 to 25 gpm. Pennsylvanian sandstones underlying the upper Cuyahoga River basin yield up to 100 gpm. In addition a few isolated areas like Akron and Cuyahoga Falls are capable of yielding up to 1,000 gpm.

Quality of ground water is also variable. Water from the Rocky River basin is generally very hard and contains high levels of dissolved minerals. The Black River basin's supply commonly contains salt and hydrogen sulfide. Waters of the Chagrin and lower Cuyahoga River basins are generally soft, but contain high iron concentrations.

Several of the aquifers (Silurian, Quarternary, Devonian, and Mississippian) have high total dissolved solids counts and exceed the 500 mg/l USPHS drinking water standard for total dissolved solids.

Ground-water yield in River Basin Group 4.3 is estimated to be 315 mgd (based on 70 percent flow-duration data).[21]

6.4.3 Water-User Profile

6.4.3.1 Municipal Water Users

In 1970 more than 3.0 million people resided in Planning Subarea 4.3. By 2020 the population is expected to exceed 5.5 million people. Nearly 30 percent of the State's total population is concentrated in 9 percent of its land area. Fifteen cities in 1970 had a total population exceeding 25,000, accounting for more than 64 percent of the planning subarea population. Cleveland and Akron have the highest populations, while their satellite communities make up the bulk of the remaining total population. Highest population densities are in Cuyahoga and Summit Counties and the adjacent shoreline counties, with an average population density of 932 people per square mile.

Population has continued to increase in areas surrounding the Cleveland-Akron complexes and along the Lake Erie shore. In 1960, 88.4 percent of the residents were classified as urban. Cuyahoga County, a virtually urbanized county, sustained a 99.6 percent urban population. In 1970 the average per capita income in Planning Subarea 4.3 was $4,600 (1970$).

Municipal water supplies served 2.7 million people (89 percent of the total population) in 1970. This is expected to increase to 5.2 million by 2020.

6.4.3.2 Industrial Water Users

Planning Subarea 4.3, one of the smallest in the Great Lakes Basin, is a giant among the manufacturing centers of the nation. In 1967 this eight-county, northeastern Ohio region accounted for 11 percent of the total value added by all Great Lakes manufacturers. Its manufacturing sector is vigorous and diverse and provides 42 percent of the total employment opportunities in the area. The products of the factories and mills range from basic chemicals to complex pharmaceuticals, from primary steel ingots to sophisticated machine tools, and from footwear to transportation equipment.. In the four-year period from 1963 to 1967, the value added by manufacture of these products increased from $4.9 billion to $6.5 billion for a gain of 33 percent, the most rapid rate of gain of any of the planning subareas of the Great Lakes Basin.

There are approximately 5,500 manufacturing establishments in the region, with the greatest concentrations in the vicinities of Cleveland, Akron, and Lorain, Ohio. Cleveland, located at the mouth of the Cuyahoga River on the Lake Erie shore, is the third largest Great Lakes port and is the port of entry and embarkation for large quantities of the raw materials and finished products of the region's manufacturers. There are more than 2,800 manufacturing plants in Cleveland alone. In the Counties of Cuyahoga, Lake, Geauga, and Medina, which comprise the Cleveland SMSA, an additional 1,300 factories are located. Among the largest of these plants are primary steel mills, metal fabricators, chemical plants, machine tool manufacturers, makers of power machinery, and transportation equipment.

In the inland City of Akron and in Summit and Portage Counties, which comprise the Akron SMSA, there are approximately 900 manufacturing plants. The rubber and plastic products, fabricated metal items, machinery and machine tools made in the factories of this two-county region supply national and world markets.

The Lorain-Elyria SMSA is within the boundaries of Lorain County whose most active economic centers are the City of Lorain, a Lake Erie port, and the inland City of Elyria. The major activities of the 270 manufacturing plants in the SMSA include the manufacture of primary metals products, metal fabrications, power machinery and equipment, and transportation equipment.

Ashtabula County and the City of Ashtabula are at the extreme northeastern part of the planning subarea. There are 160 manufacturing establishments in the city-county region, including major chemicals plants, rubber and plastic goods factories, metal fabricators, and electrical machinery makers.

Although Planning Subarea 4.3 has large land areas in many of the counties that are still predominantly rural, the general character of the region is highly technological, urban, and cosmopolitan. It has a world market for its products and its technology which are moved internationally through private and intergovernmental channels.

6.4.3.3 Rural Water Users

In 1964 Planning Subarea 4.3 contained 892,000 acres in farm. The Cities of Cleveland and Akron, Ohio, occupy a significant portion of the planning subarea. Orchards and vegetable crops, heavy water users, used more than 16,000 acres of cropland in 1964. Dairy production, a heavy water user, contributed well over half of the receipts of livestock and livestock products. Crop receipts totaled more than $42 million and livestock and livestock products more than $35 million in 1964. The 1960 census indicated 34,000 people living on farms and 13,000 employed on farms.

6.4.4 Present and Projected Water Withdrawal Requirements

Table 6–97 presents a summary of municipal, self-supplied industrial, and rural water use for Planning Subarea 4.3.

6.4.4.1 Municipal Water Use

Lake Erie and the streams of Planning Subarea 4.3 are the major sources of water supply for municipal, industrial, and agricultural purposes. Together these sources provided more than 1,600 mgd in 1970. Public water supply sources supplied more than 500 mgd in 1970. The City of Cleveland alone withdrew 395 mgd of Lake Erie water. The estimated 1970 population of Planning Subarea 4.3 is 3,029,500 people.

An average of approximately 517 mgd is currently being supplied to 2.7 million people, 89 percent of the total population, through municipal water systems in the planning subarea.

A breakdown of the various portions of this total average quantity, the maximum month average day, the maximum day, domestic and

TABLE 6–97 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Planning Subarea 4.3 (mgd)

Use	1970 mun.	1970 ind.	1970 rural	1970 total	1980 mun.	1980 ind.	1980 rural	1980 total
Withdrawal Requirements								
Ohio	516.9	1306	24.7	1848	610.2	1171	26.3	1808
Total	516.9	1306	24.7	1848	610.2	1171	26.3	1808
Consumption								
Ohio	52.0	85.3	5.8	143	82.0	117.1	5.9	205
Total	52.0	85.3	5.8	143	82.0	117.1	5.9	205
1970 Capacity-Future Needs								
Ohio	800.7	1306	24.7	2131	79.5	153	1.6	234
Total	800.7	1306	24.7	2131	79.5	153	1.6	234

Use	2000 mun.	2000 ind.	2000 rural	2000 total	2020 mun.	2020 ind.	2020 rural	2020 total
Withdrawal Requirements								
Ohio	800.3	1103	31.0	1934	1037	1946	33.4	3016
Total	800.3	1103	31.0	1934	1037	1946	33.4	3016
Consumption								
Ohio	101.0	338.1	6.9	446	140.1	781.0	7.9	929
Total	101.0	338.1	6.9	446	140.1	781.0	7.9	929
1970 Capacity-Future Needs								
Ohio	247.7	836	6.3	1090	494.8	1730	8.7	2234
Total	247.7	836	6.3	1090	494.8	1730	8.7	2234

commercial use, heavy manufacturing use, and developed water source capacities is shown in Table 6–98.

Approximately 409 mgd, 80 percent of the total, is used in the Cuyahoga River basin. About 143 mgd, 28 percent of the total demand, comes from ground-water sources, and 13 mgd of this is in the Cuyahoga River basin.

Generally the quality of water sources is good. Although there are some localized areas where surface-water pollution occurs, the quality is expected to improve with implementation of water quality management programs.

Water treatment for Lake Erie waters and some inland streams generally consists of coagulation, sedimentation, rapid sand filtration, and disinfection, with taste and odor control measures applied as needed. Some inland stream treatment plants and ground-water source plants use lime-soda softening. Ground-water treatment plants usually have iron and manganese removal, and some soften with ion exchange. A few small ground-water source systems have disinfection only.

The expansion of ground-water sources appears to be limited with the general trend to surface-water sources in the future.

The total per capita usage is 198 gpcd, of which domestic and commercial use account for 138 gpcd. Heavy industry water use accounts for the remainder. This per capita use is much higher than in northwestern Ohio, and is above the State average. The Black-Rocky complex shows the highest per capita consumption of 207 gpcd. Lower per capita consumption occurs for the Cuyahoga (195 gpcd) and Chagrin (133 gpcd) River basins, the

TABLE 6–98 Municipal Water Supply, Planning Subarea 4.3, Ohio (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Consumption
1970	GL	3029.5	2127.8	442.9	482.5	600.4	44.6
	IS		445.4	59.6	67.5	79.3	6.0
	GW		135.0	14.4	16.1	20.8	1.4
1980	GL	3476.3	2462.3	513.6	559.8	696.3	65.6
	IS		529.3	77.7	87.7	103.0	14.2
	GW		163.4	18.9	21.5	28.3	2.2
2000	GL	4389.2	3145.8	659.7	719.2	894.4	83.0
	IS		700.8	111.8	125.5	147.6	14.6
	GW		221.3	28.8	33.6	45.2	3.4
2020	GL	5526.5	3997.3	840.3	916.3	1139.2	113.9
	IS		914.4	156.3	174.8	206.1	21.3
	GW		293.5	40.2	47.7	65.2	4.9

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Consumption	Municipally Supplied Industrial Water: Average Demand	Consumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
1970	GL	138	320.8	32.0	122.1	12.6	689.4
	IS		41.1	4.1	18.5	1.9	80.0
	GW		12.2	1.2	2.2	0.2	31.3
1980	GL	140	372.1	37.2	141.5	28.4	75.8
	IS		53.2	9.3	24.5	4.9	--
	GW		16.1	1.6	2.8	0.6	3.7
2000	GL	142	478.1	47.9	181.6	35.1	232.1
	IS		75.8	7.6	36.0	7.0	3.1
	GW		24.5	2.6	4.3	0.8	12.5
2020	GL	144	609.1	61.0	231.2	52.9	426.2
	IS		105.3	9.6	51.0	11.7	45.3
	GW		34.3	3.5	5.9	1.4	23.3

Notes: Totals are generally rounded off to one decimal point. There is no Great Lakes source deficiency. The 1970 source capacity listed is works capacity. Akron's 40 mgd reservoir and Wellington's 1 mgd upground reservoir are assumed to be in use by 1980.

Ashtabula-Conneaut complex (127 gpcd), and the Grand River basin (95 gpcd).

Developed source quantities are adequate at present. Surface sources on Lake Erie have practically unlimited development potential and already provide 86 percent of the developed source quantity. Although inland stream sources amount to only 10 percent of the total water withdrawals, the expansion of inland stream source quantities is much more difficult.

Consumptive loss is approximately 52 mgd or 10 percent, with most of this being in the Cuyahoga basin where the largest cities, Cleveland and Akron, are located.

Diversions of raw water from one basin to another for treatment do not occur at present, but used treated water discharge diversions occur in several places. The population served from water withdrawals in the Ashtabula-Conneaut complex exceeds the estimated complex total population due to partial water service in the Grand basin. Also, the Chagrin basin population served is only a small portion of the total basin population due to withdrawals in the Cuyahoga and Grand basins being used and discharged in the Chagrin basin. There is no way to separate the data with the present methods of record keeping and reporting. Quantities of diversion of treated water from one river basin to another are unknown.

The total present diversion into or out of Planning Subarea 4.3 is probably insignificant. Although diversions within the area are likely to increase in future years, they probably will remain insignificant in the near future.

The average day in the maximum month of total municipal water usage per year is expected to increase from 566 mgd in 1970 to 669 mgd in 1980, 878 mgd in 2000, and 1,139 mgd in 2020 (Figure 6–49). The peak day water usage can be expected to more than double by 2020 from 700 to more than 1,400 mgd.

Approximately 10 to 14 percent of the total municipal water use will be consumptive loss and not returned to this planning subarea for reuse. This loss is expected to amount to 52 mgd in 1970, 82 mgd in 1980, 101 mgd in 2000, and 140 mgd in 2020.

Although the existing capacity for Lake Erie is listed at 690 mgd, this is not the total source available and is based largely on water works capacity. The source is practically unlimited.

The developed source capacities for inland streams indicate 80 mgd. The 1 mgd Wellington Reservoir under construction and the proposed 40 mgd Akron Hubbard Road Reservoir to be constructed in the next decade increase the developed source to 121 mgd available in 1980. An additional 3.1 mgd in 2000 and 45.3 mgd in 2020 may be necessary, but the use of the Lake Erie water source can satisfy the requirements. If the Grand River Reservoir is constructed, it can satisfy a major portion (40 mgd) of this need.

The developed source capacities for ground water indicate 31.3 mgd in 1970, but these data are generally based on a limiting works capacity and do not reflect safe yields of the aquifers. Apparent needs of 3.7 mgd in 1980, 12.5 mgd in 2000, and 23.3 mgd in 2020 can be at least partially satisfied by additional wells or switching to existing surface-water sources.

The water resource available in the plan-

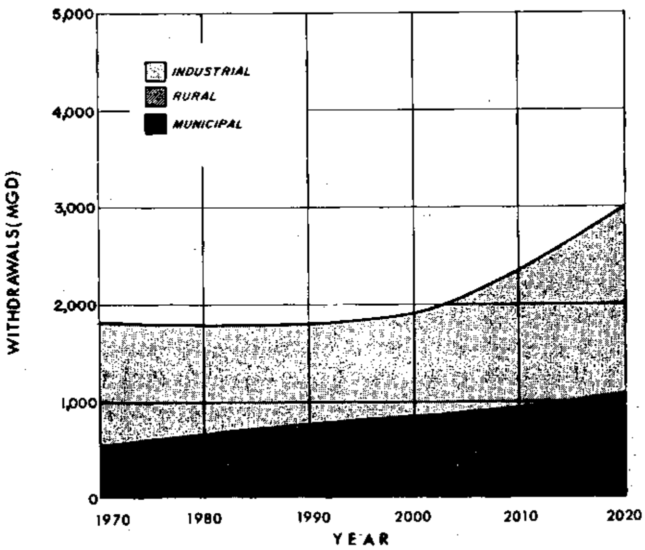


FIGURE 6–49 Municipal, Industrial, and Rural Water Withdrawal Requirements—Planning Subarea 4.3

Planning Subarea 4.3 is a highly populated portion of the Lake Erie basin. The total population was 3.0 million people in 1970. Municipal water supplies served 90 percent of the population or 2.7 million people in 1970. This is expected to increase to 5.2 million by 2020.

Agriculture occupies a relatively small portion of the planning subarea's economic activity, employing 1 percent of the total working force. Truck and dairy farming and specialty crops are prevalent.

This planning subarea contains the largest manufacturing and population concentration in Ohio. Steel production and rubber tire production are major industrial activities. Manufacturing employs 40 percent of the total working population.

ning subarea appears to be adequate to meet future needs through 2020.

6.4.4.2 Industrial Water Use

The total water withdrawals for all manufacturing in Planning Subarea 4.3 are estimated at 1,450 mgd in 1970, of which 1,305 mgd were self-supplied and 145 mgd obtained from public water supply systems. At present manufacturing water demands are the largest in the planning subarea, four times larger than the quantities withdrawn for domestic and commercial uses, and approximately 40 percent larger than the withdrawals by electric power utilities. The manufacturing sector reuses and recirculates its water, with an average recirculation rate of 1.93 in 1970, but the practice of recirculating water is expected to expand rapidly. For example, within the primary metals industry group, facilities now under construction will enable the reduction of water withdrawals by more than 100 mgd.

Greater reuse of water throughout the sector will permit the continued expansion of industrial production to occur in the planning subarea until the year 2000 without requiring an increase in total quantities withdrawn. By 1980 the withdrawal demand is expected to be 1,340 mgd, falling further to 1,320 mgd by the year 2000. Between 2000 and 2020 the withdrawal demand will increase sharply, rising to 2,130 mgd in the year 2020. The rising withdrawal requirement will accompany a growth in manufacturing production of an estimated $24 billion in value added by manufacture during the same period. Because improvements in recirculation of industrial water will be much slower after 2000, the gross water demand for the enlarged production will require increasingly larger water withdrawals.

Table 6-99 presents the base-year estimates and projections of five water-use parameters and constant dollar estimates of value added by manufacture for the five major water-using SIC two-digit industry groups and the residual manufacturing groups that comprise the industrial sector. The water-use estimates represent the needs of all establishments without differentiation between small or large water users. The large water-using establishments (those that withdrew 20 million gallons per year or more) are relatively few in number and probably do not exceed 220 factories, but they account for 97 percent of the total withdrawal needs of the entire manufacturing sector.

As may be seen in Table 6-99, two industry groups, SIC 28 and SIC 33, account for 90 percent of the total manufacturing water withdrawals in 1970. SIC 28, Chemicals and Allied Products, is a difficult industry to assess because of the diversity of its manufacturers and the rapid shifts in products and manufacturing processes. Each of the major water-using industries within the SIC 28 industry group share one common characteristic: the greatest part of their water requirements is for cooling and condensing because of the exothermal and endothermal processes generally involved in chemical manufacture. The projection of the withdrawal demand for this industry group in Planning Subarea 4.3 assumes that recirculation of cooling water will be increased so that the average recirculation rate for all water uses within the SIC 28 establishments will average 15.0 by the year 2020. In spite of the improved recirculation rate, the withdrawal demand for this industry group will increase to 1,400 mgd by the year 2020 because of the expansion of production.

SIC 33, Primary Metals Industries, at present the largest water-using SIC two-digit industry group in the planning subarea, had a withdrawal demand of 810 mgd in 1970. This industry group will continue to reduce its withdrawals to 310 mgd by the year 2020. Despite a growth in value added by manufacture of nearly 350 percent, this decrease will occur because of improvements in the average water recirculation rate from the present 1.78 to an estimated 12.0.

Improved recirculation rates have been forecast for all industry groupings in the manner discussed in the methodology.

6.4.4.3 Rural Water Use

Rural water requirements and consumption were estimated for Planning Subarea 4.3 following the methodology outlined in Subsection 1.4. Table 6-100 divides total requirements and consumption into categories of rural nonfarm and rural farm. Rural farm is further divided into domestic, livestock, and spray water requirements.

6.4.5 Needs, Problems, and Solutions

6.4.5.1 Municipal

Table 6-97 shows the capacity of existing

TABLE 6-99 Estimated Manufacturing Water Use, Planning Subarea 4.3 (mgd)

	SIC 20	SIC 26	SIC 28	SIC 29	SIC 33	Other Mfg.	Total
1970							
Value Added							
(Millions 1958$)	265	97	674	106	1025	4156	6323
Gross Water Required	35	31	989	41	1440	250	2786
Recirculation Ratio	2.36	3.74	2.01	0.2	1.78	2.43	--
Total Water Withdrawal	15	8	492	21	810	103	1449
Self Supplied	--	--	--	--	--	--	1306
Water Consumed	1.9	1.4	28	6	52	11	100
1980							
Value Added							
(Millions 1958$)	335	150	1291	160	1350	6101	9387
Gross Water Required	42	49	2020	62	1875	235	4283
Recirculation Ratio	2.77	6.03	3.64	3.0	2.82	3.05	--
Total Water Withdrawal	15	8	555	21	665	77	1341
Self Supplied	--	--	--	--	--	--	1171
Water Consumed	2.2	1.7	56	9	67	15	151
2000							
Value Added							
(Millions 1958$)	506	318	4552	372	2184	12761	20693
Gross Water Required	53	90	8073	144	2750	816	11926
Recirculation Ratio	3.15	8.00	11.7	3.5	7.06	4.80	--
Total Water Withdrawal	17	11	690	41	390	170	1319
Self Supplied	--	--	--	--	--	--	1103
Water Consumed	2.6	3.0	225	22	96	32	381
2020							
Value Added							
(Millions 1958$)	805	649	11910	801	3540	27074	44779
Gross Water Required	88	158	21000	310	3720	1760	27036
Recirculation Ratio	3.50	8.00	15.0	4.0	12.0	5.86	--
Total Water Withdrawal	25	20	1400	76	310	300	2131
Self Supplied	--	--	--	--	--	--	1946
Water Consumed	4.2	5.6	590	46	132	69	847

TABLE 6-100 Rural Water Use Requirements and Consumption, Planning Subarea 4.3 (mgd)

	1970	1980	2000	2020
REQUIREMENTS				
Rural Farm				
Domestic	1.8	0.9	0.7	0.8
Livestock	2.6	2.4	2.9	3.8
Spray Water	0.0	0.0	0.0	0.0
Subtotal	4.4	3.3	3.7	4.6
Rural Nonfarm	20.3	22.9	27.3	28.9
Total	24.7	26.3	31.0	33.4
CONSUMPTION				
Rural Farm				
Domestic	0.5	0.2	0.2	0.2
Livestock	2.3	2.2	2.6	3.4
Spray Water	0.0	0.0	0.0	0.0
Subtotal	2.8	2.4	2.8	3.6
Rural Nonfarm	3.0	3.4	4.1	4.3
Total	5.8	5.9	6.9	7.9

water supply source developments in the 1970 column. Cumulative water supply needs are shown for 1980, 2000, and 2020. A cushion of excess capacity is necessary for future as well as existing development. Construction for 2,234 mgd of new water supply capacity is needed in Planning Subarea 4.3 by the year 2020. Of this total need, 1,144 mgd or 51 percent is required between 2000 and 2020. Additional water supply capacity totaling 234 mgd is needed from 1970 to 1980. The 1980 to 2000 period will require an additional 856 mgd.

The projected need for municipal water supply capacity in Planning Subarea 4.3 is 495 mgd by the year 2020 (Table 6–98). Of this total, 426 or 84 percent is derived from Lake Erie sources.

Estimated costs for new construction and associated operations are shown in Table 6–101. All estimates are adjusted to January 1970 price levels. The costs include conveyance of the water supply and water treatment, but not surface-water storage and intraurban distribution costs.

The greatest costs are concentrated in the Cuyahoga River basin. However, estimates of costs will be dependent upon the extent of regionalization of distribution and the selection of future alternative sources, i.e., Lake Erie, the Grand Reservoir, and inland stream reservoirs. At this time no information about these factors is available.

There is a need for more efficient management of existing systems, elimination of small inefficient systems, extension of some individual systems to greater areawide distribution, provision of adequate financing and more equitable rate adjustments, and overcoming legal obstacles or public opposition to projects. Most of the new water supply in Planning Subarea 4.3 should come from Lake Erie sources. The quantity of Lake Erie water is more than adequate for meeting this demand. However, problems remain in the financing and management of this enormous amount of municipal water supply.

The Ashtabula-Conneaut River basin complex is the only drainage basin where there are no projected water resource deficiencies. Deficiencies in the other drainage basins can be corrected by expansion of existing well fields or by expansion of service areas of certain water supply systems. The Northeast Ohio Development Plan may be referred to for proposed solutions to specific water supply deficiency problems.[30]

Water is relatively abundant in the area, but shortages exist in individual communities. Lake Erie is the largest single source of water. The main problems are management and paying the costs of development. The Northeast Ohio Water Management Plan contains a detailed discussion of the needs and problems confronting the various communities of the planning subarea and potential solutions to the problems. The program for development of the Northeast Ohio Water Management Plan proceeds through four stages: Inventory, Demand Projections, Project Development, and Formulation of the Comprehensive Plan.

TABLE 6–101 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Planning Subarea 4.3 (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
Great Lakes	Capital	22.664	46.733	58.035	69.397	127.433
	Annual OMR	1.129	4.587	9.808	5.717	15.525
	Total OMR	11.294	91.754	196.173	103.048	299.221
Inland Lakes and Streams	Capital	.000	.926	12.617	.926	13.544
	Annual OMR	.000	.046	.721	.046	.767
	Total OMR	.000	.923	14.423	.923	15.347
Ground Water*	Capital	.540	1.284	1.576	1.825	3.401
	Annual OMR	.044	.196	.434	.241	.676
	Total OMR	.449	3.936	8.699	4.386	13.085
Total	Capital	23.204	48.946	72.231	72.231	144.381
	Annual OMR	1.174	4.831	10.965	6.005	16.970
	Total OMR	11.744	96.615	219.295	108.358	327.655

*Ground water unit cost assumptions are as follows:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells & pumping (see Figure 6-4)	26,000	16,700
total	146,000	24,300

6.4.5.2 Industrial

Figure 6–50 illustrates the changing characteristics of the industrial water demand in Planning Subarea 4.3 for the period 1970 to 2020, during which the output of manufacturers is expected to grow from $6.323 billion value added by manufacture to $44.779 billion. The gross water requirements to support the expansion of production of more than 700 percent will increase proportionally. If the present practices of limited recirculation of water were to continue, by 2020 nearly 10,000 mgd of water would be necessary. However, improvements in water management by industries should result in withdrawals of only 2,130 mgd by 2020.

The 700 percent increase in manufacturing output will occur in part by increasing production at existing plant locations. However, because of limitations of land at many sites, environmental quality goals, subregional economic goals, availability of water and other factors, much of the new production will occur in new plants at new locations. Figure 6–50 is constructed on the assumption that the first 100 percent increase in value added will come at existing plants by the late 1980s. After that all growth in output will occur in new plants at new locations. Thus, during the early period of industrial expansion all water withdrawal demands for the first 100 percent increase in production are assumed to be supplied from existing sources out of the excess water supply conserved by recirculation. All new production is assumed to require new water source development. Curve 1 represents the withdrawal demand to maintain 1970 production levels at existing plants. Curve 2 represents the withdrawal demand to maintain 1970 levels plus the first 100 percent increase in production at existing plant locations. Curve 3 represents the total withdrawal demand for existing plus new production at all locations. The area between Curves 2 and 3 represents the withdrawal requirements for new production at new locations. By the year 2000, 520 mgd of industrial water will be required at locations where plants do not presently exist, and by the year 2020, the demand at new locations will be 1,520 mgd.

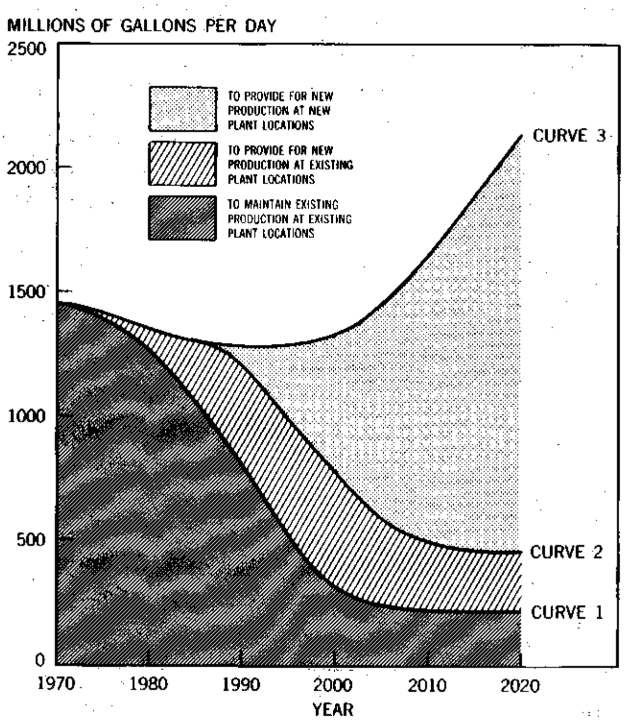


FIGURE 6–50 Total Withdrawal Demands for Manufacturing—Planning Subarea 4.3

Only 10 percent of the present water withdrawal requirements of the manufacturing sector are supplied from municipal water systems, with the remaining 90 percent self-supplied by the individual plants. All manufacturing plants in the planning subarea obtain water from municipal systems, but the cost of the water generally limits its use to essential employee needs and the relatively minor manufacturing process demands. For plants with large requirements for process and cooling water, company-owned and operated supply facilities are developed. Except for the inland area around Akron, which has water system capacity to serve several large industrial users, the majority of the very large water-using factories are located near the shore of Lake Erie or along the banks of the Cuyahoga, Black, Rocky, Chagrin, Grand, and Ashtabula Rivers.

The potential for developing inland surface-water and ground-water sources to meet the large new industrial water demand of the future does not appear to be feasible at present. Yet, if the crowding of the greatly enlarged manufacturing sector of the future along the shoreline of Lake Erie and the lower reaches of the rivers is to be avoided, consideration should be given to the development of new inland industrial areas and the development of regional industrial water supply schemes to transport large volumes of Lake Erie water to the inland locations. The return of water from the new inland industries to Lake Erie will introduce new problems in management of both the quality and quantity of the water in the return flow channels and structures.

6.4.5.3 Rural

Future rural water requirements will be drawn primarily from ground-water sources, although in some areas streams will be increasingly important. The location and quality of ground water will be very important in channeling additional development, particularly in the location of rural nonfarm dwellings. In areas where ground water is in short supply, development should proceed only after proven water supplies are located. Some areas will not develop until a central supply is available.

Rural water requirements are expected to increase 36 percent from 1970 to 2020, and consumption is expected to increase 37 percent during the same period.

Low yielding aquifers characterize much of Planning Subarea 4.3. Most can yield only a few gallons per minute to wells. The mineral content of the water at relatively shallow depths in the bedrock can cause problems. The salinity of the bedrock aquifers increases toward the south. In many areas along Lake Erie potable ground-water sources have been contaminated by salt water and oil leaking from improperly abandoned oil and gas test holes. Iron and manganese are present in most aquifer waters. There appear to have been no long-term water level declines.

6.5 Lake Erie East, Planning Subarea 4.4

6.5.1 Description of Planning Subarea

6.5.1.1 Location

Planning Subarea 4.4, located at the eastern end of Lake Erie, consists of four counties in western New York State and one county in northwestern Pennsylvania (Figure 6–51). The area is 115 miles long and 95 miles wide at its longest and widest points.

6.5.1.2 Topography and Geography

Planning Subarea 4.4 can be divided into two areas, the lake plain and the upland plateau. The lake plain is relatively flat except for the wave-cut escarpments of glacial lakes at higher levels. The upland plateau has a smoothly rolling surface cut by valleys at various intervals. The entire planning subarea is underlain by sedimentary rock, sandstone, shale, limestone, and dolomite.

Drainage in the planning subarea is generally from southeast to northwest. Streams rise in the upland plateau and flow into Lake Erie or the Niagara River. The Erie-Chautauqua complex, Cattaraugus Creek, and Tonawanda Creek, the major drainage basins in this planning subarea, combine to form a total drainage area of 761 square miles.

6.5.1.3 Climate

The climate of Planning Subarea 4.4 is classified as humid continental and characterized by variations in weather common to the interior of large land masses. Winters are cold and snowy; summers are warm and dry on the lake plain and warm and humid on the upland plateau. Pressure centers move from west to east bringing weather from the interior of the continent. Lake Erie has a moderating influence on the climate of the lake plain. The growing season varies from 120 to 165 days, increasing from northwest to southeast.

Precipitation is adequate and averages from 32 to 48 inches per year. Floods may be expected to occur at any time of the year, but they are most probable in the spring months.

The temperature range is from 78°F to 84°F in the summer and 17°F to 25°F in the winter.

6.5.2 Water Resources

6.5.2.1 Surface-Water Resources

Of the approximately 3 million acres comprising Planning Subarea 4.4, 45,900 acres are surface water. Chautauqua Lake in Chautauqua County, with 12,700 acres of surface, is the largest inland lake. Runoff averages 20 inches annually.

Presently there are no fully developed water storage areas in the planning subarea's inland lakes and streams. If all inland lakes and streams suitable for development as surface-water impoundments were developed, the total potential storage capacity would be 886,000 acre-feet.[45]

At present there are no developed water storage areas. If all potential water storage

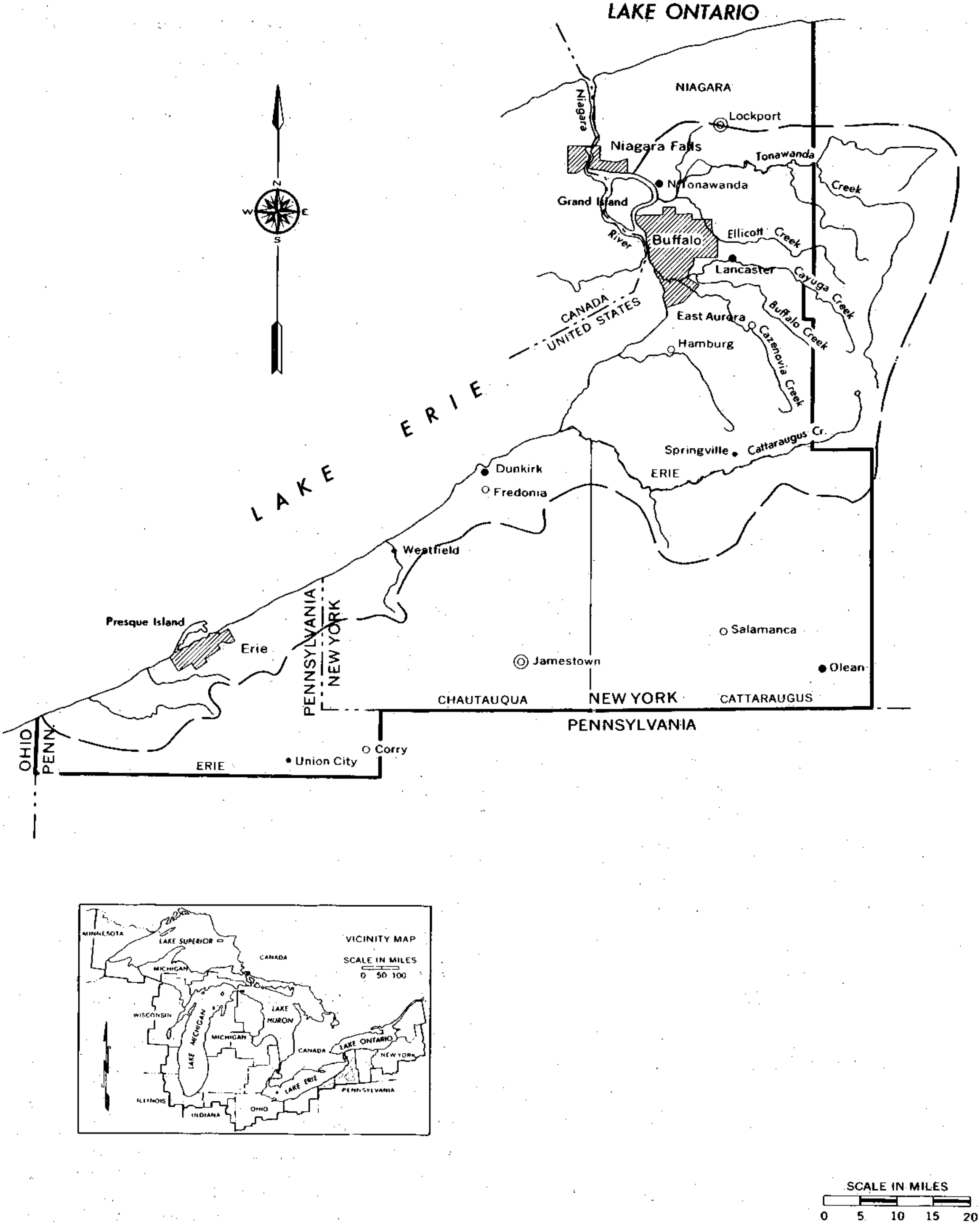


FIGURE 6–51 Planning Subarea 4.4

areas were fully developed, impounded inland lakes and streams could produce a sustained water supply yield of 1,585 mgd.[45]

Potential capacities and yields used in this section relate to the total water resource. No attempt has been made to identify that portion of the water resource not suitable or available for use.

6.5.2.2 Ground-Water Resources

Ground-water reserves are abundant. Yields are especially high in glacial deposits of sand and gravel found in partially buried valleys prevalent in the area. Water obtained from these deposits is generally hard. Yields from bedrock are not as great, except from limestone formations in the New York counties of Erie and Niagara.

Ground-water yield in River Basin Group 4.4 is estimated to be 380 mgd (based on 70 percent flow-duration data).[21] Three of the aquifer systems (Quaternary, Silurian, Silurian-Devonian) yield water that exceeds the 500 mg/1 USPSH recommended drinking water standard for total solids.

6.5.3 Water-User Profile

6.5.3.1 Municipal Water Users

In 1970 the population of Planning Subarea 4.4 was 1.8 million people, 80 percent classified as urban and the remaining 20 percent classified as rural. The 2020 population is projected to exceed 3 million persons.

The population is concentrated in and around the Cities of Niagara Falls and North Tonawanda along the Niagara River, Buffalo and Cheektowaga at the eastern end of Lake Erie, and Erie, Pennsylvania, on the southern shore of Lake Erie. Average population density is 713 people per square mile, with the highest concentration in Niagara and Erie Counties, New York, and Erie County, Pennsylvania.

Municipal water supplies served 1.7 million people in 1970, 91 percent of the population. Average per capita annual income was $4,236 (1970$) in 1970. The population served by municipal water supplies is predicted to be 2.8 million people by 2020. Manufacturing employs 38 percent of the area's population, while 6 percent are employed in agricultural activity.

6.5.3.2 Industrial Water Users

Manufacturing activities are concentrated in the vicinity of Erie, Pennsylvania, and the Buffalo, New York, SMSA, which includes Erie and Niagara Counties in New York State. The planning subarea is composed of Erie County, Pennsylvania, and the New York counties of Cattaraugus, Chautauqua, Erie, and Niagara. It includes the eastern end of Lake Erie, the U.S. portion of the Niagara River, and the southwestern shoreline of Lake Ontario. More than 2,600 manufacturing establishments were active in this five-county region in 1967. The total value added by manufacture in those plants was more than $3.6 billion, an increase of nearly 33 percent over the 1963 level of production.

Only a small portion of Erie County, Pennsylvania, lies within the Great Lakes Basin. The land rises from much of the lakeshore in steep bluffs 100 to 200 feet high and the watershed between the Great Lakes and Ohio River basins lies from only 6 to 13 miles inland. The City of Erie, located at Erie Harbor behind the 7-mile long Presque Isle Peninsula, is the center of population and economic activity in the county. Nearly all of the county's food processing, steel manufacture, paper and paper products, fabricated metal, and industrial machinery industries are located in this vicinity. Industrial water supply for the larger plants is obtained primarily through industry-operated intakes in Lake Erie, and to a lesser extent from the steep gradient streams of the region.

Chautauqua County, the westernmost New York county in the planning subarea, is similar in terrain to Erie County, Pennsylvania, with high bluffs rising sharply from the lakeshore and the watershed boundary lying only 4 to 13 miles inland from the Lake. Except for the small cities of Dunkirk, Fredonia, Silver Creek, and Westfield, this portion of the planning subarea is predominantly rural and woodland. The few industries center around food processing, metal fabrication, and textiles and draw their water supplies from Lake Erie and the several major creeks of the area.

Few industries are located in the portion of Cattaraugus County that lies within the Great Lakes drainage basin. Cattaraugus Creek is the boundary between Cattaraugus and Erie Counties, New York, and its drainage basin is predominantly rural and not heavily populated. Industries in this region include food processing plants, canneries, and small minor manufacturing plants.

The remaining portions of Erie and Niagara Counties are dominated by the Cities of Buffalo and Niagara Falls and the many large and small communities in the vicinity. In the Buffalo SMSA there are approximately 1,700 manufacturing establishments engaged in the production of a wide variety and large volume of goods. Major industries are food products, paper and paperboard, basic chemicals and plastics, petroleum and coal products, steel and iron, fabricated metals, general industrial machinery, and transportation equipment.

6.5.3.3 Rural Water Users

In 1964 Planning Subarea 4.4 contained 1.45 million acres of land in farm. Meadow crops exceeded 290,000 acres. Fruits and vegetables, heavy water users, contributed more than 37,000 and 47,000 acres respectively. Dairy farmers, a heavy water user, contributed more than three-fourths of the value of livestock and livestock product sales. Crop sales totaled $47 million and livestock and livestock product sales $64 million in 1964. The 1960 census listed 48,000 people living on farms and 14,000 employed on farms.

6.5.4 Present and Projected Water Withdrawal Requirements

6.5.4.1 Municipal Water Use

Lake Erie and the Niagara River supply the major portion of the Planning Subarea 4.4 municipal water supply. The Cities of Buffalo and Erie get their water from Lake Erie, while Niagara Falls and North Tonawanda obtain their water from the Niagara River. Approximately 70 percent of the total municipal water withdrawals serves these four cities.

Water supply needs for additional growth are shown in the 1980, 2000, and 2020 columns of Table 6–102 and in Figure 6–52. The current capacity of existing source developments is shown for 1970. A cushion of excess capacity is necessary. A total of 1,124 mgd of additional constructed capacity is needed to supply additional water uses in Planning Subarea 4.4 by the year 2020. Of this total need, 525 mgd or 47 percent is required between 2000 to 2020. Additional capacity totaling 153 mgd is needed by 1980. The 1980 to 2000 time period will require an additional 446 mgd.

The estimated total population of Planning Subarea 4.4 is 1.85 million persons. The data show that 1.7 million persons, or 91 percent of the total population, are being supplied water through central water systems.

An average of approximately 327 mgd is currently being supplied through central municipal water systems. A breakdown of the various portions of this total average quantity used in each State portion of the planning subarea and for heavy water-using industry and domestic and commercial purposes is shown in Tables 6–103, 6–104, and 6–105.

The bulk of the water use, more than 76 percent, is in the Tonawanda River basin. More

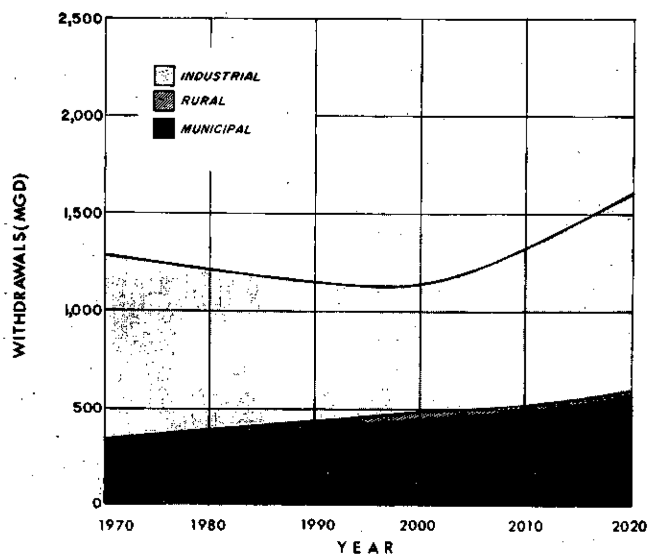


FIGURE 6–52 Municipal, Industrial, and Rural Water Withdrawal Requirements—Planning Subarea 4.4

The population of Planning Subarea 4.4 is concentrated in and around the Cities of Niagara Falls, North Tonawanda, and Buffalo in New York, and Erie in Pennsylvania. Municipal water supplies served 1.7 million people or 91 percent of the population of 1.85 million in 1970. The population served is predicted to be 2.8 million by 2020.

The planning subarea is largely an industrial region with only 6 percent of the working force employed in agricultural activity. Meadow crops are dominant, with some fruit and vegetable production.

Manufacturing employs 38 percent of the population. Electrical machinery, motor vehicles, transportation equipment, and food and kindred products are major industries.

TABLE 6-102 Summary of Municipal, Industrial, and Rural Water Use, Planning Subarea 4.4 (mgd)

	1970				1980			
Use	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
New York	272.1	911	13.8	1197	301.4	826	13.6	1141
Pennsylvania	55.1	35	2.8	93	64.5	28	2.8	95
Total	327.2	946	16.6	1290	365.9	854	16.4	1236
Consumption								
New York	24.6	79	5.3	109	28.5	111	5.9	146
Pennsylvania	5.4	3	1.1	9	6.3	4	1.2	11
Total	30.0	82	6.4	118	34.8	115	7.1	157
1970 Capacity-Future Needs								
New York	412.8	911	13.8	1338	30.8	110	--	141
Pennsylvania	78.0	35	2.8	115	8.3	4	--	12
Total	490.8	946	16.6	1453	39.1	114	--	153

	2000				2020			
Use	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
New York	372.6	639	19.5	1031	463.0	948	26.3	1437
Pennsylvania	81.0	30	4.0	115	97.9	62	5.3	165
Total	453.6	669	23.5	1147	560.9	1010	31.6	1602
Consumption								
New York	40.3	222	7.3	270	49.0	453	9.1	511
Pennsylvania	7.9	10	1.5	19	9.9	22	1.8	34
Total	48.2	232	8.8	289	58.9	475	10.9	545
1970 Capacity-Future Needs								
New York	113.0	434	5.7	553	219.2	797	12.5	1029
Pennsylvania	24.7	20	1.2	46	40.8	52	2.5	95
Total	137.7	454	6.9	599	260.0	849	15.0	1124

than 91 percent or approximately 300 mgd is supplied from Lake Erie and connecting channel sources. Heavy water-using industries in Planning Subarea 4.4 are being supplied approximately 89 mgd, 27 percent of the total municipal water supply.

Approximately 312 mgd, 95 percent of the planning subarea's municipal water supply, are received from surface waters and require purification treatment including coagulation, sedimentation, filtration, and disinfection. The remaining ground-water supplies are disinfected and some receive a type of corrective treatment such as softening or iron removal.

The total average municipal water supply requirements are expected to increase by 1.1 times to 366 mgd by 1980, 1.4 times to 454 mgd by 2000, and 1.7 times to 561 mgd by 2020. The average day in the maximum month of total municipal water use per year is expected to increase from 393 mgd in 1970 to 439 mgd in 1980, 545 mgd in 2000, and 673 mgd in 2020.

Approximately 10 percent of the municipal water use will be consumptive loss. The con-

TABLE 6–103 Municipal Water Supply, Planning Subarea 4.4, New York and Pennsylvania (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Consumption
	GL		1478.0	300.3	360.4	449.5	27.7
1970	IS	1851.9	82.0	11.3	13.6	17.4	0.8
	GW		140.4	15.6	18.7	23.5	1.5
	GL		1609.4	331.4	397.8	497.1	31.6
1980	IS	2018	93.6	14.1	16.9	21.0	1.2
	GW		159.0	20.4	24.4	30.4	2.0
	GL		1981.0	410.5	493.0	616.6	43.8
2000	IS	2454	110.1	18.2	21.8	27.3	1.8
	GW		184.1	24.9	29.9	37.3	2.6
	GL		2444.4	508.3	609.8	762.5	53.5
2020	IS	2977.3	125.6	22.4	26.8	33.7	2.3
	GW		212.6	30.2	36.2	53.7	3.1

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Consumption	Municipally Supplied Industrial Water: Average Demand	Consumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
	GL		211.2	21.1	99.1	6.6	422
1970	IS	130.6	7.7	0.7	3.6	0.1	25.8
	GW		13.3	1.2	2.3	0.3	43.0
	GL		217.2	22.2	114.2	9.4	32.1
1980	IS	131	9.3	0.9	4.8	0.3	2.9
	GW		17.4	1.7	3.0	0.3	4.1
	GL		272.4	26.2	138.1	17.6	122.4
2000	IS	134.3	12.0	1.1	6.2	0.7	7.1
	GW		21.2	2.1	3.7	0.5	8.2
	GL		340.6	33.7	167.7	19.8	235.6
2020	IS	137.2	15.4	1.5	7.0	0.8	10.7
	GW		25.9	2.5	4.3	0.6	13.7

sumptive loss can be expected to amount to 35 mgd in 1980, 48 mgd in 2000, and 59 mgd in 2020.

6.5.4.2 Industrial Water Use

Table 6–106 presents the base-year estimates and projections of five water-use parameters and constant dollar estimates of value added by manufacture for the five major water-using SIC two-digit industry groups, the combined residual manufacturing group, and the total manufacturing sector of Planning Subarea 4.4. The total water withdrawals for all manufacturing are estimated to have been 1,050 mgd in 1970, of which 945 mgd were self-supplied and 105 mgd were obtained from

TABLE 6–104 Municipal Water Supply, Planning Subarea 4.4, New York (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Con-sumption
1970	GL	1617.9	1311.0	248.5	298.2	371.7	22.5
	IS		76.3	9.5	11.4	14.7	0.5
	GW		126.0	14.1	16.9	21.3	1.4
1980	GL	1765.1	1424.4	271.1	325.3	406.6	25.6
	IS		86.2	11.8	14.1	17.6	1.1
	GW		141.9	18.5	22.2	27.6	1.8
2000	GL	2144.0	1759.0	334.9	402.3	502.9	36.2
	IS		100.9	15.1	18.1	22.7	1.7
	GW		164.7	22.6	27.1	33.9	2.4
2020	GL	2617.3	2189.4	417.3	500.8	626.0	44.1
	IS		115.3	18.6	22.3	28.0	2.1
	GW		190.9	27.1	32.6	49.1	2.8

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Con-sumption	Municipally Supplied Industrial Water: Average Demand	Con-sumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
1970	GL	116.9	158.7	16.8	89.8	5.7	352.0
	IS		6.5	0.4	3.0	0.1	22.8
	GW		11.9	1.1	2.2	0.3	38.0
1980	GL	116.5	169.1	17.5	101.2	8.1	25.4
	IS		7.9	0.8	3.9	0.3	2.1
	GW		15.6	1.5	2.9	0.3	3.3
2000	GL	120.8	215.3	20.5	119.6	15.7	101.1
	IS		10.3	1.0	4.8	0.7	5.2
	GW		19.0	1.9	3.6	0.5	6.7
2020	GL	124.2	273.6	26.7	143.7	17.4	199.7
	IS		13.4	1.3	5.2	0.8	8.1
	GW		23.0	2.2	4.1	0.6	11.4

public water supply systems. Although the availability of water from Lake Erie and the rivers and streams of the region allows for larger withdrawals, the manufacturers re-used and recirculated the water withdrawn 2.22 times to make it equivalent to their larger gross water requirements of 2,340 mgd.

Improvements in the average rates of recirculation of water in all manufacturing groups should continue over the next 50 years as the industrial output of the region grows from its present level of $3,747 billion value added by manufacture to $24,643 billion in the year 2020. The combination of individual industry growth rates and the implementation of improved recirculation practices should result in a decline of water withdrawals to 975 mgd in 1980 and 820 mgd in the year 2000. Because

TABLE 6–105 Municipal Water Supply, Planning Subarea 4.4, Pennsylvania (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Con-sumption
1970	GL	234	167	51.8	62.2	77.8	5.2
	IS		5.7	1.8	2.2	2.7	0.1
	GW		14.4	1.5	1.8	2.2	0.1
1980	GL	253	185	60.3	72.5	90.5	6.0
	IS		7.4	2.3	2.8	3.4	0.1
	GW		17.1	1.9	2.2	2.8	0.2
2000	GL	310	222	75.6	90.7	113.7	7.6
	IS		9.2	3.1	3.7	4.6	0.1
	GW		19.4	2.3	2.8	3.4	0.2
2020	GL	360	255	91.0	109.0	136.5	9.4
	IS		10.3	3.8	4.5	5.7	0.2
	GW		21.7	3.1	3.7	4.6	0.3

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Con-sumption	Municipally Supplied Industrial Water: Average Demand	Con-sumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
1970	GL	294.4	42.5	4.3	9.3	0.9	70.0
	IS		1.2	0.1	0.6	--	3.0
	GW		1.4	0.1	0.1	--	5.0
1980	GL	241.1	47.3	4.7	13.0	1.3	6.7
	IS		1.4	0.1	0.9	--	0.8
	GW		1.8	0.2	0.1	--	0.8
2000	GL	243.4	57.1	5.7	18.5	1.9	21.3
	IS		1.7	0.1	1.4	--	1.9
	GW		2.2	0.2	0.1	--	1.5
2020	GL	250.5	67.0	7.0	24.0	2.4	35.9
	IS		2.0	0.2	1.8	--	2.6
	GW		2.9	0.3	0.2	--	2.3

further improvements in reuse of industrial water will be slower, the withdrawals should increase by the year 2000. Industrial water withdrawals are projected to total 1,200 mgd by the year 2020.

Two industry groups, SIC 28 and SIC 33, account for nearly 90 percent of the present industrial withdrawals, with SIC 33 industries accounting for 64 percent. SIC 33, Primary Metals Industries, should increase production from 1970 to 2020 by more than 390 percent as indicated by value added by manufacture. During the same period the average recirculation rate is expected to improve more than 600 percent. Consequently, the withdrawal demand for SIC 33 is projected to decline from 670 mgd to 298 mgd.

SIC 28, Chemicals and Allied Products, is

TABLE 6–106 Estimated Manufacturing Water Use, Planning Subarea 4.4 (mgd)

	SIC 20	SIC 26	SIC 28	SIC 29	SIC 33	Other Mfg.	Total
1970							
Value Added							
(Millions 1958$)	340	128	493	50	836	1900	3747
Gross Water Required	57	166	543	222	1213	141	2342
Recirculation Ratio	2.77	2.93	2.12	4.41	1.81	2.39	--
Total Water Withdrawal	20.5	57	256	50	670	59	1051
Self Supplied	--	--	--	--	--	--	946
Water Consumed	1.6	8.3	16	3.8	55.8	3.8	89
1980							
Value Added							
(Millions 1958$)	430	156	922	64	1134	2767	5473
Gross Water Required	66	202	1017	337	1559	209	3390
Recirculation Ratio	3.15	6.03	3.98	7.25	2.83	3.03	--
Total Water Withdrawal	21	33	255	47	551	69	976
Self Supplied	--	--	--	--	--	--	854
Water Consumed	1.9	10.1	31	6.1	71.5	5.4	126
2000							
Value Added							
(Millions 1958$)	686	235	3194	88	1902	5641	11746
Gross Water Required	91	305	3522	608	2349	408	7283
Recirculation Ratio	3.50	8.00	11.70	19.61	6.97	4.80	--
Total Water Withdrawal	26	38	301	31	337	85	818
Self Supplied	--	--	--	--	--	--	670
Water Consumed	2.2	15	106	11	106	11.2	251
2020							
Value Added							
(Millions 1958$)	1129	361	8095	156	3302	11600	24643
Gross Water Required	123	469	8929	1100	3576	914	15111
Recirculation Ratio	3.50	8.00	15.00	23.92	12.00	5.86	--
Total Water Withdrawal	35	59	595	46	298	156	1189
Self Supplied	--	--	--	--	--	--	1010
Water Consumed	3.2	23	268	21	158	23	496

expected to increase production by more than 1,600 percent between the years 1970 and 2020, while the recirculation rate improves by more than 700 percent. Thus for this industry the demand for water to meet new production requirements is greater than the volume conserved by recirculation, and the total withdrawal demand is projected to increase from 256 mgd to 595 mgd.

Similar patterns of change in recirculation and withdrawal are observed for other industry groupings as the growing need for water for expanding production is met by varied combinations of water input and multiple reuse. In the past the major incentives for recirculation have been quantitative and qualitative inadequacies of water supply; cost savings through conservation of heat energy, product, and materials; and the maintenance of special qualities such as high pressure steam supply. Incentives to recirculate have more recently resulted from the efforts of the industries to reduce the quantities of pollutants discharged in their waste streams. In the Great Lakes Basin inadequacies of supply will continue to be a minor factor in decisions by manufacturers to recirculate. The major incentives have been cost savings, strongly influenced by added costs for the control of water pollution from their plants' activities.

Pollution control will continue to be a major incentive in the Great Lakes Basin.

The distribution of the industrial water withdrawal demands and consumption between the industrial sectors of the New York and the Pennsylvania portions of the planning subarea are presented in Table 6-107. These estimates were derived by proportioning the demand on the basis of the ratio of value added by manufacture in each State portion to the value added in the total planning subarea, as reported in the Census of Manufactures. There are no large water-using establishments in the SIC 28 and 29 industry groups in the Pennsylvania portion; therefore the demands of these industries were assigned to the New York portion.

TABLE 6–107 Estimated Manufacturing Water Use by State, Planning Subarea 4.4 (mgd)

	New York Portion	Pennsylvania Portion	Total
1970			
Self-Supplied	911	35	946
Municipally Supplied	95	10	105
Consumed	85	4	89
1980			
Self-Supplied	826	28	854
Municipally Supplied	108	14	122
Consumed	120	6	126
2000			
Self-Supplied	639	30	669
Municipally Supplied	128	20	148
Consumed	239	12	251
2020			
Self-Supplied	948	62	1010
Municipally Supplied	153	26	179
Consumed	472	24	496

6.5.4.3 Rural Water Use

Rural water requirements and consumption were estimated for Planning Subarea 4.4 following the methodology outlined in Subsection 1.4. Table 6–108 divides total requirements and consumption into categories of rural nonfarm and rural farm. Rural farm is further divided into domestic, livestock, and spray water requirements.

6.5.5 Needs, Problems, and Solutions

6.5.5.1 Municipal

The presently developed quantity of water supply is not adequate to meet all projected future requirements. However, a need exists only in development of the water resource because the quality of the water resources available is adequate to meet the projected future requirements.

TABLE 6–108 Rural Water Use Requirements and Consumption, Planning Subarea 4.4 (mgd)

	1970	1980	2000	2020
REQUIREMENTS				
Rural Farm				
Domestic	2.6	3.2	2.8	2.9
Livestock	4.8	5.8	6.6	7.9
Spray Water	0.0	0.0	0.0	0.0
Subtotal	7.4	9.0	9.4	10.8
Rural Nonfarm	9.1	7.4	14.1	20.9
Total	16.6	16.4	23.5	31.6
CONSUMPTION				
Rural Farm				
Domestic	0.6	0.8	0.7	0.7
Livestock	4.4	5.2	5.9	7.1
Spray Water	0.0	0.0	0.0	0.0
Subtotal	5.0	6.0	6.6	7.8
Rural Nonfarm	1.4	1.1	2.1	3.1
Total	6.4	7.1	8.8	10.9

Development of municipal water supplies to provide 39 mgd by 1980, 138 mgd by 2000, and 260 mgd by 2020 for additional growth is necessary. Approximately 236 mgd, 91 percent of the total need, is projected as additional development of Lake Erie and Niagara River sources.

The estimated costs for new construction and associated operations are presented in Table 6–109. The costs include conveyance of the raw water supply and water treatment, but not surface water storage and urban distribution.

In Pennsylvania, water supplies in the Lake Erie basin are composed of relatively small ground-water sources which supply primarily residential needs. The major exception is the Erie city water supply which obtains water directly from Lake Erie and supplies more than a third of its water to industry. The Northeast Borough Water Department obtains up to 70 percent of its supply through interbasin transfer from the Upper Allegheny basin (the West Branch of French Creek).

Future requirements present no problem because the Erie city supply is virtually unlimited and should needs in the surrounding areas unexpectedly surpass the quantities available, additional water can be obtained through the Erie city supply. Treatment at this time is no problem, but it could become a future problem if the increasing trend in deterioration of water quality continues.

Future needs for public water supply in New York will present no problems. Treatment is not a major problem but, as in the city of Erie,

TABLE 6-109 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Planning Subarea 4.4 (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
Great Lakes	Capital	10.614	27.926	34.295	38.541	72.836
	Annual OMR	.528	2.449	5.550	2.978	8.528
	Total OMR	5.289	48.991	111.005	54.280	165.285
Inland Lakes and Streams	Capital	.657	1.166	1.225	1.823	3.049
	Annual OMR	.032	.123	.242	.156	.399
	Total OMR	.327	2.473	4.857	2.801	7.658
Ground Water*	Capital	.450	.690	.855	1.140	1.995
	Annual OMR	.024	.087	.173	.112	.286
	Total OMR	.249	1.759	3.469	2.008	5.478
Total	Capital	11.723	29.783	36.376	41.505	77.881
	Annual OMR	0.587	2.662	5.966	3.248	9.214
	Total OMR	5.867	53.224	119.331	59.091	178.423

*Ground water unit cost assumptions are as follows:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells and pumping (see Figure 6-4)	30,000	9,000
total	150,000	16,600

it may become one at a later date as pollution levels of Lake Erie continue to increase.

Present considerations for the Lake Erie basin in Pennsylvania are included in the State Water Plan, a comprehensive water resources study under way to investigate water supply and needs throughout Pennsylvania. Proposals are being formulated for all areas to insure availability of needed water supplies until the year 2020.

A comprehensive multipurpose planning study by the Erie-Niagara Basin Regional Water Resources Planning Board has recently been completed.[18] This study evaluates present water resources and determines future water requirements, including water supply for a 2,000 square mile area consisting of portions of Cattaraugus, Erie, Niagara, Genesee and Wyoming Counties (New York).

In the Buffalo metropolitan area three large systems served 924,000 people in 1966 by using Lake Erie and the Niagara River as sources. These systems are the City of Buffalo, the Erie County Water Authority, and the town of Tonawanda. The Erie-Niagara Board Plan includes continued expansion of these and other systems as the source for most future water supplies.[18]

The New York counties have intermunicipal water supply studies currently under way or completed and financed entirely by the State of New York. This program was initiated to assure adequate water supplies in all areas of the State of New York to the year 2020 and to encourage intermunicipal cooperation in the development of water supply facilities.

6.5.5.2 Industrial

Manufacturing production in Planning Subarea 4.4 is projected to increase from the 1970 level of $3.6 billion (1958$) value added by manufacture to a 2020 level of $24.6 billion. Undoubtedly, existing manufacturing plants can expand at their present locations to provide some of the increased production, but a large part of the increase can be provided only by the installation of new plants at new locations. Figure 6-53 shows the changing characteristics of the water withdrawal requirements during the 50-year period of expanding production. In constructing this chart it was assumed that the first 100 percent increase in production would occur at the existing plants, the doubling of output being achieved by 1990.

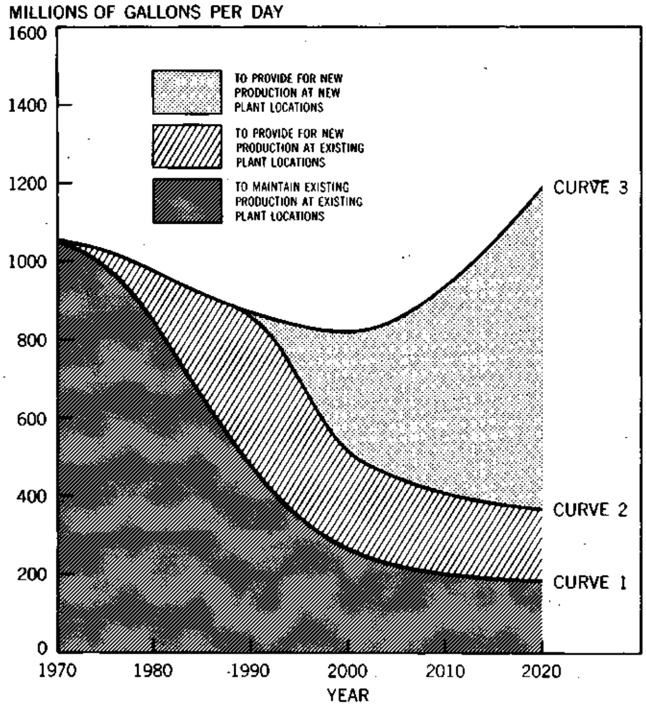


FIGURE 6–53 Total Withdrawal Demands for Manufacturing—Planning Subarea 4.4

During this time the improving practices of water reuse would allow the water needs for increased production to be met by using the water from existing sources without the need to expand those sources. After 1990 all additional increases in manufacturing production should require new manufacturing plants at new locations for which new water supplies must be provided.

Curve 1 represents the withdrawal demand to maintain 1970 production levels at existing plants. Curve 2 represents the withdrawal demand to maintain the 1970 production levels plus the first 100 percent increase in production at existing plant locations. Curve 3 represents the total withdrawal demand for all manufacturing production at all locations. The area between Curves 2 and 3 represents the withdrawal demands for new production at new locations and thus represents the future water supply needs. By the year 2000, 300 mgd of new industrial water supply will have to be provided at locations where plants do not presently exist, and by the year 2020 the new water supply need will be 840 mgd.

Only 10 percent of the industrial water supply is obtained from municipal water systems in the planning subarea. In the Buffalo metropolitan area an industrial supply system has been in operation for a number of years to provide approximately 200 mgd of Lake Erie water to several major manufacturing companies. Other supply sources developed for individual plant needs obtain water from Lake Erie and to a lesser extent the rivers of the region. Although information on quantities of well water used by manufacturers in the region is not available, it is estimated that the total quantity of well water presently used is less than 25 mgd.

The determination of the methods by which the water will be supplied in the future (individual company supplies or municipal or regional water systems) will be strongly influenced by the land use planning for the area. If industrial development continues to occur near the lakeshore and major streams, it is probable that individual company suppliers will be developed. However, if land use planning includes the development of inland sites for future industrial development, the extension of municipal systems or development of regional industrial supply systems would provide more positive management of the water resource of the planning subarea.

6.5.5.3 Rural

Future rural water requirements will be drawn primarily from ground-water sources, although in some areas streams will be increasingly important. The location and quality of ground water will be very important in channeling additional development, particularly in the location of rural nonfarm dwellings. In areas where ground water is in short supply, development should proceed only after water supplies are located. Some areas will not develop until a central supply is available.

Rural water requirements are projected to increase 91 percent and consumption is expected to increase 71 percent between 1970 and 2020.

Poor chemical quality is probably the greatest ground-water problem in Planning Subarea 4.4 High amounts of dissolved solids are present at relatively shallow depth throughout most of the area. The northeastern portion has extremely mineralized ground water, too mineralized for public supply use. In Pennsylvania shallow saline water is present locally. In general individual domestic wells can obtain potable water from shallow aquifers throughout the planning subarea.

Section 7

LAKE ONTARIO BASIN

7.1 Summary

7.1.1 The Study Area

The Lake Ontario basin drains 17,575 square miles of land in the State of New York and 95 square miles in the Commonwealth of Pennsylvania. Following the long axis of Lake Ontario, the study area is approximately 250 miles long and 140 miles wide at its widest point. Approximately 15 percent of the Great Lakes Basin is included in the Lake Ontario study area (Figure 6–54). Approximately one-third of New York State is within the basin. For planning purposes the basin has been subdivided into three areas described as Lake Ontario West, Planning Subarea 5.1; Lake Ontario Central, Planning Subarea 5.2; and Lake Ontario East, Planning Subarea 5.3.

7.1.2 Economic and Demographic Characteristics

In 1970 the resident population of the Lake Ontario region totaled slightly more than 2.5 million people, an 11 percent increase over the 1960 population level. Major population concentration occurs in the Finger Lakes region, along the Lake Ontario shore, and within the region's three Standard Metropolitan Statistical Areas, Rochester, Syracuse, and Utica-Rome. In 1960 the nine counties comprising these SMSAs in the Lake Ontario region contained more than 72 percent of the population. Small towns and rural communities dot the entire region, with the exception of the eastern highlands. Major cities include Rochester, Irondequoit, Auburn, Syracuse, Rome, Utica, and Watertown. By the year 2020 the resident population of the Lake Ontario basin is expected to be 4.4 million, a 76 percent increase over the 1970 level.

The Lake Ontario region is largely rural, with fruit, vegetable, and dairy production of major importance along with localized areas of diversified manufacturing and industry. Poor climate, soils, and topography discourage agriculture (with the exception of dairy farming) in Planning Subarea 5.3, but mineral, forest, and recreational resources strengthen the area's economy. Industrial activity is highly diversified in Planning Subarea 5.2. Syracuse is the principal industrial center, producing such things as machinery, food, paper, and chemicals such as caustic soda. Dominant agricultural activity in this area includes dairy farming and fruit and vegetable production. Grape production is especially good in this region. Near the lakeshores fruit orchards and dairy farms dominate the landscape of Planning Subarea 5.1, while livestock production is prevalent in the more rugged inland plateaus. Industrial activity in the Rochester area is characterized by paper products, chemical products, and specialized photographic equipment. All the major cities in the Lake Ontario basin serve as trade and service centers for the residents.

The Lake Ontario basin has four Federal harbors: Rochester, Great Sodus Bay, Oswego, and Ogdensburg. Coal, food products, chemicals, and petroleum products are major commodities shipped from these ports. In 1968 Lake Ontario carried 47.1 million tons of traffic. The St. Lawrence River, between the International Boundary and Lake Ontario, carried 33.1 million tons the same year. An abundance of generally high quality land and water resources form the basis for the important tourist and recreational enterprises in the Lake Ontario basin. It has been estimated that approximately $273 million are spent annually by tourists in the basin. Lakeshore and interior resorts are favorite summer and winter recreation areas.

In 1960 approximately 835,000 persons were employed in agriculture, forestry, fisheries, mining, manufacturing, trades and services, and other occupations in the Lake Ontario region. Manufacturing and trades and services were the region's major employers. Total personal income generated in the region in 1962 neared $5.4 billion. Only Planning Subarea 5.1 exceeded the national per capita income av-

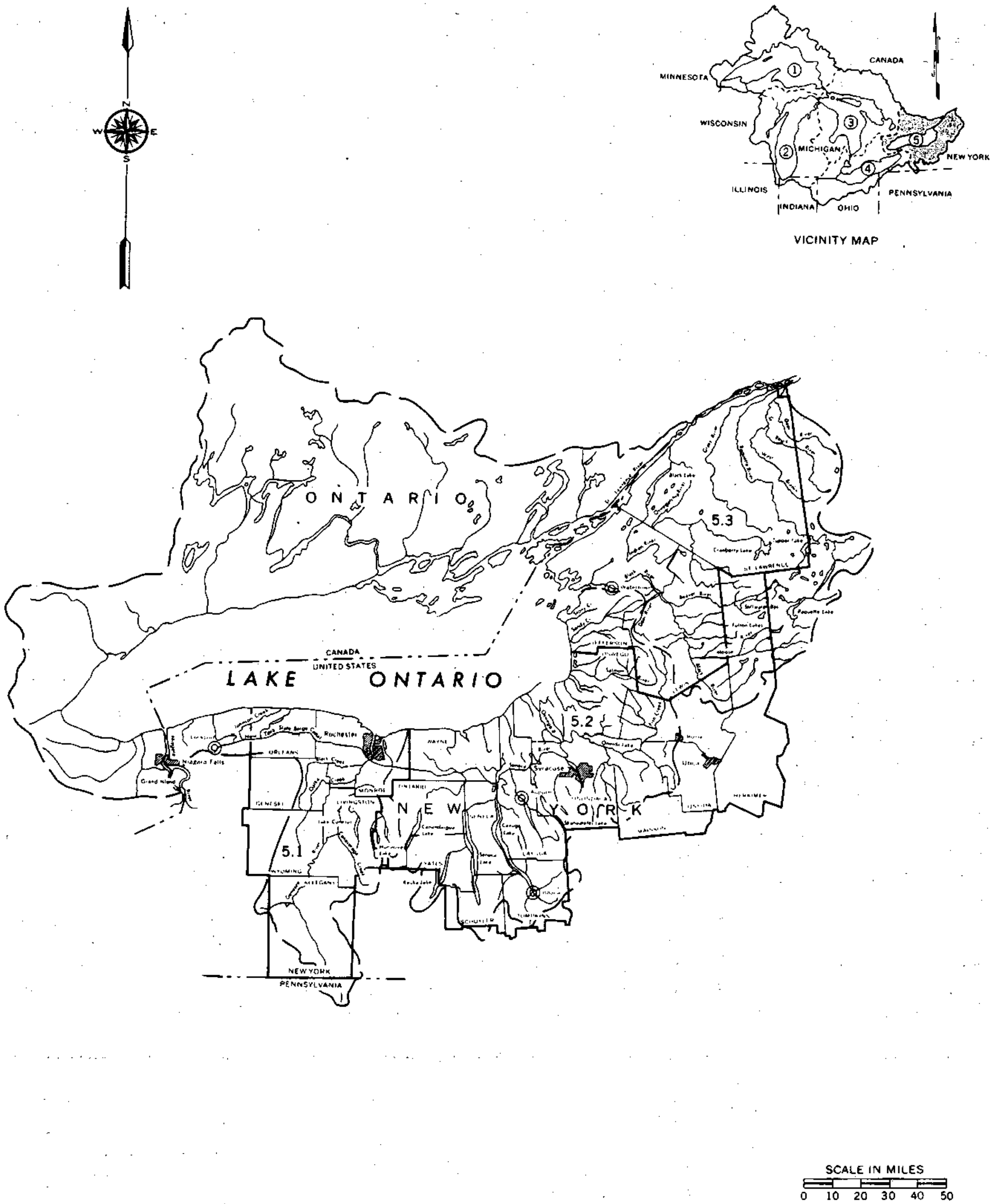


FIGURE 6–54 Lake Ontario Basin

erage in 1970 of $4,783 (1970$). Planning Subareas 5.2 and 5.3 averaged $4,017 and $3,478 respectively (1970$).

7.1.3 Water Resources

Water resource systems in the Lake Ontario basin are complex and variable. Climatic, topographic, and geological factors influence the flow and runoff of area streams. The basin contains more than 28,000 miles of rivers and streams. Going from east to west and north to south, average runoff increases from approximately 15 inches to 50 inches annually. Originating in the highland regions of the Adirondacks, Tug Hill Plateau, and the Appalachians, many regional streams exhibit flashy, steep gradients with numerous waterfalls. As the streams reach the flatter lake plain areas, they become sluggish and meander before draining into Lake Ontario. Major rivers in the basin include the Genesee, Oswego, Oneida, Seneca, Black, and Raquette Rivers. Rivers, lakes, and embayments in the Lake Ontario region cover a surface area of 449,300 acres. Inland lakes in the region account for 74 percent of this water area. As might be expected, most inland lakes are found in the headwater areas of the basin. Planning Subarea 5.3 contains more than 281 inland lakes, most of which are located in St. Lawrence County. In contrast to the many lakes in the easternmost portion of the basin, the central section (Planning Subarea 5.2) has fewer lakes (approximately 85), but they cover 191,000 acres. Glaciation, erosion, and surface upheaval have given rise to the Finger Lakes, which occupy a series of nearly parallel troughs in the southwestern portion of the Oswego River basin. These lakes range in size from 30 square miles to Lake Oneida's 80 square miles. The numerous natural lakes in the Lake Ontario basin provide a high degree of natural flood control.

Moderate to poor ground-water resources are available in the Lake Ontario basin. Fine grained sedimentary or igneous rocks underlie most of the basin. The better yielding aquifers occur locally in the carbonate rocks of central New York, the sandstone and carbonate rocks along the St. Lawrence Valley, and the sand and gravel in the glacial drift in valley bottoms. The Adirondack area of Planning Subarea 5.3 has the greatest estimated ground-water yield of the basin and one of the greatest in the entire Great Lakes Basin at 3,070 mgd. The Lake Ontario basin could produce more than 4.9 billion gallons per day of ground water.

Water-critical areas occur along the entire Lake Ontario lowland from Niagara Falls to the Black River. The bedrock aquifers are low yielding and, in addition, saline water is present in much of the lowland south of the Lake. Sustained droughts create severe water shortages in the dairy counties of the Ontario lowland and in the Black River valley. Locally the sand and gravel aquifers are very productive.

Lake Ontario is the fourth largest of the Great Lakes with a total surface area of 7,340 square miles (3,460 square miles in U.S.) and a volume of 393 cubic miles. The Lake is 193 miles long and 53 miles wide. There are no major diversions out of the Lake, and outflow through the St. Lawrence River averages 239,000 cfs. Chemical quality conditions are largely determined by those of Lake Erie, its major inflow source.

7.1.4 Present and Projected Water Withdrawal Requirements

In 1970 the Lake Ontario basin total water withdrawals, 802 mgd, accounted for 5 percent of the withdrawals for the entire Great Lakes Basin. A summary of present and projected withdrawal requirements and needs for the municipal, industrial, and rural water-using sectors is shown in Table 6–110 and Figure 6–55.

The waters of Lake Ontario are expected to provide 52 percent of the total municipal water supply requirements by 2020. Inland surface-water resources and ground-water resources are projected to supply 41 percent and 7 percent, respectively, of the remainder of the projected withdrawal requirements for the municipal sector. Lake Ontario is considered unlimited in its ability to provide for the future water supply needs of the basin but the water resource must be properly developed and managed.

Estimates of the costs of developing, operating, and maintaining municipal water supply facilities to meet the projected needs in the Lake Ontario basin are shown in Table 6–111. During the 50-year period of this study, $124 million will be required for capital investment in municipal water supply facilities, and $278 million will be required for total OMR expenditures in the Lake Ontario basin.

Lake Ontario can be classified as suitable for domestic water supply in all periods to the

TABLE 6-110 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Lake Ontario Basin (mgd)

Use	1970				1980			
	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
5.1	131.0	50	10.8	191.8	150.2	51	14.9	216.1
5.2	186.7	262	32.1	480.8	225.7	240	36.5	502.2
5.3	44.4	76	9.3	129.7	47.3	41	10.2	98.5
Total	362.1	388	52.2	802.3	423.2	332	61.6	816.8
Consumption								
5.1	11.3	5	5.2	21.5	13.8	6	6.9	26.7
5.2	16.8	19	12.3	48.1	21.4	30	14.8	66.2
5.3	4.4	7	4.9	16.3	4.0	8	5.6	17.6
Total	32.5	31	22.4	85.9	39.2	44	27.3	110.5
1970 Capacity-Future Needs								
5.1	173.8	50	10.8	234.6	14.3	4	4.1	22.4
5.2	239.7	262	32.1	533.8	29.2	55	4.4	88.6
5.3	82.1	76	9.3	167.4	3.8	--	0.9	4.7
Total	495.6	388	52.2	935.8	47.3	59	9.4	115.7

Use	2000				2020			
	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
5.1	209.4	66	14.4	289.8	280.1	140	17.6	437.7
5.2	319.0	211	43.4	573.4	429.4	486	47.1	962.5
5.3	53.1	17	12.1	82.2	60.4	22	13.4	95.8
Total	581.5	294	69.9	945.4	769.9	648	78.1	1496.0
Consumption								
5.1	22.7	9	8.0	39.7	33.1	23	10.2	66.3
5.2	34.2	83	17.9	135.1	49.1	212	21.1	282.2
5.3	6.4	10	6.6	23.0	7.6	13	7.5	28.1
Total	63.3	102	32.5	197.8	89.8	248	38.8	376.6
1970 Capacity-Future Needs								
5.1	82.6	21	3.6	107.2	144.4	84	6.8	235.2
5.2	123.3	159	11.3	293.6	251.3	435	15.0	701.3
5.3	14.1	--	2.8	16.9	28.7	--	4.1	32.8
Total	220.0	180	17.7	417.7	424.4	519	25.9	969.3

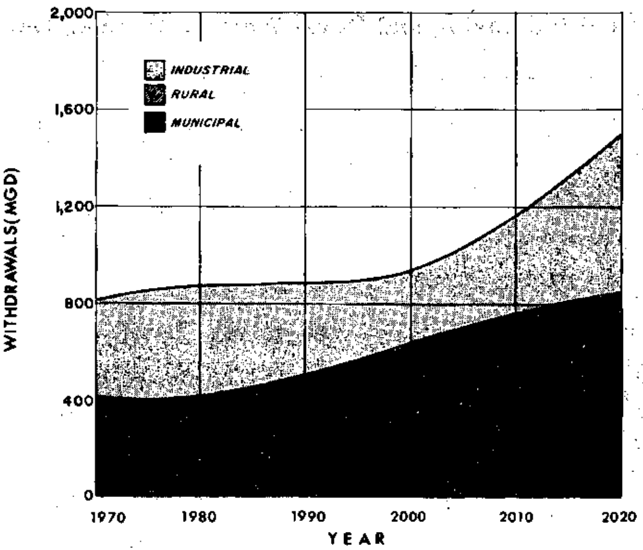


FIGURE 6–55 Municipal, Industrial, and Rural Water Withdrawal Requirements—Lake Ontario Basin

In 1970, 2.5 million people, 9 percent of the total Great Lakes Basin population, resided in the Lake Ontario basin. Major population centers are Rochester, Syracuse, and Utica-Rome. Municipal water supply served 2.0 million people, 80 percent of the total basin population, in 1970. By 2020 this is projected to increase to 3.9 million.

The Lake Ontario region is largely rural, with fruit, vegetable, and dairy production of major importance. Near the lakeshore fruit orchards and dairy farms predominate, while livestock production is prevalent in the rugged inland plateau regions.

Industrial activity in the basin is highly diversified. Machinery, food products, paper, chemicals, and specialized photographic equipment are the predominant manufacturing enterprises in the Lake Ontario basin.

year 2020. Although some problems may be experienced, the water quality standards program requires these waters as a source of municipal water supply and includes plans of implementation and timetables for making this possible.

7.1.5 Acknowledgements

Municipal water supply data were compiled by the State of New York's Department of Environmental Conservation on an individual community basis, summarized by county line boundaries and compiled into the three planning subarea reports. Data for the base year 1970 were obtained from draft reports prepared by contract consultants for each county except Lewis and Cayuga Counties. Data for these counties were obtained from files of the Division of Water Resources, New York State Department of Environmental Conservation. Data for Monroe County were obtained from State of New York Water Resources Commission files.

Data and the analysis pertaining to industrial and rural water supplies were furnished by the Bureau of Domestic Commerce, U.S. Department of Commerce, and the Economic Research Service, U.S. Department of Agriculture, respectively.

7.2 Lake Ontario West, Planning Subarea 5.1

7.2.1 Description of Planning Subarea

7.2.1.1 Location

Planning Subarea 5.1, located in the northeastern portion of the Great Lakes Basin along the southern shore of Lake Ontario, encompasses six northwestern New York counties (Figure 6–56). Stretching more than 56 miles from its east to west extremities and more than 94 miles from north to south, Planning Subarea 5.1 is bordered to the north by Lake Ontario, to the east by the Wayne-Cayuga complex and the Oswego River basin, and to the south and west by the Susquehanna River, Allegheny River, and Erie-Niagara River basins. The headwaters of the Genesee River are located in the Allegheny mountains, while streams in the Niagara-Orleans complex begin on the Lake Ontario plains.

7.2.1.2 Topography and Geography

The Genesee River basin consists of a series of terraces descending northward from the Allegheny plateau to Lake Ontario and separated by northward facing escarpments. The headwater plateau area consists of broad valleys at elevations of 1,000 to 2,000 feet above sea level, rising to the south and separated by rounded ridges rising up to 500 feet above the valley floor. North of the Portage escarpment, the Genesee River flows across two plain

TABLE 6–111 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Lake Ontario Basin (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
Great Lakes	Capital	7.086	33.966	34.983	41.052	76.035
	Annual OMR	.353	2.398	5.834	2.752	8.586
	Total OMR	3.531	47.978	116.696	51.509	168.206
Inland Lakes and Streams	Capital	6.996	16.624	22.365	23.621	45.986
	Annual OMR	.348	1.525	3.468	1.874	5.343
	Total OMR	3.486	30.515	69.374	34.001	103.376
Ground Water*	Capital	.030	.528	1.857	.558	2.416
	Annual OMR	.002	.045	.231	.048	.279
	Total OMR	.023	.916	4.629	.940	5.569
Total	Capital	14.113	51.121	59.217	65.234	124.450
	Annual OMR	0.704	3.973	9.551	4.676	14.226
	Total OMR	7.039	79.444	191.026	86.483	277.510

*Ground water unit cost assumptions are as follows:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells & pumping (see Figure 6-4)	31,000	15,850
total	151,000	23,450

areas, known as the Erie and Huron plains. A poorly defined Onondaga escarpment separating these areas crosses the basin north of LeRoy and Honeoye Falls. The plains are areas of undulating terrain in which elevations rise unevenly from 500 feet near Rochester to 1,000 feet near the Portage escarpment. Near Lake Ontario, cutting through the City of Rochester, the Niagara escarpment separates the Huron plain from the Ontario plain. The escarpment is well defined with several falls at Rochester. Elevations in the Ontario plain range from 500 feet above sea level to 250 feet just above Lake Ontario.

The Niagara escarpment cuts the Niagara-Orleans complex from east to west, largely separating distinctive topographic regions. The Ontario plain north of the escarpment is dominated by lacustrine features. The region is of low relief with elevations generally less than 500 feet above sea level.

Bedrock formations in the Genesee River basin consist of shales, limestones, and sandstones which dip gently south at 40 to 60 feet per mile. Thickness of these layers exceeds 100 feet in most places. Glacial deposits of sand, clay, and gravel overlie these bedrock formations. Although these glacial deposits are generally less than 50 feet thick in the uplands, their thickness in the valleys varies between 100 and 300 feet. Bedrock in the Niagara-Orleans complex consists largely of sandstones, limestones, and shales. Glacial and lacustrine deposits blanket these formations. The Niagara-Orleans complex and the Genesee River basin combine to drain over 3,515 square miles of land in New York and Pennsylvania.

7.2.1.3 Climate

Cold, snowy winters and mild summers typify the humid, continental climate found in Planning Subarea 5.1. Significant differences in temperature and annual precipitation exist between the Ontario plains and the Allegheny uplands in the Genesee basin. Lake Ontario moderates temperatures along the shore and provides average frost-free periods from 140 to 160 days in the Ontario plains, while the Allegheny region averages 110 to 150 days of growing season. Temperature extremes in the region are very marked, ranging from 104°F to −40°F. Average temperatures for December,

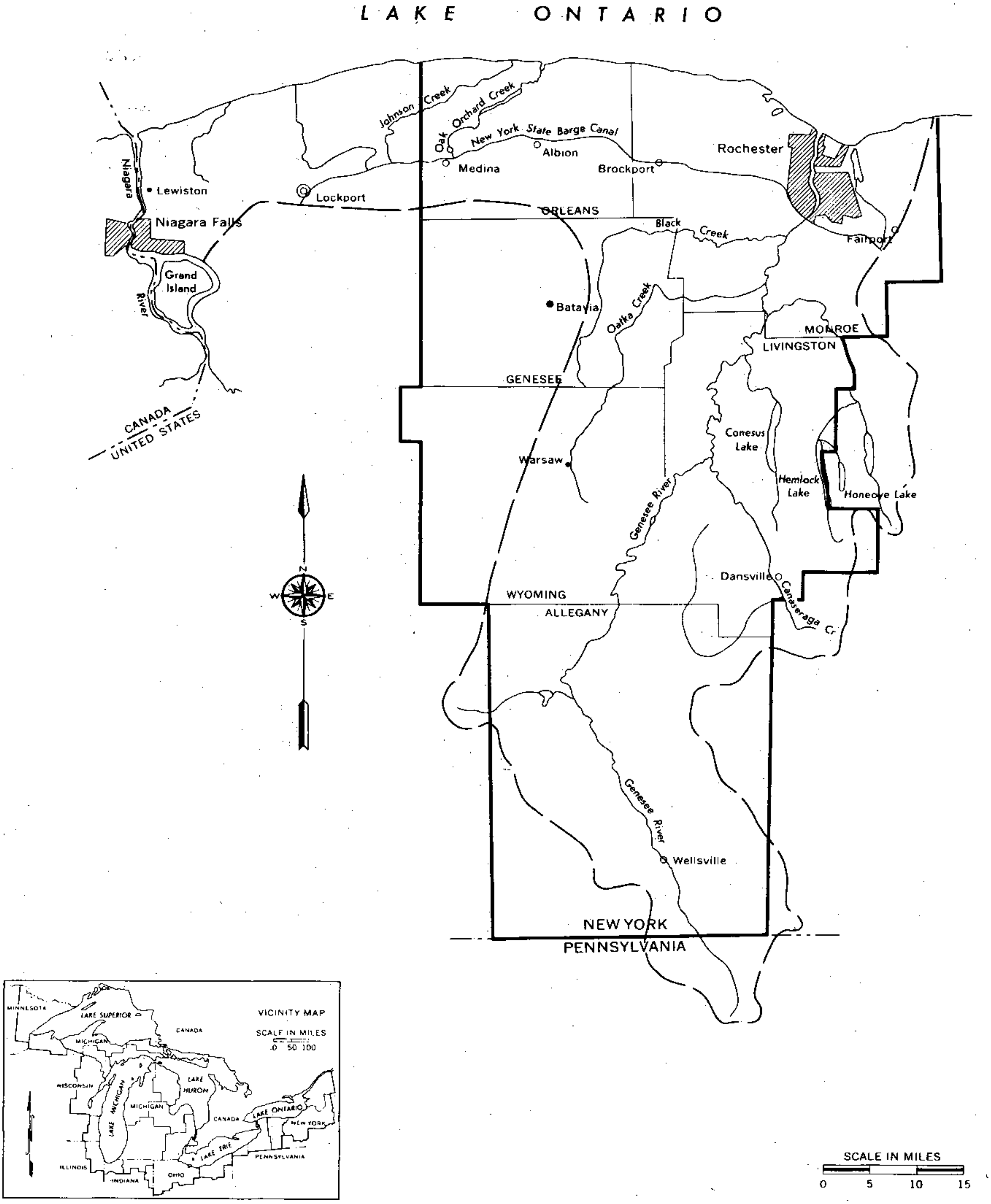


FIGURE 6–56 Planning Subarea 5.1

January, and February in the Genesee basin remain below freezing.

Average annual precipitation, while fairly well distributed throughout the years, varies from 32 inches in the Ontario plains to 26 inches in the central Genesee basin, to nearly 40 inches along the western rim of the basin. During March and April a combination of frozen soils, rising temperatures, melting snow, and rainfall produce periods of heavy runoff in the Genesee basin. Drought conditions in the Lake Ontario plains are not uncommon from the last week of July through September. Due to the snow squall effects created by Lakes Erie and Ontario and the topographic features in the southern portion of the region, snowfall accumulations are substantial.

7.2.2 Water Resources

7.2.2.1 Surface-Water Resources

Principal streams draining the region include the Genesee River and its tributaries, Oak Orchard Creek, Eighteenmile Creek, and Johnson Creek. Average annual runoff totals approximately 14 inches and ranges from 12 to 20 inches, increasing from northeast to southeast. Total surface-water yield from the basins has been estimated at 1,300 mgd. Approximately 50 percent of the annual runoff occurs during the February-April snowmelt period, and only 10 percent occurs during the summer months, June through August.

The Genesee River varies from a steep gradient stream in its headwaters (slopes up to 102 feet per mile) to a sluggish, meandering stream in its flow over flat alluvial plains (slopes average 0.8 feet per mile). Streams in the Niagara-Orleans complex are not steep, and their flows are relative stable.

Except for Livingston County, inland lakes are not plentiful in the region. Principal lakes in the Genesee basin include the Little Finger Lakes: Conesus, Hemlock, Canadice, and Honeoye. In addition, Silver Lake above Mount Morris Dam and Rushmore Lake are artificial impoundments.

Fully developed water storage areas in the planning subarea's inland lakes and streams provide an existing storage capacity of 337,000 acre-feet. If all inland lakes and streams suitable for development as surface-water impoundments were developed, the total potential storage capacity would increase to 778,050 acre-ft.[45]

Presently developed water storage areas can produce a sustained water supply yield of 761 mgd. If all potential water storage areas were fully developed, impounded inland lakes and streams could produce a sustained water supply yield of 1,344 mgd.[45]

Potential capacities and yields used in this section relate to the total water resource. No attempt has been made to identify that portion of the water resource not suitable or available for use.

7.2.2.2 Ground-Water Resources

Ground-water resources in Planning Subarea 5.1 are moderate in both quantity and quality. Sandstones, limestones, and glacial drift-filled valleys produce the highest water quantities, while shales, siltstones, and lacustrine sediments are poor ground-water sources. Ground water from the Ordovician-Silurian acquifers exceeds the 500mg/l USPHS standard for total dissolved solids. Wells in bedrock formations across much of the region generally do not produce more than 10 gpm. An exception to this general condition occurs from a line south of the Erie Barge Canal to the Onondaga escarpment. Bedrock wells in this area can yield from 10 to 100 gpm. Surficial deposits, composed largely of glacial drift in the Genesee basin and lacustrine sediments on the Ontario plains area, produce less than 10 gpm. However, drift-filled stream valleys in the Genesee basin often produce quantities in excess of 100 gpm.

Ground-water supplies are not large enough to be an adequate sole source of water supply for large cities and major water-using industries, nor are they so small that they can be ignored. Ground-water resources can be used by villages, farms, and commercial or industrial establishments with small or moderate water needs. The present basinwide ground-water use averages 18 mgd.

Ground-water yield in River Basin Group 5.1 is estimated to be 550 mgd (based on 70 percent flow-duration data).[21]

7.2.3 Water-User Profile

7.2.3.1 Municipal Water Users

With the exception of Monroe County (the Rochester metropolitan area), Planning Subarea 5.1 has a sparse, evenly distributed population with few significant urban centers. The rural landscape is broken only by the sprawling Rochester urban complex on the shores of Lake Ontario. In 1970 nearly 886,200 persons lived in the region. Approximately 28 percent of the 1960 total was classified as rural, with 72 percent classified as urban. Monroe County accounted for nearly 90 percent of the urban population. Average population density in 1970 was 252 people per square mile. Municipal water supplies serve 794,700 people, or 90 percent of the population. The 2020 population is projected to be 1.53 million with 1.45 million to be served by municipal water supplies. Average annual per capita income in 1970 was $4,783 (1970$).

The Rochester metropolitan area serves as a center for trades and services for the region. Smaller centers occur throughout the basin to serve rural and tourist needs. Wholesale and retail trades sales exceeded $2.3 billion in 1963, while selected services provided jobs for approximately 39 percent of the 1960 work force in the planning subarea.

7.2.3.2 Industrial Water Users

Manufacturing activities in Planning Subarea 5.1 are greatly concentrated in the City of Rochester, New York, and Monroe County, which surrounds the city. The planning subarea lies entirely within the State of New York and is comprised of Monroe and Orleans Counties along the Lake Ontario shoreline, and Genesee, Livingstone, Wyoming, and Allegany Counties reaching inland in the drainage basin of the Genesee River. Manufacturing plants are found in all counties, but of the 1,250 factories in the planning subarea, 950 are located in Monroe County, mainly in the City of Rochester. Monroe County provides 87 percent of the total manufacturing employment and 89 percent of the value added by manufacture.

Nearly one-third of the manufacturing employment and one-half of the total value added is accounted for by industries in SIC 38, Scientific Instruments, Photographic and Optical Goods, which is represented by approximately 60 plants located principally in Monroe and Orleans Counties. Although this industry group is not usually considered to be a large water user, it dominates among water users in Planning Subarea 5.1 because of its size. SIC 20, with its large output of canned and frozen food products, is also large in total employment, value added, and water requirement. The manufacture of machinery, metal parts, and electrical equipment is also important. In general, manufacturing in Planning Subarea 5.1 is in capital intensive industries that employ highly skilled workers with the result that productivity per employee is among the highest in the nation.

7.2.3.3 Rural Water Users

In 1964 Planning Subarea 5.1 contained 1.4 million acres of land in farm. Meadow crops exceeded the acreage of any other individual crop with 271,000 acres. However, vegetables and fruits, heavy water users, contributed significantly to crop acreage with more than 45,000 and 18,000 acres respectively. Dairy farming, also a heavy water user, contributed 77 percent of the receipts of livestock and livestock products. Crop receipts were more than $43 million and livestock and livestock product receipts more than $61 million in 1964. The 1960 census listed 38,000 people living on farms and 12,000 employed on farms.

7.2.4 Present and Projected Water Withdrawal Requirements

Table 6–112 presents a summary of municipal, self-supplied industrial and rural water use for Planning Subarea 5.1. Figure 6–57 details municipal, industrial, and rural water withdrawal requirements.

7.2.4.1 Municipal Water Use

An inventory of water used in the region indicates that the Rochester metropolitan area accounts for most of the total water consumption. Forty-one water supply systems, which withdraw water from ground water, inland lakes, and Lake Ontario, serve the Genesee River basin. Average annual municipal requirements for the Genesee basin in 1960 totaled 129 mgd, including industrial requirements from municipal sources. Municipal supplies for Rochester are obtained from Hemlock and Canadice Lakes and from Lake Ontario. The Monroe County Water Authority systems obtain supplies from Lake Ontario and provide water to several communities. Small inland communities generally rely on ground water, although surface-water supplies are important in local areas such as Wellsville, Warsaw, Perry, Avon, Livonia, and

TABLE 6-112 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Planning Subarea 5.1 (mgd)

Use	1970 mun.	1970 ind.	1970 rural	1970 total	1980 mun.	1980 ind.	1980 rural	1980 total
Withdrawal Requirements								
New York	131.0	50	10.8	191.8	150.2	51	14.9	216.1
Total	131.0	50	10.8	191.8	150.2	51	14.9	216.1
Consumption								
New York	11.3	5	5.2	22	13.8	6	6.9	27
Total	11.3	5	5.2	22	13.8	6	6.9	27
1970 Capacity-Future Needs								
New York	173.8	50	10.8	235	14.3	4	4.1	22
Total	173.8	50	10.8	235	14.3	4	4.1	22

Use	2000 mun.	2000 ind.	2000 rural	2000 total	2020 mun.	2020 ind.	2020 rural	2020 total
Withdrawal Requirements								
New York	209.4	66	14.4	289.8	280.1	140	17.6	437.7
Total	209.4	66	14.4	289.8	280.1	140	17.6	437.7
Consumption								
New York	22.7	9	8.0	40	33.1	23	10.2	66
Total	22.7	9	8.0	40	33.1	23	10.2	66
1970 Capacity-Future Needs								
New York	82.6	21	3.6	107	144.4	84	6.8	235
Total	82.6	21	3.6	107	144.4	84	6.8	235

LeRoy. Municipal systems in the Niagara-Orleans complex supply 2.0 mgd to basin communities. The Monroe County Water Authority and the Niagara County Water District also serve parts of this region, tapping ground-water and surface-water supplies as sources.

The estimated total population of Planning Subarea 5.1 is 886,200. Table 6-113 shows that 795,000 people, 90 percent of the total population, are being supplied water through central water systems.

An average of approximately 131 mgd is currently supplied through central water systems in Planning Subarea 5.1. A breakdown of the various portions of this total average quantity is shown in the accompanying tables.

Approximately 74 mgd, 56 percent of the water use, is supplied from Lake Ontario sources. Heavy water-using industries in Planning Subarea 5.1 are being supplied approximately 50 mgd or 38 percent of the total municipal water use through municipal systems.

Approximately 124 mgd, 95 percent of the planning subarea's municipal water supply, is received from surface waters and requires purification treatment including coagulation, sedimentation, filtration, and disinfection. The remaining ground-water supplies are disinfected and some receive some type of corrective treatment such as softening or iron removal.

The average daily demand in the maximum

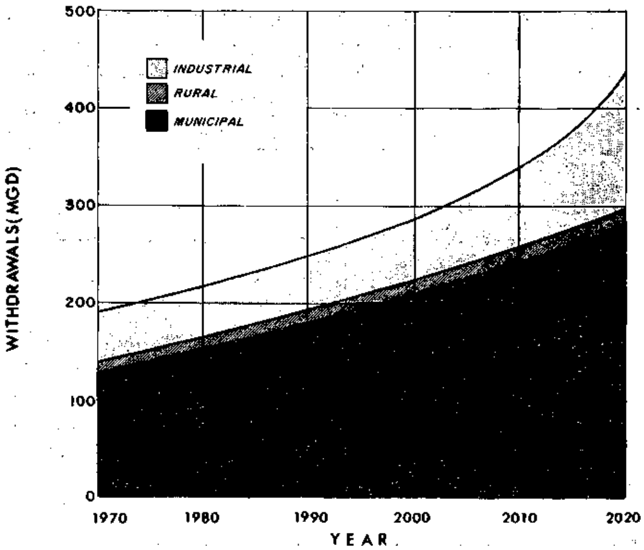


FIGURE 6–57 Municipal, Industrial, and Rural Water Withdrawal Requirements—Planning Subarea 5.1

Planning Subarea 5.1 has a relatively sparse population with 794,700 people, 90 percent of the total population, served by municipal water supplies in 1970. This figure is expected to reach 1.5 million by 2020. Approximately 28 percent of the 1960 population was classified as rural.

Important agricultural crops are hay and pasture, fruits, and vegetables. Dairying is the dominant livestock activity.

Major manufacturing activities are located in Monroe County. Manufacturing activities are dominated by Eastman Kodak and the Xerox Corporation in Rochester, with 40 percent of the working force employed in manufacturing activities.

month of water use is 1.2 times the average demand per year. The per capita usage of total municipal water use is 165 gpcd, and domestic and commercial per capita use is 111 gpcd when heavy industry water is subtracted. Developed source capacities appear to be adequate at present.

The total average municipal water supply requirements are expected to increase by 1.2 times to 150 mgd by 1980, 1.6 times to 209 mgd by 2000, and 2.1 times to 280 mgd by 2020. The average day in the maximum month of total municipal water use per year is expected to increase from 157 mgd in 1970 to 180 mgd in 1980, 251 mgd in 2000, and 317 mgd in 2020.

Approximately 11 percent of the municipal water use is predicted to be consumptive loss. In Planning Subarea 5.1 the consumptive water loss can be expected to amount to 14 mgd in 1980, 23 mgd in 2000, and 33 mgd in 2020.

7.2.4.2 Industrial Water Use

Table 6–114 presents the base year estimates and projections of five water-use parameters and constant dollar estimates of value added by manufacture for four major water-using SIC two-digit industry groups, the combined residual group of other manufacturing industries, and the total manufacturing sector of Planning Subarea 5.1. Total water withdrawals for all manufacturing were estimated at 100 mgd in 1970 of which 49.6 mgd was obtained from public water supply systems. Self-supplied water for manufacturing obtained from company-owned wells was believed to be 8 mgd, and the remaining self-supplied water was obtained from surface-water sources. Although the availability of water from Lake Ontario and the rivers and streams of the region allows for large withdrawals, the manufacturers reused and recirculated the water they withdrew 2.45 times rather than increasing withdrawals for once-through use to meet their gross water requirement of 245 mgd.

Improvements in the average rates of recirculation of water in all manufacturing groups should continue over the next 50 years as the output of the planning subarea grows from the present level of $1.857 billion (constant 1958$) to $14 billion in the year 2020. Water withdrawals will increase slowly to the year 2000, since water needs for increased production can be met in large part by water conserved through reuse and recirculation. Beginning in approximately 2000, further improvements in reuse of industrial water will be impractical and withdrawals will increase rapidly to meet the requirements of rising production. Withdrawals are projected to be 248 mgd by the year 2020.

SIC 20, Food and Kindred Products, accounts for 42 mgd of the present withdrawals. This SIC two-digit group of industries will continue to be a major user of water with withdrawals increasing to 71 mgd in the year 2020, 30 percent of the total manufacturing sector withdrawals. At present the major use of water by this industry group is for dairy products and for the canning and freezing of fruits, for which recirculation and reuse of water is limited by the need to maintain high stand-

TABLE 6-113 Municipal Water Supply, Planning Subarea 5.1, New York (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Consumption
1970	(3) GL	886.2	(1),(2) 638.7	110.4	132.5	165.6	9.4
	IS		89.3	13.4	16.1	20.2	1.2
	GW		66.7	7.2	8.6	10.8	0.7
1980	GL	978.2	(1),(2) 686.8	125.4	150.5	188.1	11.5
	IS		100.5	16.2	19.4	24.3	1.5
	GW		71.3	8.6	10.3	12.9	0.8
2000	GL	1221.8	(2) 921.7	176.6	211.9	264.8	19.3
	IS		130.2	22.2	26.6	33.3	2.3
	GW		86.2	10.6	12.7	15.8	1.1
2020	GL	1538.0	1191.9	237.5	265.1	356.3	28.2
	IS		159.7	29.0	35.2	47.7	3.3
	GW		102.7	14.1	16.4	21.1	1.6

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Consumption	Municipally Supplied Industrial Water: Average Demand	Consumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
1970	GL	102	65.8	6.6	44.6	2.8	136.2
	IS		9.6	1.0	3.8	0.2	19.7
	GW		6.0	0.6	1.2	0.1	17.9
1980	GL	108	74.8	7.4	50.6	4.1	14.3
	IS		11.3	1.1	4.9	0.4	--
	GW		6.9	0.7	1.6	0.1	--
2000	GL	113	105.0	10.5	71.6	8.8	75.7
	IS		15.3	1.5	6.9	0.8	6.9
	GW		8.6	0.9	1.9	0.2	--
2020	GL	119	141.8	14.2	95.7	14.0	128.9
	IS		19.4	1.9	9.6	1.4	15.5
	GW		11.5	1.2	2.5	0.4	--

Notes: (1) Does not include 6880 in the village of Medina and Town of Ridgeway now served by Niagara County Water District. (2) Includes population of City of Rochester which has both an upland and a Lake Ontario source. (3) 36 mgd obtained from upland sources by the City of Rochester is included in the 1970 Great Lakes figures shown.

TABLE 6-114 Estimated Manufacturing Water Use, Planning Subarea 5.1 (mgd)

	SIC 20	SIC 26	SIC 28	SIC 33	Other Mfg.	Total
1970						
Value Added (Millions 1958$)	218	38	88	30	1483	1857
Gross Water Required	111	3	13.5	7.3	110	245
Recirculation Ratio	2.77	2.93	1.93	1.81	2.39	--
Total Water Withdrawal	42	1	7	4	46	100
Self Supplied	--	--	--	--	--	50.4
Water Consumed	2	0.1	2.6	0.4	2.9	8
1980						
Value Added (Millions 1958$)	282	53	160	41	2261	2797
Gross Water Required	135	4	25.4	9.6	167	341
Recirculation Ratio	3.15	6.03	3.98	2.83	3.03	--
Total Water Withdrawal	43	0.7	6.4	3.4	55	108.5
Self Supplied	--	--	--	--	--	51.4
Water Consumed	2.4	0.1	2.9	0.5	4.5	10.4
2000						
Value Added (Millions 1958$)	448	99	499	71	5155	6272
Gross Water Required	184	6.5	87.6	15.3	398	691
Recirculation Ratio	3.50	8.00	11.70	6.97	4.80	--
Total Water Withdrawal	53	0.8	7.5	2.1	83	146.4
Self Supplied	--	--	--	--	--	66.0
Water Consumed	3.3	0.2	3.6	0.9	10.3	18.3
2020						
Value Added (Millions 1958$)	750	185	1196	126	11720	13977
Gross Water Required	248	10.6	241.5	22.2	926	1448
Recirculation Ratio	3.50	8.00	15.00	12.00	5.86	--
Total Water Withdrawal	71	1.3	16.1	1.9	158	248
Self Supplied	--	--	--	--	--	140.2
Water Consumed	4.5	0.4	10	1.2	23.1	39

ards of plant sanitation. These industries will continue to account for the major growth in the food industries of the planning subarea and the greatest share of the increase in withdrawals.

The category other manufacturing in Table 6-114 includes the manufacturing plants that account for 80 percent of all value added by manufacture. The large output of the scientific, photographic, and optical industries is included, as well as the output of the metal fabricators, machinery, and electrical equipment plants which are responsible for much of the value added in this category. This large group of industries withdrew an estimated 46 mgd of water in 1970 which was reused at an average of slightly less than 2.5 times to meet their significantly large gross water requirement. Most of the growth in manufacturing output during the next 50 years will occur in this large mix of industries. Value added by manufacture is expected to grow in constant 1958$ value from $1.483 billion in 1970 to $11.720 billion in the year 2020. To match this growth in output, water withdrawals will increase from an estimated 46 mgd to 158 mgd while the recirculation rate improves to almost 6 to 1.

7.2.4.3 Rural Water Use

Rural water requirements and consumption were estimated for Planning Subarea 5.1 following the methodology outlined in Subsection 1.4. Table 6-115 divides total requirements and consumption into categories of rural nonfarm and rural farm. Rural farm is further divided into domestic, livestock, and spray water requirements.

7.2.5 Needs, Problems, and Solutions

7.2.5.1 Municipal

The presently developed quantity of municipal water supply sources is not adequate to meet all projected water supply requirements, but the quantity of the water resource available is adequate to meet the projected future requirements. However this resource must be developed and managed. Development must provide an additional 14 mgd by 1980, 83 mgd by 2000, and 144 mgd by 2020. Approximately 90 percent of this need is projected as additional development of the Great Lakes sources.

TABLE 6–115 Rural Water Use Requirements and Consumption, Planning Subarea 5.1 (mgd)

	1970	1980	2000	2020
REQUIREMENTS				
Rural Farm				
Domestic	2.0	3.1	2.6	2.7
Livestock	4.5	5.8	7.4	9.7
Spray Water	0.1	0.0	0.0	0.0
Subtotal	6.6	9.0	10.1	12.4
Rural Nonfarm	4.3	5.9	4.3	5.2
Total	10.8	14.9	14.4	17.6
Consumption				
Rural Farm				
Domestic	0.5	0.8	0.7	0.7
Livestock	4.1	5.2	6.7	8.7
Spray Water	0.1	0.0	0.0	0.0
Subtotal	4.6	6.1	7.4	9.4
Rural Nonfarm	0.6	0.9	0.6	0.8
Total	5.2	6.9	8.0	10.2

Future needs for public water supply will present no major problem in the planning subarea. Water treatment is not a major problem at present, but may become so at some future date if pollution levels in Lake Ontario continue to increase. Upstream multipurpose reservoir development potential in the Genesee basin is sufficient to meet projected water quality needs and to meet future water supply needs of communities removed from Lake Ontario. These upstream reservoirs may be considered as alternatives to additional diversion from Lake Ontario to serve Monroe County.

The estimated costs of providing municipal water supply to meet the projected needs in the planning subarea are included in Table 6–116 at January 1970 price levels.

A comprehensive multipurpose planning study by the Genesee River Basin Regional Water Resources Planning Board is under way.[20] This study will evaluate present water resources and determine future requirements for the Genesee River basin. The Genesee River Basin Study Coordinating Committee report is being used as a base for the Regional Board Study.

In the Rochester metropolitan area two large systems serve 500,000 people, mainly from Lake Ontario. These systems are the City of Rochester and the Monroe County Water

TABLE 6–116 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Planning Subarea 5.1 (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
Great Lakes	Capital	4.275	18.358	15.906	22.634	38.541
	Annual OMR	.213	1.341	3.048	1.554	4.602
	Total OMR	2.130	26.820	60.970	28.950	89.921
Inland Lakes and Streams	Capital	.000	2.063	2.571	2.063	4.634
	Annual OMR	.000	.102	.333	.102	.436
	Total OMR	.000	2.056	6.675	2.056	8.731
Total	Capital	4.275	20.421	18.478	24.697	43.175
	Annual OMR	.213	1.443	3.382	1.656	5.039
	Total OMR	2.130	28.876	67.646	31.006	98.652

*Ground water unit cost assumptions are as follows:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells & pumping (see Figure 6-4)	-	-
total	120,000	7,600

Authority. The Authority wholesales raw water to the City of Rochester and treated water to many municipalities in Monroe County. The Authority also retails water in portions of the City of Rochester and, under contract, operates several townwide water districts in the county. The capacity of the Authority's Lake Ontario intake is 140 mgd and the Authority has facilities adequate to treat 68 mgd of water.

The City of Rochester obtains water from upland sources in addition to purchasing 40 mgd of raw Lake Ontario water from the Monroe County Water Authority. The city's upland sources, Hemlock and Canadice Lakes, have a safe yield of 36 mgd and this water receives ammoniation, chlorination, and fluoridation.

All counties in the planning subarea have intermunicipal public water supply studies under way that are completely financed by the State of New York. The purpose of this aid program is to assure adequate water supplies in all areas of the State to the year 2020 and to encourage intermunicipal cooperation in the development of water supply facilities. Where applicable these studies were used in preparing the data presented in this appendix.

7.2.5.2 Industrial

Most of the manufacturing growth in Planning Subarea 5.1 is expected to occur in Monroe, Orleans, and Genesee Counties. The concentration of industrial growth in this essentially metropolitan area presents opportunities for management of the supply of industrial water through existing public water supply systems. It is presently estimated that such systems may provide 118 mgd out of their total supply need of 248 mgd to industries in year 2020. It is reasonable to assume that the public system responsibility could be enlarged.

7.2.5.3 Rural

Future rural water requirements should be drawn primarily from ground-water sources, although in some areas streams will be increasingly important. The location and quality of ground water will be important in channeling additional development, particularly in the location of rural nonfarm dwellings. In areas where ground water is in short supply, development should proceed only after water supplies are located. Some areas will not develop until a central supply is available.

Rural water requirements are projected to increase 62 percent and consumption is expected to increase 95 percent between 1970 and 2020.

The moderate ground-water supply in this planning subarea requires careful development to overcome local problems. Poor yields occur where the glacial drift is thin. Mineralized and hard ground water is present at relatively shallow depths in most locations. In order to obtain fresh water, careful and shallow exploration is needed to prevent encountering nonpotable water. The poorer quality water generally occurs in the northern part of the basin. Salt mining in the central Genesee River basin results in leaking of saline water into local streams and probably into the local ground water. Hydrogen sulfide gas in ground water is a local problem.

7.3 Lake Ontario Central, Planning Subarea 5.2

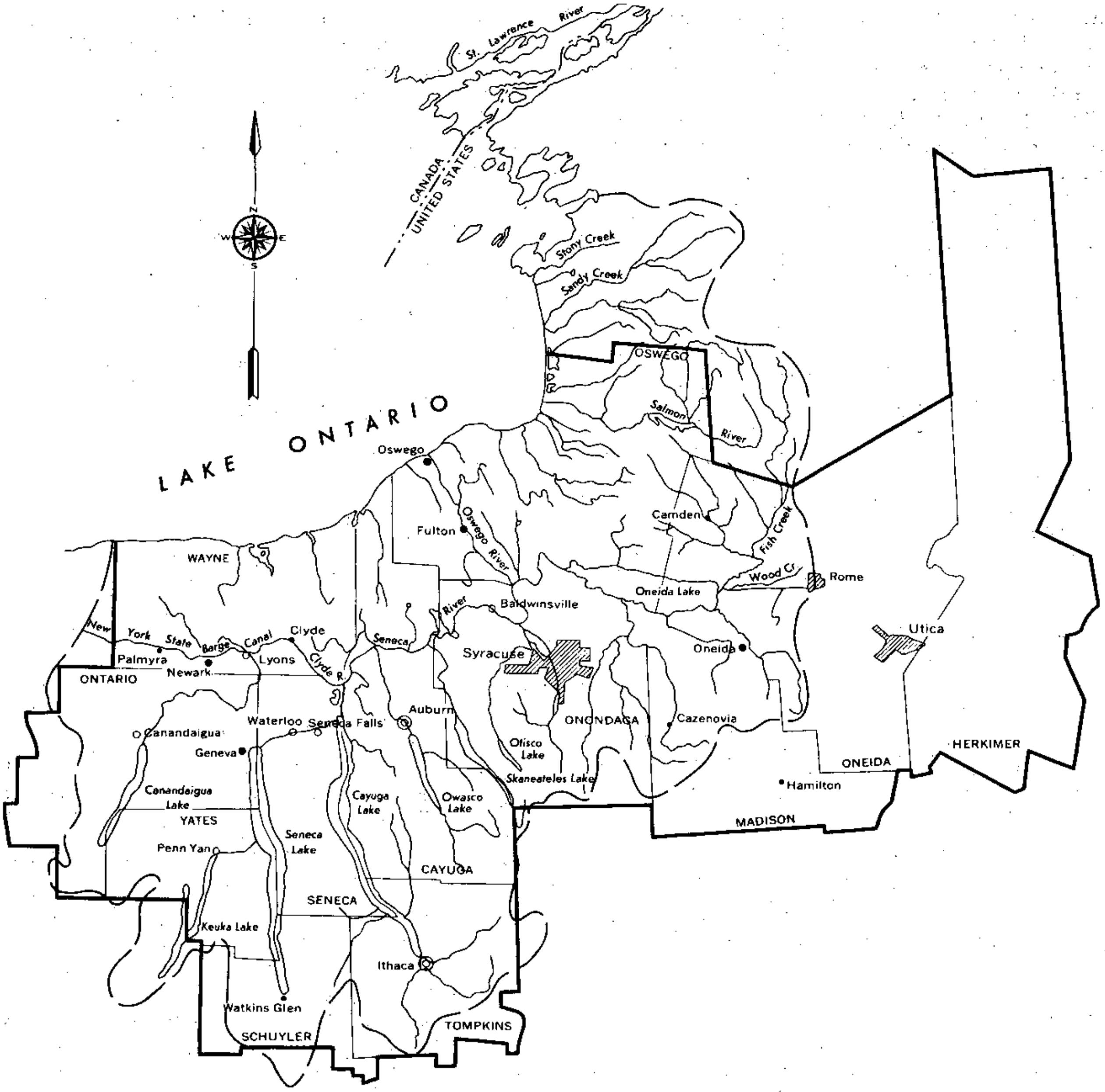
7.3.1 Description of Planning Subarea

7.3.1.1 Location

Planning Subarea 5.2, located within the north central portion of New York State, presents a unique mix of urban, rural, and recreational environments. The region is bounded by Lake Ontario and the Black River basin to the north, the Mohawk River basin to the east, and the Susquehanna and Genesee River basins to the south and west. The basin has a length of more than 100 miles from east to west and extends approximately 120 miles from north to south. Figure 6–58 shows the 12 counties that make up this area and their location in relation to the rest of the basin.

7.3.1.2 Topography and Geography

Planning Subarea 5.2 drainage basins have been extensively glaciated by the movement of ice masses out of Canada. The glaciers left a layer of soil composed of silt, clay, sand, and gravel overlying a series of southward sloping bedrock formations. Sedimentary rocks comprising the bedrock strata range in age from Ordovician to Devonian. They are composed of limestone, dolomite, sandstone, and shale lo-



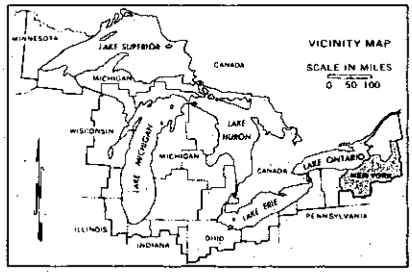


FIGURE 6–58 Planning Subarea 5.2

cally interbedded with gypsum and salt layers. Barriers of glacial debris left by the retreating ice form the drainage divides in the planning subarea.

The planning subarea may be arbitrarily divided into four topographic regions. The lake plains, which occupy the northern portion, are characterized by low relief and numerous marshes. The land is typically flat to gently rolling, and elevations range from 300 to 600 feet above sea level. A notable number of falls occur on streams found in the western portion of the lake plains region. In contrast, the eastern portion of the lowlands is characterized by gently rolling hills with wide swampy areas between and streams with few falls. Stream profiles become steeper toward their headwaters in the Tug Hill plateau. Northwest of Syracuse the land is dominated by asymmetrical glacial features called drumlins, giving the region a distinct hilly appearance. The Appalachian upland escarpment roughly follows an east-west line through the northern ends of the Finger Lakes. Deeply glaciated valleys, oriented in a north to south direction, characterize the Finger Lakes region. The uplands between the Finger Lakes are relatively level with elevations more than 1,000 feet above sea level. Elevations increase gradually to more than 2,000 feet in the Tug Hill and Appalachian plateau regions. Actually an outlier of the Appalachian plateau, the Tug Hill plateau drops off from almost 2,100 feet to the adjacent lowlands. The main drainage areas are the Wayne-Cayuga, Oswego, Salmon-Perch, and Black River basins. The drainage area is approximately 6,650 square miles.

7.3.1.3 Climate

Climate in Planning Subarea 5.2 is classified as humid continental. It is tempered by the proximity of Lake Ontario and the presence of large bodies of water including the Finger Lakes. Prevailing winds blow from west to east in the summer and from southwest to northeast in the winter. Passing over the lakes, these winds absorb considerable moisture which is deposited as orographic precipitation in the Tug Hill-Adirondack plateau regions of the planning subarea. Mean annual precipitation ranges from 32 inches along the lakeshore to 52 inches in the eastern portion of the basin. In winter much of the precipitation comes as snow. On the average 64 inches fall annually along the shores, while depths up to 128 inches accumulate in the northeastern portions of the planning subarea. Monthly distribution of precipitation throughout the year is normally uniform.

The tempering effects of Lake Ontario and the Finger Lakes become most apparent in the range in temperature that occurs in different portions of the planning subarea. Winters are coldest and summers wettest in the easternmost portions of the planning subarea. The lake plains and Finger Lakes regions offer warm, drier summers making recreation pleasant. The number of frost-free days varies from 160 to 200 days along the Lake to 120 to 160 days in the interior. Storms with periods of intense rainfall are common in the planning subarea. The temperature range is 78°F to 84°F in the summer and 17°F to 25°F in the winter.

7.3.2 Water Resources

7.3.2.1 Surface-Water Resources

Planning Subarea 5.2 is rich in surface-water resources. Annual runoff ranges from an average of 10 inches in the west to 40 inches in the northeast section of the planning subarea. The total annual average runoff is estimated at more than 2,150 billion gallons. Variations in streamflow differ greatly between and within the basins.

More than 40 percent of the annual runoff occurs during the spring months. The Finger Lakes region provides a natural regulating effect on the peak flows of the Oswego River. Minimum daily recorded flows range from 0 to 0.11 cfs per square mile. That is, zero-flow conditions consistently occur on Flint Creek for periods up to 20 days, while Oneida Creek has a minimum recorded flow of 0.11 cfs.

The Barge Canal makes use of the Oswego River and its two major tributaries. Where the Seneca, Oneida, and Oswego Rivers have been canalized, the dependable supply is equal to the low flow of the river. However, subject to legal constraints, these flows can be supplemented by water from Lake Erie and the Genesee River on the west, from the Finger Lakes, and from the Rome-Summit area by minimum diversion of 120 cfs from the Mohawk and Black Rivers and a small reservoir on the Susquehanna headwaters.

The greatest surface water asset of the planning subarea is its abundance of large inland lakes. In addition to frontage on Lake Ontario, lake resources include more than 85 inland lakes with total surface area exceeding 191,000 acres. The Oswego basin contains nine major lakes in the Finger Lakes region, which control 3,400 square miles of drainage area. These natural reservoirs make possible a dependable yield of more than 580 mgd. Some 4,485 farm ponds with approximately 2,095 acres of water surface also dot the counties of the planning subarea.

Fully developed water storage areas in inland lakes and streams provide an existing storage capacity of 3.6 million acre-feet. If all inland lakes and streams suitable for development as surface-water impoundments were developed, the total potential storage capacity would increase to 4.04 million acre-feet.[45]

Presently developed water storage areas can produce a sustained water supply yield of 5,746 mgd. If all potential water storage areas were fully developed in Planning Subarea 5.2, impounded inland lakes and streams could produce a sustained water supply yield of 6,028 mgd.[45]

Potential capacities and yields used in this section relate to the total water resource. No attempt has been made to identify that portion of the water resource not suitable or available for use.

The majority of the surface-water resources have a quality suitable for domestic, agricultural, and most industrial uses. Sediment loadings, ranging from 100 to 500 tons per square mile per year, impair water quality and gradually fill up lakes and reservoirs in the planning subarea. The higher loads tend to be in the steep sloping streams, including those draining into the Finger Lakes and those in the Tug Hill upland areas. In addition, high levels of chlorides and hardness occur in the Oswego River. Oneida River tributaries contain higher iron concentrations than most streams in the planning subarea.

7.3.2.2 Ground-Water Resources

In the upland areas glacial deposits of fine materials overlie shale bedrock of low overall porosity. Wells produce no more than 20 gpm in this area. Deposits in the lowlands near the lakeshore overlie fine grained sandstone and produce comparable quantities. Ground water in these areas is usually hard and locally high in iron and manganese.

A broad band of carbonate and shale bedrock with interbedded layers of gypsum crops out along the northern half of the Oswego basin. The movement of ground water in this formation readily dissolves the soluble layers of limestone, dolomite, and particularly the gypsum and salt members. Wells sustain quantities ranging from 20 to 350 gpm, but the water is generally of poor quality, containing objectionable amounts of iron, carbonate hardness, and manganese. Sand and gravel deposits along the Seneca River from Baldwinsville to Syracuse yield from 250 to 700 gpm. Water in this area is usually of good quality except where it overlies the soluble rock formations described above.

Ground-water yield in River Basin Group 5.2 is estimated to be 1,290 mgd (based on 70 percent flow-duration data).[21]

7.3.3 Water-User Profile

7.3.3.1 Municipal Water Users

Growth rates and population densities from 1960 to 1970 were highest in counties sustaining major urban and industrial centers such as Syracuse, Utica, Oswego and cities along the Erie Barge Canal. Sixty-two percent of the 1960 population was classified as urban. Suburban growth continues to eliminate agricultural land in expanding counties such as Onondaga, Seneca, Cayuga, Tompkins, and Oneida. However, most of the area should continue to have a low population density. Average population density was 195.3 people per square mile in 1970. Population levels are not excessive along the Lake Ontario shore. The population pressure increases seasonally with summer residents supplementing the year-round resident total.

Annual average per capita income in 1970 was estimated to be $4,017 (1970$). Municipal water supplies served 91,800 people, 75 percent of the total population of the planning subarea. The projected 2020 population is 2.55 million with 2.2 million served by municipal water supplies. Manufacturing activities account for 32 percent of the planning subarea's working force, and trades and services account for 42 percent. Agriculture employs only 5 percent of the population even though a large percentage of the land area is considered rural.

In 1960 more than 42 percent of the work force was employed in activities that provide goods and services to the planning subarea. Major centers of activity occur in large urban centers such as Syracuse, Ithaca, Oswego, and

Utica. A large number of educational institutions such as Syracuse, Cornell, and Colgate Universities are important factors in the planning subarea's present and future economy.

7.3.3.2 Industrial Water Users

Industry is highly developed and diversified in Planning Subarea 5.2. The economic center of the region is the rapidly growing industrial city of Syracuse in Onondaga County, where approximately 600 manufacturing plants are located. In 1967, 40 percent of the $1.96 billion of value added by manufacture was accounted for by the mills and factories of Syracuse and Onondaga County. Smaller industrial centers include Utica, Auburn, Geneva, Newark, and Ithaca. Manufacturing plants are found in all 12 counties. The total number of plants decreased from 1,730 to 1,636 between 1963 and 1967. However, the decrease in total number was offset by expansion of many surviving plants and construction of new plants. Nine thousand new jobs increased employment to a total manufacturing employment level of 142,200.

High quality machinery and other metal working industries are the most prominent industrial activities, but food processing, paper manufacture, and basic chemical industries are also significant. The largest soda ash, caustic soda plant in the world is located on the shores of Onondaga Lake. Rope, shoes, diesel engines, and woolen goods are manufactured in Auburn; paper, boilers, and machinery in Oswego; guns, adding machines, and machine parts in Ithaca; optical goods and castings in Geneva; and paper products in Fulton.

7.3.3.3 Rural Water Users

In 1964 Planning Subarea 5.2 contained almost 2.7 million acres of land in farm. Meadow crops exceeded the acreage of any other individual crops with 548,000 acres, and vegetable and fruit crops, heavy water users, contributed more than 48,000 and 45,000 acres respectively. Important specialty crops are snap beans, cabbage, onions, apples, sweet cherries, grapes, and pears. Dairy farming, also a heavy water user, is important in the area and contributes almost 80 percent of the receipts from livestock and livestock products. Crop receipts totaled more than $59 million and livestock and livestock product receipts nearly $129 million in 1965. The 1960 census listed 79,000 people living on farms and 24,000 employed on farms.

7.3.4 Present and Projected Water Withdrawal Requirements

7.3.4.1 Municipal Water Use

In 1970 public water systems provided 75 percent of the residents with more than 186 mgd. Lake Ontario provides the public water supply for the major urban area around Syracuse in Onondaga County. Communities on the major lakes take their supply from those lakes. Some use is made of the limited quantity of ground water available in the planning subarea for small community supplies.

Total water withdrawals in Planning Subarea 5.2 are expected to double to 962 mgd by the year 2020 (Table 6–117 and Figure 6–59). The largest increase in water withdrawals will be through central distribution systems. Municipal water supply withdrawals are expected to increase by a factor of 2.6 by the year 2020. Water users will become more dependent upon central distribution systems as the quantity of total water supply increases.

Table 6–118 contains quantitative data pertaining to municipal water supply in Planning Subarea 5.2. The estimated total population of Planning Subarea 5.2 was 1.38 million people in 1970. The data show that 1.05 million people, 75 percent of the total population, were supplied through central water systems.

An average of 187 mgd are currently being supplied through central water systems in Planning Subarea 5.2. Table 6–118 indicates the portions of this total average quantity used by heavy water-using industry and domestic and commercial users.

The bulk of the water use, more than 88 percent, is in the Oswego River basin. More than 12 percent, approximately 23 mgd, is supplied by Lake Ontario sources. Heavy water-using industries in Planning Subarea 5.2 are using approximately 51 mgd or 27 percent of the total municipal water supply.

Approximately 170 mgd or 91 percent of the municipal water supply is received from surface waters and requires purification treatment including coagulation, sedimentation, filtration, and disinfection. The remaining

TABLE 6-117 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Planning Subarea 5.2 (mgd)

Use	1970 mun.	1970 ind.	1970 rural	1970 total	1980 mun.	1980 ind.	1980 rural	1980 total
Withdrawal Requirements								
New York	186.7	262	32.1	481	225.7	240	36.5	502
Total	186.7	262	32.1	481	225.7	240	36.5	502
Consumption								
New York	16.8	19	12.3	48	21.4	30	14.8	66
Total	16.8	19	12.3	48	21.4	30	14.8	66
1970 Capacity-Future Needs								
New York	239.7	262	32.1	534	29.2	55	4.4	89
Total	239.7	262	32.1	534	29.2	55	4.4	89

Use	2000 mun.	2000 ind.	2000 rural	2000 total	2020 mun.	2020 ind.	2020 rural	2020 total
Withdrawal Requirements								
New York	319.0	211	43.4	573.4	429.4	486	47.1	962.5
Total	319.0	211	43.4	573.4	429.4	486	47.1	962.5
Consumption								
New York	34.2	83	17.9	135	49.1	212	21.1	282
Total	34.2	83	17.9	135	49.1	212	21.1	282
1970 Capacity-Future Needs								
New York	123.3	159	11.3	294	251.3	435	15.0	701
Total	123.3	159	11.3	294	251.3	435	15.0	701

ground-water supplies are disinfected and some receive a type of corrective treatment such as softening or iron removal.

The average daily demand in the maximum month of water use is 1.2 times the average demand per year. The per capita usage of total municipal water use is 177 gpcd. Domestic and commercial per capita use is 129 gpcd when heavy industry water use is subtracted from the total usage.

Developed source capacities appear to be adequate at present with the exception of Ithaca and some communities along the Seneca-Cayuga Canal which require development of water treatment facilities.

The total average municipal water supply requirements are expected to increase 1.2 times to 226 mgd in 1980, 1.7 times to 317 mgd in 2000, and 2.3 times to 429 mgd in 2020. The average day in the maximum month of total municipal water use per year is expected to increase from 224 mgd in 1970 to 271 mgd in 1980, 380 mgd in 2000, and 516 mgd in 2020.

Approximately 10 percent of the municipal water use will be consumptive loss. In Planning Subarea 5.2 the consumptive loss can be expected to amount to 17 mgd in 1970, 21 mgd in 1980, 34 mgd in 2000, and 49 mgd in 2020.

7.3.4.2 Industrial Water Use

Manufacturing water withdrawals at present are more than double the withdrawals for domestic and commercial uses. In 1970 the

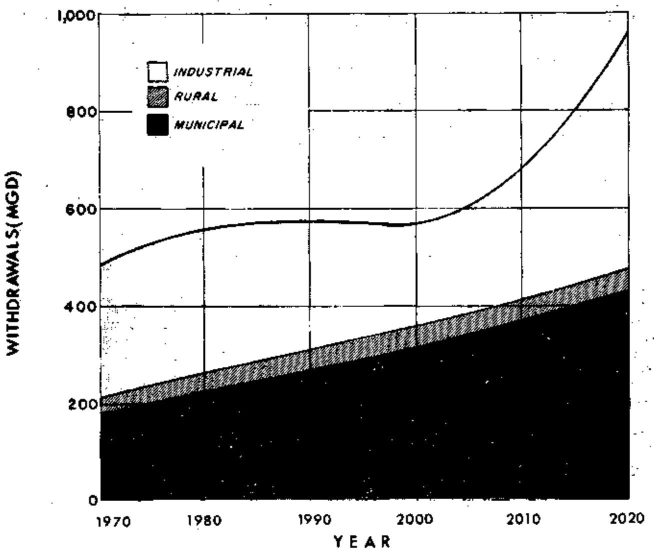


FIGURE 6–59 Municipal, Industrial, and Rural Water Withdrawal Requirements—Planning Subarea 5.2

In 1970 more than 1.38 million people resided in Planning Subarea 5.2, with municipal water supplies serving 1,050,000 people, 75 percent of the total population. Municipal water supplies are expected to serve 2.2 million by 2020.

Agriculture employs only 5 percent of the population. Dairying and fruit and vegetable production are important activities.

Industry is highly developed and diversified in the planning subarea. The principal industrial center is Syracuse. The main industries are metalworking, food processing, paper, chemical, and optical equipment manufacturing, and other diversified industrial activities. Manufacturing employed 32 percent of the working force in 1960.

total withdrawals for manufacturing were approximately 98 billion gallons for the year. Assuming an average six-day work week, the estimated withdrawals were 313 mgd of which 50 mgd were obtained from public water supply systems. Self-supplied industrial water, 260 mgd, is obtained largely from inland streams and lakes.

Table 6–19 presents the base-year estimates and projections of five water-use parameters and constant dollar estimates of value added by manufacture for four major water-using SIC two-digit industry groups and the residual manufacturing groups that comprise the sector. The value-added parameter is derived from OBERS projections and is included to serve as an indicator of the rates of growth of the industry groups. The water-use estimates represent the needs of all establishments without differentiation between small and large water users. The large water-using plants (those that withdrew 20 million gallons or more per year) are relatively few in number, but they have a great impact on water requirements. Approximately 80 large water-using establishments account for more than 95 percent of the total withdrawals by the sector.

In addition to the concentration of water use among a few plants, there is also a concentration of water use by SIC industry groups. The largest water withdrawals in 1970 and throughout the projection period are found in SIC 28, Chemicals and Allied Products (Table 6–119). In 1970 this group of industries withdrew from their own supply sources and purchased from municipal systems a total of 177 mgd, more than one-half of the total manufacturing requirement. The output of SIC 28, derived from OBERS projections of employment and employee productivity, is expected to increase by more than 1,600 percent between 1970 and the year 2020. As a consequence the gross water requirements would increase in similar magnitude. The industry's increasing need for water will most likely be met by improvement of the present low recirculation rate.

Other manufacturing represents a large assortment of both small and large industrial establishments whose sum total growth during the planning period should exceed 720 percent. The potential for improvement in water management in this group varies between industries. A close study of this residual industry group was not within the scope of this study, and therefore net changes in recirculation have been forecast conservatively.

In January 1971 the New York State Department of Environmental Conservation published a report entitled "Oswego River Basin—Industrial Water Requirements Study."[31] The New York State study considered industrial water-use characteristics and future requirements of manufacturers located within the hydrologic boundaries of the Oswego River basin rather than the county boundaries of Planning Subarea 5.2. Although somewhat smaller in area, the Oswego River basin constitutes the major part of the planning subarea and includes the major manufacturing centers with the exception of Utica, New York.

The New York State study incorporated

TABLE 6–118 Municipal Water Supply, Planning Subareas 5.2, New York (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Consumption
	GL		124.3	22.5	27.0	33.7	2.1
1970	IS	1384.7	810.8	147.8	177.3	221.7	13.1
	GW		118.4	16.4	19.7	24.6	1.6
	GL		286.8	44.5	53.4	66.7	4.4
1980	IS	1571.7	832.6	162.5	195.0	243.7	15.3
	GW		122.9	18.7	22.5	28.1	1.7
	GL		625.2	92.0	110.4	138.0	9.4
2000	IS	2015.9	892.9	194.2	236.7	295.8	21.4
	GW		168.8	32.8	33.1	41.3	3.4
	GL		1019.4	148.3	178.0	222.5	15.3
2020	IS	2556.5	996.3	242.2	291.7	362.6	29.5
	GW		229.7	38.9	46.7	58.3	4.3

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Consumption	Municipally Supplied Industrial Water: Average Demand	Consumption	Source Capacity (1970) & Needs (1980, 2000,2020)
	GL		18.0	1.8	4.5	0.3	31.9
1970	IS	129	104.0	10.4	43.7	2.7	175.2
	GW		13.8	1.4	2.6	0.2	32.6
	GL		38.9	3.9	5.5	0.5	8.8
1980	IS	131	109.2	10.9	53.3	4.4	20.4
	GW		15.0	1.5	3.7	0.2	--
	GL		84.5	8.5	7.5	0.9	59.1
2000	IS	137	119.5	12.0	74.7	9.1	61.5
	GW		27.4	2.7	5.4	0.7	2.7
	GL		138.3	13.8	10.0	1.5	120.5
2020	IS	139	142.8	14.3	100.2	15.2	116.5
	GW		31.3	3.1	7.6	1.2	14.0

1964 employment data on individual manufacturing plants in the hydrologic area and interviews with selected manufacturing plant management staff. Projections of manufacturing employment and employee productivity were developed by the Department of Environmental Conservation and may differ from OBERS derived projections. Future water-use prerogatives by manufacturers in the Oswego River basin study differ considerably from those of the Water Supply Work Group, resulting in smaller gross water use and recirculation rates, but in somewhat similar intake requirements (Table 6–120).

TABLE 6–119 Estimated Manufacturing Water Use, Planning Subarea 5.2 (mgd)

	SIC 20	SIC 26	SIC 28	SIC 33	Other Mfg.	Total
1970						
Value Added (Millions 1958$)	168	52	189	71	985	1465
Gross Water Required	28	111	272	103	74	588
Recirculation Ratio	2.77	2.93	1.54	1.81	2.39	--
Total Water Withdrawal	10	38	177	57	31	313
Self Supplied	--	--	--	--	--	262
Water Consumed	0.6	5.4	9.0	4.8	1.9	22
1980						
Value Added (Millions 1958$)	221	72	344	88	1555	2280
Gross Water Required	35	145	541	125	118	964
Recirculation Ratio	3.15	4.64	3.03	2.83	3.03	--
Total Water Withdrawal	11	31	178	44	39	303
Self Supplied	--	--	--	--	--	240
Water Consumed	1.0	7.0	17.6	5.8	3.2	35
2000						
Value Added (Millions 1958$)	355	129	1182	128	3591	5385
Gross Water Required	47	232	2060	156	278	2773
Recirculation Ratio	3.50	8.00	11.70	6.97	4.80	--
Total Water Withdrawal	13.5	29	174	22.4	58	299
Self Supplied	--	--	--	--	--	211
Water Consumed	1.3	11	68	7	7	94
2020						
Value Added (Millions 1958$)	606	229	3073	214	6494	10616
Gross Water Required	65	352	5340	228	973	6958
Recirculation Ratio	3.50	8.00	15.00	12.00	5.86	--
Total Water Withdrawal	18.6	44	356	19	166	604
Self Supplied	--	--	--	--	--	486
Water Consumed	1.6	17	176	10	25	230

TABLE 6–120 Manufacturing Employment, Employee Productivity, and Water Requirements, Oswego River Basin, Planning Subarea 5.2

	1964	1990	2020
Manufacturing Employment	109,447	132,832	160,131
Employee Productivity Ratio	1.00	1.96	4.19
Gross Intake (mgd)	362	579	1,081
Initial Intake (mgd)	252	358	640
Recirculation Ratio	1.44	1.62	1.69

7.3.4.3 Rural Water Use

Rural water requirements and consumption were estimated for Planning Subarea 5.2 following the methodology outlined in Subsection 1.4. Table 6-121 divides total requirements and consumption into categories of rural nonfarm and rural farm. Rural farm is further divided into domestic, livestock, and spray water requirements.

TABLE 6-121 Rural Water Use Requirements and Consumption, Planning Subarea 5.2 (mgd)

	1970	1980	2000	2020
REQUIREMENTS				
Rural Farm				
Domestic	4.1	5.7	4.6	4.5
Livestock	9.3	11.7	14.5	18.0
Spray Water	0.1	0.1	0.0	0.0
Subtotal	13.6	17.4	19.2	22.6
Rural Nonfarm	18.6	19.1	24.2	24.5
Total	32.1	36.5	43.4	47.1
CONSUMPTION				
Rural Farm				
Domestic	1.0	1.4	1.2	1.1
Livestock	8.4	10.5	13.1	16.2
Spray Water	0.1	0.1	0.0	0.0
Subtotal	9.5	12.0	14.3	17.4
Rural Nonfarm	2.8	2.9	3.6	3.7
Total	12.3	14.8	17.9	21.1

7.3.5 Needs, Problems, and Solutions

7.3.5.1 Municipal

Municipal water supply development is needed to provide an additional 29.5 mgd by 1980, 123.3 mgd by 2000, and 251.0 mgd by 2020. Approximately 117 mgd, 46 percent of the total need, should come from additional development of inland lake and stream sources.

Future needs for public water supply will present no major problem in this planning subarea. Shifts from ground water to Great Lakes sources will occur in many areas of Onondaga County. The Onondaga County Water District obtains 25 mgd from Lake Ontario and wholesales treated water to the Onondaga County Water Authority and the City of Syracuse. The Onondaga County Water Authority also receives a limited supply (20 mgd) of water from Otisco Lake. The Authority in turn sells water to many municipal subdivisions in the county. The City of Syracuse obtains water from Skaneateles Lake where the maximum practical withdrawal is 43.5 mgd. Water in excess of this amount is obtained from the Onondaga County Water District. Ground-water sources in Onondaga County are judged to be of insufficient quantity and of poor quality. Many systems now using ground-water sources will shift to purchasing water from the Authority. A major increase in the Onondaga County Water District pumping, transmission, and treatment facilities will be needed by 1990.

Treatment of raw water is not a major problem at present, but it may become one at a later date if pollution levels of Lake Ontario continue to increase unchecked.

This report has estimated the costs of treatment and conveyance of the municipal water supply, but it does not include costs of the distribution system. Estimated costs for projected water supply needs in Planning Subarea 5.2 are listed in Table 6-122. All estimates are made at January 1970 price levels.

Comprehensive multipurpose planning studies are under way for the Cayuga Lake Basin Regional Board (Seneca, Tompkins, and Cayuga Counties),[34] the Wa-Ont-Ya Regional Board (Wayne, Ontario, and Yates Counties),[35] the Eastern Oswego Regional Board (Cayuga, Madison, Oneida, Onondaga, and Oswego Counties),[36] and the Black River Basin Board (Oneida, Jefferson, Herkimer, and Lewis Counties).[37] These studies will evaluate present water resource requirements and determine future requirements for all purposes for the entire Oswego and Black River basins.

7.3.5.2 Industrial

Water withdrawals by manufacturers in Planning Subarea 5.2 were estimated at 313 mgd for 1970. As manufacturing production expands, the accompanying increase in gross water requirement will be met in part by new withdrawals of water and by recirculation and redirection of water use. As a result of improvements in recirculation, total water withdrawals are not expected to increase significantly until the year 2000. Then, as improvements in recirculation rates increase, the withdrawal demand will increase sharply to a total sector demand of 600 mgd.

Figure 6-60 illustrates the changing characteristics of the industrial water demand during the 50-year planning period. In the preparation of this figure the effects of improving recirculation rates by the major water-using industries and the increases in manufacturing output were taken into ac-

TABLE 6-122 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Planning Subarea 5.2 (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
Great Lakes	Capital	2.631	15.039	18.358	17.670	36.029
	Annual OMR	.131	1.011	2.676	1.142	3.818
	Total OMR	1.311	20.234	53.520	21.545	75.066
Inland Lakes and Streams	Capital	6.099	12.288	16.445	18.388	34.833
	Annual OMR	.303	1.220	2.652	1.524	4.176
	Total OMR	3.039	24.406	53.044	27.445	80.489
Ground Water*	Capital	.000	.410	1.717	.410	2.128
	Annual OMR	.000	.034	.216	.034	.251
	Total OMR	.000	.699	4.325	.699	5.024
Total	Capital	8.731	27.739	36.522	36.470	72.991
	Annual OMR	0.435	2.267	5.544	2.702	8.246
	Total OMR	4.351	45.339	110.890	49.690	160.581

*Ground water unit cost assumptions are as follows:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells & pumping (see Figure 6-4)	32,000	18,300
total	152,000	25,900

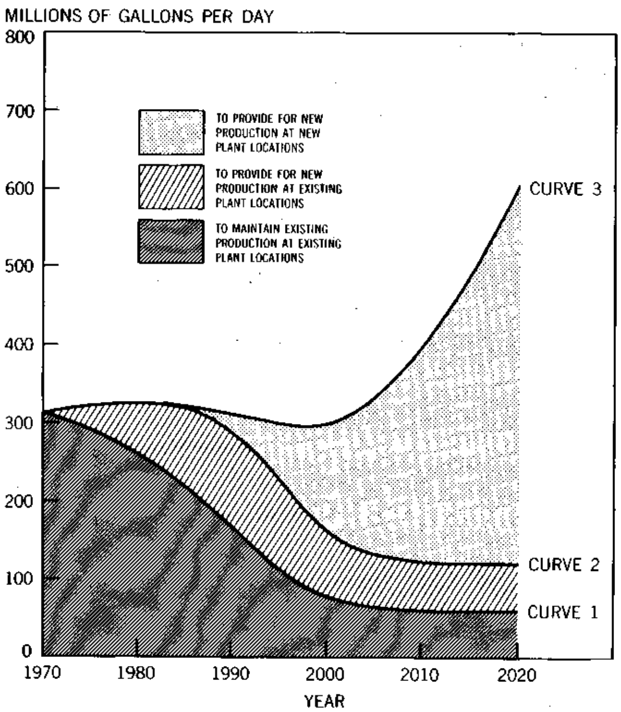


FIGURE 6-60 Total Withdrawal Demands for Manufacturing—Planning Subareas 5.2

count. It is assumed that the first 100 percent of present value added will occur in existing plants and that all additional increases will occur at new locations. Curve 1 represents the withdrawal demand to maintain 1970 production levels at existing plants. Curve 2 represents the withdrawal demand to maintain 1970 production levels and to meet the withdrawal demand assuming that the first 100 percent increase in production will occur at the existing plants. Curve 3 represents the total withdrawal demand for all production regardless of plant location. The area between Curves 2 and 3 represents the withdrawal demands to occur at new locations. By the year 2000, 135 mgd of new industrial water will be needed at locations where plants do not presently exist. By the year 2020 the demand at new locations will be 445 mgd.

The problems associated with meeting these new withdrawal needs will be related to other planning goals such as land use, environmental quality, and subregional economic development. In anticipation of the large growth in industrial activities forecast for the planning subarea, development planning should include alternatives for meeting new industrial water demands by supply through regional industrial water systems and by the enlargement of capacity and expansion of service areas of municipal systems.

7.3.5.3 Rural

Future rural water requirements will be drawn primarily from ground-water sources, although in some areas streams will be increasingly important. The location and quality of ground water will be important in channeling additional development, particularly in the location of rural nonfarm dwellings. In areas where ground water is in short supply, development should proceed only after water supplies are located. Some areas will not develop until a central supply is available.

Rural water requirements are projected to increase 46 percent and consumption is projected to increase 71 percent between 1970 and 2020.

Ground water is generally available only in quantities sufficient for domestic and farm supplies. Water quality is a problem. More than half the planning subarea has water at depths of less than 500 feet containing an undesirable concentration of dissolved solids. Better quality water occurs in the poorer yielding uplands in the south and northeast. Ground-water contamination in local areas has occurred from septic tank seepage.

7.4 Lake Ontario East, Planning Subarea 5.3

7.4.1 Description of Planning Subarea

7.4.1.1 Location

Planning Subarea 5.3 is a sparsely populated region whose water and land resources provide an excellent base for recreation. Located along the St. Lawrence River and the northeastern shore of Lake Ontario, the planning subarea comprises three counties and has an area of approximately 90 square miles (Figure 6–61).

7.4.1.2 Topography and Geography

Distinct geologic and glacial action helped to form the region's topography. The St. Lawrence marine plain is a flat to gently rolling strip along the St. Lawrence River with elevations ranging from 300 feet along its banks to 500 feet inland. Limestone and sandstone bedrock underlie marine clays which predominate in the area. The St. Lawrence Hills, encompassing much of the northern portion of the planning subarea south of the marine plain, become gently rolling and elevations increase southward to almost 900 feet. Sandstone underlies the region covered with glacial drift. Igneous and metamorphic rocks underlie the western Adirondack Hills south of these two regions. The Hills actually form a broad zone of foothills complementing the higher Adirondack peaks to the east. Elevations range from 1,000 to 4,621 feet, the highest peaks being farthest southeast. Glacial action rounded most peaks in the planning subarea and formed many lakes. Streams cut deep valleys in their flow across the land. The Tug Hill plateau reaches elevations from 1,800 to 2,000 feet, dropping off to lowlands in all directions. Paleozoic sandstones, limestones, and shales underlie the plateau which is actually an outlier of the Appalachian Uplands.

The eastern Ontario hills rise quickly from Lake Ontario at elevations near 250 feet to predominantly low hills composed of glacial drift at elevations near 800 feet at the foot of Tug Hill. Lying between Tug Hill and the Adirondacks, the Black Valley forms a lowland whose valley floor averages 750 feet in elevation. Carbonate and crystalline rocks underlie the valley which also has many lacustrine deposits.

Drainage basins in the area include the Perch, Black, Oswegatchie, and Grass-Raquette-St. Regis basins. This hydrologic area drains 7,340 square miles of New York lands. The Oswegatchie, Grass, Raquette, and St. Regis Rivers, rising in the Adirondack Mountains, flow northwest along roughly parallel courses to the main valley floor where they change course to a northeasterly direction and empty into the St. Lawrence. The Black River watershed drains the Adirondacks and the Tug Hill Plateau and flows generally from southeast to northwest across the planning subarea. The St. Lawrence complex drains low plain areas with typically short rivers discharging into Lake Ontario and the St. Lawrence River.

7.4.1.3 Climate

Planning Subarea 5.3 experiences cold, snowy winters and moderate summers. Wide

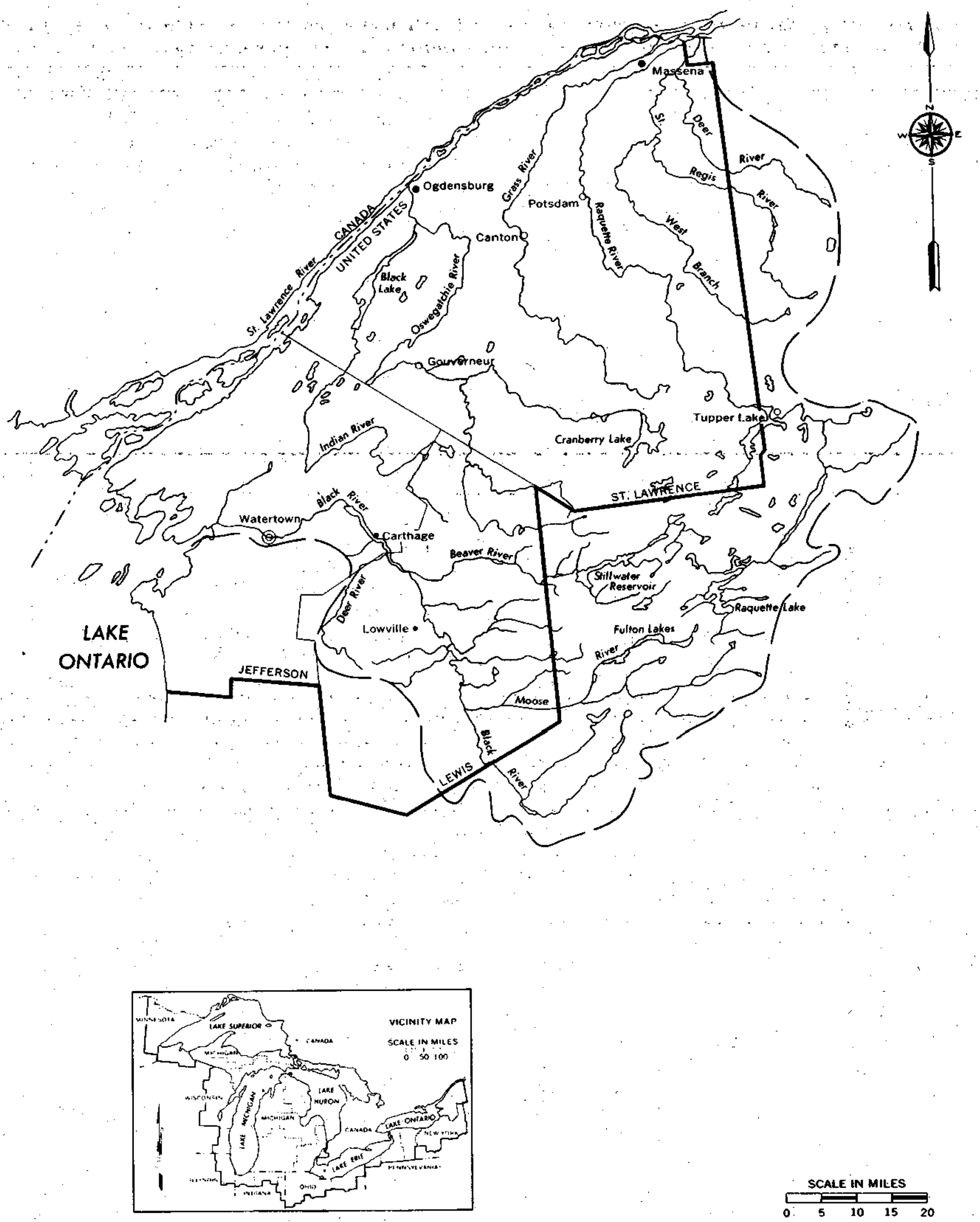


FIGURE 6–61 Planning Subarea 5.3

variation in precipitation patterns occurs over the planning subarea. In the northern and western lake plains regions precipitation averages 36 inches, while significantly higher quantities fall in the Adirondacks and the Black River basin. The moisture provided by the Great Lakes, the prevailing winds, and the orographic effects of the mountains combine to produce the heaviest rainfall of any major drainage area in the State in the Black River basin. It is not uncommon for average precipitation to reach 52 inches annually in the higher elevations in southwestern Lewis County. In winter, snow accumulation averages 80 inches along the northern boundary and increases to an average of 128 inches in the Adirondacks.

Mean annual temperatures are typically cold in the winter and mild in the summer. Jefferson County experiences some moderating climatic effect from Lake Ontario. Length of the growing season varies from 165 to 120 days, decreasing from west to east and with increasing elevation. The temperature ranges from 78°F to 84°F in the summer and 17°F to 25°F in the winter in Planning Subarea 5.3.

7.4.2 Water Resources

7.4.2.1 Surface-Water Resources

Surface water is in ample supply in Planning Subarea 5.3. Major streams drain and have their origins in the highland regions of the Adirondacks and the Tug Hill plateau. The streams flow quickly in their upper reaches and become sluggish as they meander in the plains areas near their outlets to the St. Lawrence River or Lake Ontario. Average annual runoff, which increases from 20 inches in the plains to 40 inches in highland areas, is commonly highest in spring and lowest in late summer.

Lakes, ponds, and swamps occur throughout the drainage basins. The upper reaches of the basins contain most of the lakes. A source of excellent scenic attractions and recreation facilities, some major lakes include the Fulton Chain of Lakes, Stillwater Reservoir, Raquette Lake, Long Lake, Tupper Lake, Carry Falls Reservoir, Lake of the Woods, Black Lake, and Cranberry Lake. Streamflow regulation is common on the Black and Raquette Rivers.

Fully developed water storage areas in inland lakes and streams provide an existing storage capacity of 162,100 acre-feet. If all inland lakes and streams suitable for development as surface-water impoundments were developed, the total potential storage capacity would increase to 4.78 million acre-feet.[45]

Presently developed water storage areas can produce a sustained water supply yield of 876 mgd. If all potential water storage areas were fully developed in Planning Subarea 5.3, impounded inland lakes and streams could produce a sustained water supply yield of 7,098 mgd.[45]

Potential capacities and yield used in this section relate to the total resource. No attempt has been made to identify that portion of the water resource not suitable or available for use.

7.4.2.2 Ground-Water Resources

Availability of ground water depends on existing geologic conditions. Several ground-water regimes result from the environments of the crystalline rocks of the Adirondacks, the sandstones and shales of Tug Hill, the sedimentary rocks of the lowlands, and the glacial mantle overlying much of these bedrock types. The metamorphic and igneous bedrock in the Adirondacks produces low to moderate ground-water supplies.

Although they are adequate for farm and domestic use, the ground-water resources in this region are relatively undeveloped. Sedimentary rocks found in the periphery of the Highlands have produced large supplies of ground water. Recorded yields of 700 gpm have been obtained from dolomites in the Massena area, but the average drilled well yields 15 to 30 gpm.

Deep wells in these units are plagued with sulfide and chloride contamination, while ground water from the Ordovician aquifer exceeds the 500 mg/l USPHS drinking water standard for total dissolved solids. In addition, water from calcareous rocks ranges from moderately to extremely hard. Sandstone and shales of the Tug Hill region also produce only moderate ground-water supplies. Variability in thickness and stratification in glacial drift deposits make ground-water supplies uncertain. Ranging from less than a foot to several hundred feet in thickness, the glacial drift produces sufficient quantities to supply farm and domestic uses. The quality of water derived from till and other types of overburden is generally the same as that found in the underlying bedrock.

Ground-water yield in River Basin Group 5.3 is estimated to be 3,070 mgd (based on 70 percent flow-duration data).[21]

7.4.3 Water-User Profile

7.4.3.1 Municipal Water Users

Planning Subarea 5.3 is a sparsely populated region, the 1970 population numbering 214,500 people. Principal urban centers include Watertown, Ogdensburg, and Massena. Few cities in the planning subarea exceed a population of 5,000. In 1960, 40 percent of the population was classified as urban. Lewis County is decidedly rural with 15.6 percent of its 1960 population classified as urban. Population concentrations occur during recreational seasons, placing additional pressure on available resources. Average population density in 1970 was 29.3 people per square mile. Average per capita income in 1970 was $3,500 (1970$). In 1970 municipal water supplies served 146,200 people, 68 percent of the population. The projected 2020 population is 298,586, of which 230,600 should be served by municipal water supplies.

7.4.3.2 Industrial Water Users

Planning Subarea 5.3 is situated at the extreme eastern end of the Great Lakes Basin along the shore of Lake Ontario and the headwaters of the St. Lawrence River in New York State. Three counties, Jefferson, Lewis, and St. Lawrence, form the political boundaries of the planning subarea. In 1963 there were 282 operating manufacturing establishments employing 15,200 people. By 1967 the number of plants had decreased to 246, but the growth in size of many of the remaining plants resulted in an increase in employment of 11 percent to 16,600 employees. Output of manufacturers also increased from $195 million (constant 1958$) to $233 million between 1963 and 1967.

Most of the manufacturing plants employ less than 20 people and have relatively small water requirements, which are commonly met by purchase of water from public systems. One-fourth of the manufacturers are engaged in dairy and food products processing. Among the larger manufacturing plants are 25 establishments producing many grades of paper and paperboard products that require large quantities of water. There are five large establishments producing primary metals products that have large water requirements for material processing, cooling, and condensing. Machinery and equipment, fabricated metals, wood, and wood products are also products of the region's manufacturers. The major manufacturing centers are Massena and Watertown, and there are clusters of plants near Ogdensburg, Potsdam, Carthage, and several smaller communities.

7.4.3.3 Rural Water Users

In 1964 Planning Subarea 5.3 contained 1.4 million acres in land in farm. Meadow crops comprised almost half of the acreage with 651,000 acres in 1964. Specialty crops are insignificant in the planning subarea. Dairy farming, a heavy water user, is very important in the area, providing nearly 80 percent of all farm receipts. In 1964 less than $4 million were derived from crop sales while more than $60 million were derived from livestock and livestock product sales. The 1960 census listed 30,000 people living on farms and only 9,000 employed on farms.

7.4.4 Present and Projected Water Withdrawal Requirements

Table 6–123 gives a summary of municipal, self-supplied industrial and rural water use for Planning Subarea 5.3.

7.4.4.1 Municipal Water Use

Surface- and ground-water sources provide adequate water for municipal water supply systems. Surface-water sources provide the bulk of supply for public water systems. Urban areas within the planning subarea used 44 mgd in 1970. Industrial water users in the planning subarea consume almost two-thirds of the total municipal water supply. However, most industrial water is self-supplied from rivers and wells. Principal industrial users are manufacturers of paper and paperboard products, and milk receiving or cheese companies.

An average of 45 mgd is currently being supplied to domestic, commercial, and industrial users through municipal water systems in Planning Subarea 5.3. Table 6–124 shows the various portions of this total average

TABLE 6–123 Summary of Municipal, Self-Supplied Industrial, and Rural Water Use, Planning Subarea 5.3 (mgd)

	1970				1980			
Use	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
New York	44.4	76	9.3	130	47.3	41	10.2	99
Total	44.4	76	9.3	130	47.3	41	10.2	99
Consumption								
New York	4.4	7	4.9	16	4.0	8	5.6	18
Total	4.4	7	4.9	16	4.0	8	5.6	18
1970 Capacity-Future Needs								
New York	82.1	76	9.3	167	3.8	--	0.9	4.7
Total	82.1	76	9.3	167	3.8	--	0.9	4.7

	2000				2020			
Use	mun.	ind.	rural	total	mun.	ind.	rural	total
Withdrawal Requirements								
New York	53.1	17	12.1	82	60.4	22	13.4	96
Total	53.1	17	12.1	82	60.4	22	13.4	96
Consumption								
New York	6.4	10	6.6	23	7.6	13	7.5	28
Total	6.4	10	6.6	23	7.6	13	7.5	28
1970 Capacity-Future Needs								
New York	14.1	--	2.8	16.9	28.7	--	4.1	32.8
Total	14.1	--	2.8	16.9	28.7	--	4.1	32.8

quantity used for heavy water-using industry and domestic and commercial purposes.

The bulk of the water use, more than 78 percent, is in the Grass-Raquette-St. Regis River basin. More than 15 percent, approximately 7 mgd, is supplied from Lake Ontario and connecting channel sources. Heavy water-using industries in Planning Subarea 5.3 use approximately 29 mgd, 64 percent of the total municipal water supply.

Approximately 42 mgd, 94 percent of the municipal water supply, is withdrawn from surface waters and requires purification treatment including coagulation, sedimentation, filtration, and disinfection. The remaining ground-water supplies are disinfected and some receive a type of corrective treatment such as softening or iron removal.

The average daily demand in the maximum month of water use is 1.2 times the average demand per year. Daily per capita usage of total municipal water use is 304 gpcd. Domestic and commercial per capita use is 109 gpcd when heavy industry water is subtracted from the total per capita usage.

The total average municipal water supply requirements are expected to increase by 1.1 times to 47 mgd by 1980, 1.2 times to 53 mgd by 2000, and 1.3 times to 60 mgd by 2020. The average day in the maximum month of total municipal water use per year is expected to increase from 53 mgd in 1970 to 57 mgd in 1980, 64 mgd in 2000, and 72 mgd in 2020.

Approximately 10 to 20 percent of the municipal water use will be consumptive loss. In Planning Subarea 5.3 the consumptive loss

TABLE 6–124 Municipal Water Supply, Planning Subarea 5.3, New York (mgd)

Year	Source	Total Population (thousands)	Population Served (thousands)	Total Municipal Water Supply: Average Demand	Maximum Month	Maximum Day	Consumption
	GL		46.8	6.7	8.1	10.1	0.7
1970	IS	214.5	75.0	35.0	42.0	52.5	3.5
	GW		24.4	2.7	3.3	4.1	0.2
	GL		49.9	7.4	8.8	11.0	0.8
1980	IS	225.7	81.6	36.8	44.1	55.1	2.9
	GW		25.8	3.1	3.7	4.7	0.3
	GL		59.9	9.1	10.9	13.7	0.9
2000	IS	257.2	98.0	40.1	48.1	60.2	5.1
	GW		30.9	3.9	4.7	5.9	0.4
	GL		72.5	11.1	13.3	16.6	1.2
2020	IS	298.6	120.4	44.3	53.1	66.5	5.8
	GW		37.7	5.0	6.0	7.5	0.6

Year	Source	Domestic and Commercial Municipal Water Supply: Gallons per capita daily	Average Demand	Consumption	Municipally Supplied Industrial Water: Average Demand	Consumption	Source Capacity (1970) & Needs (1980, 2000, 2020)
	GL		6.0	0.6	0.8	0.1	18.8
1970	IS	109	7.5	0.8	27.5	2.8	50.4
	GW		2.4	0.2	0.3	0.0	12.9
	GL		6.5	0.7	0.9	0.1	0.6
1980	IS	117	9.1	0.9	27.9	2.0	3.0
	GW		2.8	0.3	0.3	0.0	0.2
	GL		8.0	0.8	1.1	0.1	2.5
2000	IS	121	11.3	1.2	28.7	3.9	10.6
	GW		3.5	0.3	0.5	0.1	1.0
	GL		9.8	1.0	1.3	0.2	4.9
2020	IS	124	14.5	1.5	29.7	4.3	21.8
	GW		4.4	0.5	0.5	0.1	2.0

can be expected to amount to 4 mgd in 1970 and 1980, 6 mgd in 2000, and 7 mgd in 2020.

7.4.4.2 Industrial Water Use

Table 6–125 presents estimates and projections of five water-use parameters and values added by manufacture for three SIC two-digit major water-using industry groups and for the residual industry groups that are categorized as other manufacturing, which make up the manufacturing sector. Manufacturing water use is concentrated in two SIC two-digit industry groups: SIC 26, Paper and Allied Products, which withdrew an estimated

32 mgd in 1970, and SIC 33, Primary Metals Products, which withdrew 68 mgd. The combined withdrawals of those two industry groups accounted for more than 95 percent of industrial water use in the planning subarea. Any action taken by those manufacturers that results in an improvement in reuse and recirculation of water will have dramatic effects on the industrial water demand/supply relationships for the entire region.

The total withdrawal requirements for the manufacturing sector were estimated at 105 mgd in 1970. Total withdrawal requirements are expected to decline to 70 mgd in 1980 and 47 mgd in 2000, and then increase to 52 mgd in year 2020 as the opportunities diminish for further improvements in recirculation.

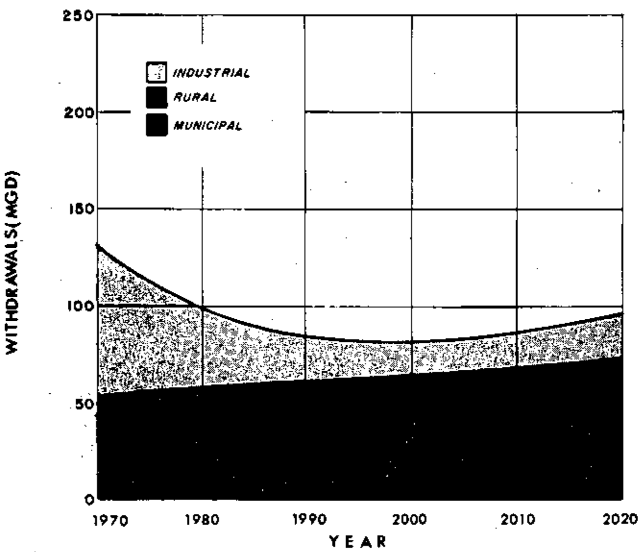


FIGURE 6–62 Municipal, Industrial, and Rural Water Withdrawal Requirements—Planning Subarea 5.3

Planning Subarea 5.3 is a sparsely populated area, with 68 percent of the population, or 146,200 people, served by municipal water supplies in 1970. This is expected to increase to 230,600 by 2020.

Dairying is the principal agricultural activity in all counties, although some mixed general farming occurs in the Black River valley and eastern Lake Ontario region. Employment in agriculture involves 20 percent of the working population in the planning subarea.

Major centers of manufacturing activity include Massena, Ogdensburg, and Watertown. Major industries include pulp and paper mills, mills receiving and processing, and primary metals. Large-scale industrial activity is not widespread in the planning subarea.

7.4.4.3 Rural Water Use

Rural water requirements and consumption were estimated for Planning Subarea 5.3 following the methodology outlined in Subsection 1.4. Table 6–126 divides total requirements and consumption into categories of rural nonfarm and rural farm. Rural farm is further divided into domestic, livestock, and spray water requirements.

7.4.5 Needs, Problems, and Solutions

7.4.5.1 Municipal

Municipal water supply development to provide an additional 28.7 mgd by 2020 is needed. Approximately 21.8 mgd, 76 percent of the total need, should come from additional development of inland lake and stream sources.

Water resources can easily supply future public water demand, but problems may arise at a later date if pollution levels of Lake Ontario continue to increase.

Two regional comprehensive water resources planning studies, sponsored by the State of New York, are under way in Planning Subarea 5.3. These studies are in the Black River basin,[37] involving Herkimer, Jefferson, Lewis, and Oneida Counties, and in the St. Lawrence River basin,[33] involving Franklin and St. Lawrence Counties. These studies will evaluate present water resources and determine future resource requirements for the region.

The New York counties have intermunicipal public water supply studies under way or completed, financed wholly by the State. This aid program was initiated to assure adequate water supplies in all areas of New York State to the year 2020, and to encourage intermunicipal cooperation in the development of water supply facilities.

This report has estimated the costs of treatment and conveyance of the municipal water supply, but it does not include the cost of the distribution system. Estimated costs for projected water supply needs in Planning Subarea 5.3 are listed in Table 6–127. All estimates are made at January 1970 price levels.

7.4.5.2 Industrial

At present 29 mgd of industrial water with-

TABLE 6–125 Estimated Manufacturing Water Use, Planning Subarea 5.3 (mgd)

	SIC 20	SIC 26	SIC 33	Other Mfg.	Total
1970					
Value Added (Millions 1958$)	30	44	85	110	269
Gross Water Required	4.2	94	123	8	229
Recirculation Ratio	2.77	2.93	1.81	2.07	--
Total Water Withdrawal	1.6	32	68	3.2	105
Self Supplied	--	--	--	--	76
Water Consumed	0.1	4.5	5.5	0.3	10
1980					
Value Added (Millions 1958$)	40	49	91	178	358
Gross Water Required	5.1	100	132	13	250
Recirculation Ratio	3.15	6.03	2.83	3.03	--
Total Water Withdrawal	1.9	16.3	47	4.5	70
Self Supplied	--	--	--	--	41
Water Consumed	0.15	4.8	5.6	0.3	10
2000					
Value Added (Millions 1958$)	69	66	112	422	669
Gross Water Required	7.4	119	162	30	318
Recirculation Ratio	3.50	8.00	6.97	4.80	--
Total Water Withdrawal	2.6	14.8	23	6.9	47
Self Supplied	--	--	--	--	17
Water Consumed	0.2	5.8	6.9	0.8	14
2020					
Value Added (Millions 1958$)	127	93	150	967	1337
Gross Water Required	10.1	142	217	69	438
Recirculation Ratio	3.50	8.00	12.0	5.86	--
Total Water Withdrawal	4.2	17.8	18	13.1	53
Self Supplied	--	--	--	--	22
Water Consumed	0.3	7.0	9.2	1.9	18

TABLE 6–126 Rural Water Use Requirements and Consumption, Planning Subarea 5.3 (mgd)

	1970	1980	2000	2020
REQUIREMENTS				
Rural Farm				
Domestic	1.4	1.5	1.0	1.0
Livestock	4.5	5.2	6.2	7.2
Spray Water	0.0	0.0	0.0	0.0
Subtotal	6.0	6.8	7.2	8.2
Rural Nonfarm	3.3	3.4	4.9	5.2
Total	9.3	10.2	12.1	13.4
CONSUMPTION				
Rural Farm				
Domestic	0.4	0.4	0.3	0.3
Livestock	4.1	4.7	5.6	6.5
Spray Water	0.0	0.0	0.0	0.0
Subtotal	4.5	5.1	5.8	6.7
Rural Nonfarm	0.5	0.5	0.7	0.8
Total	4.9	5.6	6.6	7.5

drawal requirements are supplied by municipal water supply systems. The quantity should increase to 31 mgd by the year 2020. If industrial water withdrawals in the future remain at the present-day magnitudes, there should be no major problem in meeting those needs.

7.4.5.3 Rural

Future rural water requirements will be drawn primarily from ground-water sources, although in some areas streams will be increasingly important. The location and quality of ground water will be important in channeling additional development, particularly in

TABLE 6-127 Estimates of Costs Incurred for the Development of Municipal Water Supply Facilities to Meet the Projected Needs, Planning Subarea 5.3 (millions of 1970 dollars)

SOURCE	COST	1970-1980	1980-2000	2000-2020	1970-2000	1970-2020
Great Lakes	Capital	.179	.568	.717	.747	1.465
	Annual OMR	.008	.046	.110	.055	.165
	Total OMR	.089	.923	2.205	1.013	3.218
Inland Lakes and Streams	Capital	.897	2.272	3.348	3.169	6.518
	Annual OMR	.044	.202	.482	.247	.730
	Total OMR	.447	4.052	9.655	4.499	14.155
Ground Water*	Capital	.030	.120	.150	.150	.300
	Annual OMR	.002	.012	.031	.014	.046
	Total OMR	.021	.252	.630	.273	.903
Total	Capital	1.106	2.960	4.217	4.067	8.283
	Annual OMR	0.056	0.262	0.625	0.317	0.941
	Total OMR	0.557	5.229	12.490	5.786	18.276

*Ground water unit cost assumptions are as follows:

	Capital ($/mgd)	Annual OMR ($/mgd-yr)
transmission	120,000	7,600
wells & pumping (see Figure 6-4)	30,000	13,400
total	150,000	21,000

the location of rural nonfarm dwellings. In areas where ground water is in short supply, development should proceed only after water supplies are located. Some areas will not develop until a central supply is available.

Between 1970 and 2020, rural water requirements are expected to increase 45 percent and consumption is expected to increase 52 percent.

Major ground-water resources are not available in the areas where they are needed. Water problems occur during droughts, especially for the dairy farms in the Black River valley. Chemical quality of the ground water is generally good, but hard water is prevalent. Saline water is commonly present in the carbonate aquifer at shallow depth. Deep-well digging should be avoided to prevent salt water contamination of the upper fresh water zones. High sulfate content of ground water can also be a problem in the carbonate aquifer area. Iron problems are not as widespread.

Section 8

ALTERNATIVE POSSIBILITIES RELATED TO FUTURE WATER USE PROSPECTS IN THE GREAT LAKES BASIN

The numerical data in most of these planning subarea reports, based on the OBERS projections of population and the economy, have suggested that the supply of water for municipal, industrial, and rural uses will be adequate for the projected time period, provided the water resources are well managed. In the future, water supply needs of the Great Lakes Basin may be satisfied by systems significantly different from those existing today. This possibility is already incorporated into the quantitative estimates made for industrial water supply. This section discusses future water-use practices that may differ slightly from past trends, either in character or in relative importance.

8.1 Ground-Water Management

Wells comprise the most widespread source of water, with local conditions largely determining ground-water development practices. The kind of proper management assumed in this study centers around the principle of sustained yield, with due attention to well spacing, scheduling of withdrawals, and other factors. Some flexibility over limited periods is afforded by the presence of very large quantities of water in deep aquifers which, in some instances, can be mined judiciously, provided adequate consideration is given to the possibilities of aquifer compaction and practical limits on drilling depth.[48]

Although it is difficult to estimate the degree to which various ground-water management practices are assumed in the numerical data of this report, there is expected to be continuing and increasing attention to replenishment of ground water. Natural recharge is expected to be aided in rural areas by use of recommended runoff-retarding farming practices such as contour plowing and terracing, as well as control of plants that transpire freely. In urban areas, places where sand or gravel aquifers are near the surface can be preserved as open space and remain unpaved for their recharge value.

Artificial recharging may be increased to maintain ground-water supplies, particularly in more shallow aquifers. Already in use in some places, this practice involves depositing stormwater, treated sewage, or other appropriate surplus water in a well, pit, or basin leading to the desired aquifer. Kalamazoo, Michigan, is an example of a fairly large city with an operational ground-water recharge basin. With favorable circumstances and competent design, such facilities can maintain water levels to a useful degree. As with all methods of water handling, the operation must be carefully fitted to local conditions.

8.2 Storage of Surface Water

8.2.1 Offstream Storage

An upground or offstream reservoir is an earth structure designed to impound water. Unlike the more common onstream reservoir, an upground storage reservoir is located off the main stream channel and water is conveyed to it from a stream by pump or canal. Upground reservoirs can be constructed almost anywhere, and they have smaller overall land requirements than onstream reservoirs due to uniform depth, minor siltation problems, and flexibility in location. There are many offstream reservoirs in areas of relatively flat topography in the Great Lakes Basin. Offstream reservoirs are generally used for water supply for serving municipal and industrial systems, but these reservoirs can also be used for low-flow augmentation.

Other proposed storage techniques not primarily directed toward water supply goals might nonetheless contribute to the dependable quantity of water available for withdrawal. Where storm flows have been a problem, excess flow could be stored in natural aquifers, in underground excavations, or on rooftops and other urban surfaces designed intentionally to retard runoff or recharge ground water. It must be noted that there are often important quality differences in water from surface and subsurface sources, but the possibility of transferring water back and forth between surface and underground locations (conjunctive use) may afford a flexibility tantamount to an increase in the quantity available.

8.2.2 Onstream Storage

To satisfy future water supply needs it may be necessary to stabilize streamflow through reservoir or onstream storage control. There are many existing and potential reservoir sites within the Great Lakes Basin. Some of the potential sites may have to be set aside to prevent development that would preclude reservoir construction. Appendix 2, *Surface Water Hydrology*, presents a tabulation of existing and potential reservoir sites in each of the planning subareas of the Great Lakes Basin.

8.2.3 Evaporation Reduction in Storage

Evaporation is not likely to be a problem because of the relative abundance of water in the area. However, in future times in some localized areas, evaporation reduction may become important. Ways to reduce evaporation include chemical means (floating monomolecular films), wind and solar screens, proper site location of storage reservoirs, and mechanical covers.

8.3 Improved Distribution Systems

It is estimated that leaks in water distribution systems amount to a loss of 10 gallons of water per capita each day. This loss is a significant portion of the total per-capita use of water supplied through distribution systems, and elimination of the loss would result in substantial savings of water as well as offering fewer opportunities for contamination. Other possible improvements include replacements of systems or portions of systems having insufficient capacity because of pipe size and/or deposits on pipe linings; computer controlled distribution to direct water under proper pressure to need points within the system; sufficient emergency and back-up capacity; line-ups with neighboring systems; and further training of operating personnel.

8.4 Increased Transport of Water

As the need for additional water supply increases beyond the capability of nearby sources, water transmission by pipeline will become more practical. Where inland water sources provide the best prospects for expanding supplies, pipelines to more plentiful streams may be developed. It is expected that most of the long distance pipelines will use the Great Lakes as the source of water. Because of the large capital cost, many pipelines will serve regional areas or other combinations of user units. A handful of Michigan cities are already served by long-distance pipelines, and further extension of this practice is assumed in the numerical data presented in this report. Several regional water supply systems exist or are planned within the Great Lakes Basin such as those in southeastern Wisconsin, southeastern Michigan, and the Duluth-Superior area.

One objection to this method is that piping water to upstream users from the Great Lakes may create a cyclical flow of water. Therefore, adequate waste treatment becomes particularly important under these circumstances to prevent the cumulative buildup of waste materials in the stream receiving the discharges.[65]

8.5 Technological Improvements

8.5.1 Process Modification in Industries

The wide variations of water use within many industries, such as steel manufacturing, are well known. Unproved possibilities in various manufacturing processes (e.g., a relatively new dry method of making paper) could affect industrial water use to an unforeseen degree. This study assumes virtually across-the-board steps to reduce water use in manufacturing. Such steps could help serve the multiple purpose of providing for the industry's water needs, meeting legal restrictions on industrial effluent, recovering valuable byproducts, and achieving improvements in production efficiency as well.

8.5.2 Recirculation

There is good potential for reuse of water, whether by complete recirculation or through cascading into progressively less demanding use. Considerable technology for reuse is now available, and some incentive exists to reclaim byproducts and to reduce effluent (Subsection 8.6.4). Now and in the immediate future, reuse is practical for purposes requiring less than complete reclamation: industrial uses or ground-water recharge. Large-scale industrial reuse has great potential and was considered in the calculation of the figures presented in this appendix. Large-scale reuse may in turn release natural sources of water for potable supply.

8.5.3 Reclamation of Wastewater

The concept of reclaiming wastewater for domestic or industrial uses is not new, but conventional sources of water have generally been preferred because of abundantly available water and inadequate reclamation technology. However, shortages of water in some areas of the country and technological breakthroughs enhance the prospects for use of reclaimed wastewater. Industry is already treating and reusing increasing shares of its water supply. Several new or modified treatment techniques have been developed which are capable of reducing both organic and inorganic components of wastewater to extremely low levels. Experiments are being conducted or proposed for evaluating the possible uses of treated sewage to fertilize pasture and forage crops, to grow useful aquatic plants and fish for harvest, and—in the final stage of the reclamation process—to provide water suitable for swimming.[53]

Ultimately, direct reuse for potable supply may be possible. The future of reuse for general municipal supply is dependent upon three main factors: economics, public acceptance, and assurance of virological safety. At present alternative sources of supply are more economical than the supply made available by advanced treatment. Therefore, there has been no demand for reuse for general supply. Such demand will build up gradually and in selected locations of water scarcity. Given sufficient economic demand and clearance of health factors, public acceptance will follow. Even so, in the Great Lakes region the general abundance of water available from more conventional sources may well delay the adoption of domestic reuse measures.

8.5.3.1 U.S. Environmental Protection Agency Policy Statement on Water Reuse

The Environmental Protection Agency has issued the following statement on the reuse of water:

> The demand for water is increasing both through population growth and changing life styles, while the supply of water from nature remains basically constant from year to year. This is not to imply that the nation will shortly be out of water, although water shortages are of great concern in some regions and indirect reuse has been common for generations. It must be recognized that there is a need to use and reuse wastewater. Therefore,
>
> (1) EPA supports and encourages the continued development and practice of successive wastewater reclamation, reuse, recycling and recharge as a major element in water resource management, providing the reclamation systems are designed and operated so as to avoid health hazards to the people or damage to the environment.
>
> (2) In particular, EPA recognizes and supports the potential for wastewater reuse in agriculture, industrial, municipal, recreational and ground-water recharge applications.
>
> (3) EPA does not currently support the direct interconnection of wastewater reclamation plants with municipal water treatment plants. The potable use of renovated wastewaters blended with other acceptable supplies in reservoirs may be employed once research and demonstration has shown that it can be done without hazard to health. EPA believes that other factors must also receive consideration, such as the ecological impact of various alternatives, quality of available sources, and economics.[17]

8.5.3.2 American Water Works Association Policy Statement on the Use of Reclaimed Wastewaters as a Public Water Supply Source

The views of the American Water Works Association about reuse of wastewater are summarized in the following statement:

> The American Water Works Association recognizes that properly treated wastewaters constitute an increasingly important element of the total available water resources in many parts of the North American continent as well as elsewhere in the world.
>
> Historically, wastewaters have been reused after discharge of the effluents to streams and into the ground. This practice has provided dilution, separation in time and space, and has allowed natural treatment phenomena to operate before reuse. In contrast to such indirect reuse, planned direct reuse is increasingly being made of reclaimed waters for wide varieties of beneficial uses such as industrial cooling, certain industrial processes, irrigation of specific

crops and recreational areas. Moreover, there is increasing use of reclaimed waters for planned ground water recharge.

The Association believes that the full potential of reclaimed water as a resource should be exploited as rapidly as scientific knowledge and technology will allow, to the maximum degree consistent with the overriding imperative of full protection of the health of the public and the assurance of wholesome and potable water supplied for domestic use. The Association encourages an increase in the use of reclaimed wastewaters for beneficial purposes, such as industrial cooling and processing, irrigation of crops, recreation, and (within the limits of historical practice), ground water recharge. Further, the Association commends efforts that are being made to upgrade wastewater treatment and to improve quality before discharge into sources of public water supplies.

The Association is of the opinion, however, that current scientific knowledge and technology in the field of wastewater treatment are not sufficiently advanced to permit direct use of treated wastewaters as a source of public water supply, and it notes with concern current proposals to increase significantly both indirect and direct use of treated wastewaters for such purposes. It urges, therefore, that immediate steps be taken, through intensive research and development, by the AWWA Research Foundation and the Water Supply Section of the Office of Water Programs in the Environmental Protection Agency to advance technological capability to reclaim wastewaters for all beneficial uses. Such research and development is considered to be of greater national need than that now being directed to desalinization. It should:

(1) Identify the full range of contaminants possibly present in treated wastewaters that might affect the safety of public health, the palatability of the water, and the range of concentrations.

(2) Determine the degree to which these contaminants are removed by various types and levels of treatment.

(3) Determine the long-range physiological effects of continued use of reclaimed wastewaters, with various levels of treatment, as the partial or sole source of drinking water.

(4) Define the parameters, testing procedures, analytical methodology, allowable limits, and monitoring systems that should be employed with respect to the use of reclaimed wastewaters for public water-supply purposes.

(5) Develop greater capability and reliability of treatment processes and equipment to produce reclaimed water of reasonably uniform quality, in view of the extreme variability in the characteristics of untreated wastewaters.

(6) Improve the capabilities of operational personnel.

The Association believes that the use of reclaimed wastewaters for public water-supply purposes should be deferred until research and development demonstrates that such use will not be detrimental to the health of the public and will not affect adversely the wholesomeness and potability of water supplied for domestic use.[5]

8.5.4 Other Prospective Technological Advances

Technological advances in water quality control will probably make more water available for withdrawal at a lower unit cost. In addition, improvements in distribution system design, better pipe materials, improved water treatment practices, better storage facilities, and other improvements will help to meet the increasing demand for water. Industry's growing ability to conserve water has been noted. For domestic water conservation, there are possibilities of individual home water reclamation through recycling systems and new types of chemically operated flushless toilets. Further improvement of desalting techniques, reverse osmosis and other means may eventually make feasible the use of some ground water now considered too brackish for most purposes.

8.6 Water-Use Management

8.6.1 Metering and Pricing Policies

Present practices of accounting for and pricing water withdrawals reflect a variety of attitudes toward the apportionment of this resource. The tradition (common in humid parts of the country) that water is a "free good" shows up in some municipal supplies which are partly or completely unmetered, or where rates are charged with cover service charges only, and place little economic value on the water itself. In recent years dramatic reductions in water use have been recorded in municipalities replacing flat rates with charges based on metered use. Because water is increasingly recognized as a valuable resource rather than a free good, it seems probable that there will be a continued spread of metering and quantity-related rate structures (perhaps proportional to gallons used, or even ascending as some would recommend). As a result, some of the wastage included in present use rates may be eliminated, dampening to some degree the expected upward swing of the water-use curve in some parts of the Basin.

8.6.2 Water Rationing

A limited type of water rationing, affecting the main consumptive use of municipal water, already exists in many Great Lakes Basin communities where lawn sprinkling is restricted to alternate days. While extension of rationing to uses (chiefly nonconsumptive) inside the home is conceivable, this should be a rare, last-resort emergency measure rather than a long-term practice. Over the long haul, a realistic price structure for water, discussed in Subsection 8.6.1, would seem able to combine any necessary limitations on use with a desirable degree of flexibility and administrative feasibility.

8.6.3 Public Education

Over the past few years both public and private users of the mass communications media have transmitted a vast amount of information and exhortation related to the wise use of natural resources, and a great deal of active interest has been aroused. Various efforts are being made to make natural resources instruction a required subject in public school curricula. In at least one major university, the former home economics program has been renamed human ecology. Attitudes fostered by such public education may tend to lower the amounts of water taken in by municipalities and industries, perhaps by encouraging voting citizens to support institutional changes in that direction.

8.6.4 Effluent Restrictions and Related Measures

The future level of industrial water intake is being held down significantly by governmental effluent restrictions because it is sometimes easier for a manufacturer to make wastewater reusable within the factory than to render it suitable for discharge to a stream. An additional inducement for industries to reduce effluent, and hence intake, is exemplified in Michigan's new practice of charging industries a fee, based on quantity and strength of liquid waste, for the purpose of financing the necessary effluent monitoring operations. There has been some debate on the nationwide academic level[55] as to whether an incentive system of systematic effluent charges should be developed to replace or supplement the present standards-and-penalties arrangements for insuring water quality. It is not clear how such a possible shift might affect water demand in the Great Lakes Region.

8.6.5 Water Supply Service as a Tool for Guiding Regional Development

Traditionally the responsibility of the water supply industry has been to provide good, safe, efficient water service in response to existing and foreseeable demand. This role is probably still prevalent and may represent the only immediately practical approach. However, the argument has been advanced by some economists, planners, and others that decisions to provide or withhold water supply service should be based on social and environmental considerations, as part of overall plans for the general welfare and desirable development of the regional area concerned. In this latter view, water supply and other utilities would be extended where settlement and development should be encouraged, but would be refused to areas where such services might foster overpopulation or other detrimental social or environmental effects. If these proposed new decision-making criteria were accepted and acted upon, their effects within the Great Lakes Basin would appear primarily on a local scale, rather than affecting whole planning subareas significantly.

8.7 Land-Use Management

8.7.1 Land-Use Changes

Upstream land-use changes can have an effect on the amount of water available for downstream users. An obvious case in point is the reduction in quantity or quality of water available downstream stemming from the presence of municipal and industrial use upstream. Other examples are the effects on streamflow that would be expected from rural land uses and practices: vegetation types, land treatment, erosion reduction measures, and other factors. Wise upstream land management can help to maintain streamflows and reduce the magnitude and number of streamflow variations. By influencing land use, and the location or density of various types of water uses, zoning can be used to encourage a more desirable distribution of water use (Subsection 8.7.3). Possible future opportunities to establish planned new towns may provide dramatic, though perhaps not numerous, instances of such land management. Advance news of a forthcoming United Nations report indicates that thought is being given to the possibility of future worldwide watershed "zoning" to conserve water supply.[6]

8.7.2 Rural Land Management

In places where water shortages exist, the amount of water evapotranspired from the land surface is particularly important, because this water is, for practical purposes, lost forever. To minimize consumptive use where desirable, reductions in irrigation water requirements can be accomplished by soil conditioning and cultivation practices, proper spacing of plants, utilization of rotation practices aimed at conserving water (based upon soil and evaporation conditions), and correct use of efficiently designed irrigation systems.

Management of watershed vegetation may be able to increase the available runoff for downstream withdrawal, although at least one recognized authority cautions against "the widespread and erroneous myth . . . that there is a direct, invariable and positive relationship between forest growth and stream flow."[71] Some research suggests that a watershed is likely to yield more water if it is covered by grass than if it is covered by trees, and that some species of trees transpire significantly more than others.[67] Broad-scale efforts to increase runoff seem remote in the Great Lakes Basin with its abundance of water, but the potential may exist.

8.7.3 Zoning of Industrial Sites

Water may be a major limiting factor in industrial growth in a particular area. The unguided course of industrial growth sometimes results in severe water shortages and costly importation of water to meet industrial demands. The future may see attempts to avoid many such problems through investigation and assessment of the location and amount of available water supplies and enactment of a good zoning ordinance to control the type of industry in an area, industrial density, and other factors affecting water supply. Zoning may be used as a tool to insure that supplies of water will not be outstripped by demand. The numerical data presented in this appendix have not been adjusted to reflect this possibility.

8.8 Weather Modification

In some parts of the United States, techniques for stimulating precipitation through cloud seeding figure in long-range thinking about adequacy of water supplies. However, for the future water supply of the humid Great Lakes Region the potential direct effects of rainmaking are not as great as in the arid West, where the scarcity of water is used to justify large storage facilities to hold runoff from large areas of the countryside until it can be used. In the Great Lakes Basin, where the specific location and timing of available water are the major causes of such shortages as may develop, present knowledge of potential weather modification capabilities offers little assurance that sufficient precision for "water on demand" will be possible.[60]

Apart from intentional stimulation of precipitation, it is acknowledged that considerable inadvertent weather modification is already taking place, particularly around cities. Heat and vapor-attracting particles are released into the atmosphere, apparently causing increases in precipitation, fog, and clouds. It is possible that the water regimen of the Great Lakes Region could be changed by side effects of future precipitation-modification efforts upwind or storm-suppression measures being devised. Another possible result is that weather modification activities elsewhere might affect the comparative economic advantage status of the Great Lakes Basin in some respects and bring about a shift in water users. If weather modification efforts should further extend to "sunlight management" to lengthen the growing season, the demand for water in warm-weather uses could change correspondingly.[60]

8.9 Exogenous Factors Affecting Water Needs

There are some basic assumptions underlying this study:

(1) It is assumed for planning purposes that the region will develop in a reasonably orderly way, propelled chiefly by forces internal to the United States, and that any disruptions that may occur in this pattern will be short-lived.

(2) It is assumed that there will be no major wars directly affecting the Great Lakes Basin in the various target years.

(3) It is assumed that there will be no massive influxes of population in reaction to natural conditions or man-made pressures outside the Basin.

(4) It is assumed that there will be no wholesale, long-term contamination of the major sources of water within the Basin.

(5) It is assumed that any possible increase in the net amount of water diverted out of the Great Lakes Basin in the future will not be great enough to cause shortages for projected uses.

These assumptions, and others cited elsewhere, may all prove to be true, but any major departure of future fact from this general perspective could call for new conclusions regarding the area's water supply.

8.10 Summary

This section has reviewed several broad approaches to water resource management and public water supply. Table 6–128 lists several management measures currently in use in northeastern Illinois, specifies the problems these measures are designed to mitigate, and sets forth broad prerequisites for their application. Although the various management measures are separated in the previous discussions and in the table, it is essential to remember that a metropolitan water system is a complex integrated unit. All of the components and all of the uses are inextricably interrelated. Any change in one component caused by a particular management measure will influence the other components to some extent. The influence of changing any of the components should be thoroughly evaluated prior to the adoption of a particular water resource management program.

TABLE 6–128 Water Resource Management Measures

MEASURES	WATER PROBLEMS REDUCED	PREREQUISITES	CURRENT APPLICATION
I. Interbasin transfer			
A. Tunnels	flooding; low flow; water supply needs; recreation needs	basins with surplus water	Chicago Sanitary Canal System
B. Open channel			
C. Pipelines			Chicago Sanitary Canal System
II. Storage and surface runoff			
A. Preservation of natural storage	flooding; preserve natural recharge	open space in flood plains	forest preserve flood plains, stream channels
B. Downstream storage	flooding	downstream space and channel capacity	Salt Creek, Weller Creek, and St. Joseph Creek improvements
C. Artificial storage	flooding; low flow, water supply needs; recreation needs	sites for storage	Skokie Lagoons, on Skokie River, Fox Chain O'Lakes
III. Ground-water management			
A. Withdrawal	water supply needs; low flow	unused water, collection of hydrologic and geologic data	shallow aquifers (locally) Cambrian-Ordovician aquifer
1. Development of maximum sustained yield			
2. Withdrawal from storage			Cambrian-Ordovician aquifer
B. Replenishment	water supply needs; low flow	prime recharge areas	forest preserve flood plains
1. Natural recharge preservation	flow; flooding	open space	
2. Artificial recharge		surplus water, storage space suitable geologic and hydrologic conditions	none
IV. Conjunctive use of surface and subsurface reservoirs	flooding; low flow, recreation needs	surplus water, surface and subsurface storage space, artificial recharge and pumping facilities	none
V. Water quality management			
A. Pollution source control	pollution; recreation needs; water supply needs	treatment plants	widespread for a few pollutants, none for others
B. Transport of pollutants	pollution, recreation needs	transport water	widespread use of streams to transport waste
C. Accommodate pollutants	pollution	safe geologic environments	
VI. Water-use management			
A. Increase use efficiency	water supply needs, transport	ordinances, information	during emergency situations
B. Use transfer	water needs, pollution		
C. Increase reuse			
D. Match use with supply			

Source: "The Water Resource in Northeastern Illinois: Planning Its Use," Technical Report No. 4[48]

GLOSSARY

alkalinity—the capacity of water to accept protons or neutralize acids, usually imparted by the bicarbonate, carbonate, and hydroxide components of a natural or treated water supply.

aquifer—a formation of a relatively permeable water-bearing rock. The terms water-bearing bed, water-bearing stratum, and water-bearing deposit are used synonymously. The water from an aquifer is generally available to wells.

average daily demand—average quantity of water delivered in a day by a central water supply system, usually expressed in million gallons daily.

bedrock—any solid rock exposed at the surface or overlain by unconsolidated material.

bicarbonates and carbonates—chemical compounds formed by the action of carbon dioxide in water on carbonate rocks such as limestone and dolomite. They produce alkalinity, and a combination with calcium and magnesium cause carbonate hardness.

boiler feedwater—water used for steam generation to replace steam losses, to maintain steam quality, and to control solids content of boiler water, i.e., all water used to replace the loss of water in a boiler system.

commercial water use—water use of businesses (shopping centers, stores, laundries, and car washes, etc.) or some small industries with small water-use requirements for processing or sanitary purposes.

consumption (depletion)—the loss of water through use, measured indirectly as the difference between the volumes of water intake and water discharge. It is the result primarily of evaporate losses, but includes water incorporated into manufactured processes, seepage from holding ponds, water consumed by people and animals, and similar unaccounted losses. It is representative of a depletion of a water resource to the extent that the water consumed may be transferred out of a particular watershed and to the extent that the water may be relocated to the vapor phase of the hydrologic cycle. It is water that is not immediately available for planned reuse.

contact cooling water—water used to remove heat from process materials, products, or equipment by water sprays, flooding, quenching in baths, or other direct contact.

cubic feet per second—unit expressing rates of discharge. One cubic foot per second is equal to the discharge of a stream of a rectangular cross section one foot wide and one foot deep, flowing at an average velocity of one foot per second.

dolomite—sedimentary carbonate rock of varying proportions of magnesium carbonate (magnesium limestone).

domestic water use—water used in residences for drinking, bathing, culinary, lawn sprinkling, and sanitary purposes.

drawdown—the difference between the water level before pumping began and the water level during pumping.

fume scrubbing water—water used for emissions control and recovery of material, products, or byproducts in gaseous or vapor effluent streams from hoods, stacks, cupolas, towers, etc.

gallons per capita per day—water use expressed in gallons used per person per day, obtained by dividing the total water use per day by the population served.

glacial drift—any rock material transported by a glacier and deposited by the ice or water derived from the melting of the ice.

glacial till—nonsorted, nonstratified sediment carried or deposited by a glacier.

gross water use—the total quantity of water that would have been used if no water had been recirculated. For example, if 5 million gallons are used for processing and no water is recirculated in that step, the gross water use would be 5.0 million gallons. However, if in addition to the 5 million gallons of intake water, 10 million gallons of process water is recirculated, then the gross water use would be 15.0 million gallons. The gross water use can be reported as gross freshwater use if the intake water that is mixed with the recirculated water is fresh water, and as gross brackish water use if the intake water is brackish.

ground water—water in the ground in the zone of saturation, from which wells, springs, and ground-water runoff are supplied. The terms underground water and subterranean water are sometimes used as synonymous with ground water and sometimes as synonymous with subsurface water in general.

ground-water recharge—the addition of water to the zone of saturation. Infiltration of precipitation and its movement to the water table is one form of natural recharge. Injection of water into an aquifer through wells is one form of artificial recharge.

hardness—originally, hardness was understood to be a measure of the capacity of water for precipitating soap and the incrustations left when heated. Calcium and magnesium are the only two ions that both precipitate soap and occur in natural waters in significant quantities. Hardness is therefore defined as a characteristic of water that represents the total concentration of the calcium and magnesium ions, expressed as calcium carbonate. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any other hardness is called noncarbonate. Waters of hardness up to 60 mg/l are considered soft; 61 to 120 mg/l, moderately hard; 121 to 180 mg/l, hard; more than 180 mg/l, very hard.

iron, total—the total iron present may be either in true solution, in a colloidal state which may be peptized by organic matter, in the form of inorganic or organic complexes, or in the form of relatively coarse suspended particles. Furthermore, it may occur at two levels of oxidation, either as bivalent ferrous iron or as trivalent ferric iron. The importance of iron in municipal water supplies is indicated by stains on laundry and porcelain and the bitter taste that may be detected by some persons at concentrations of more than 0.3 mg/l.

limestone—a rock consisting of at least 50 percent calcium carbonate. Most limestones are partly or wholly of organic origin and contain the hard parts of various organisms such as the shells of mollusks and the skeletons of corals. The calcium carbonate or limestone is readily soluble in water that contains carbon dioxide, and many limestone areas develop underground drainage and other characteristic features.

loess—an unstratified deposit of yellowish-brown loam thought to be chiefly deposited by wind.

maximum daily demand—maximum quantity of water delivered in a day by a central water supply system, generally expressed in millions of gallons per day.

maximum monthly demand—maximum total monthly water production (in any given year of record) averaged on a daily basis, expressed in millions of gallons per day.

milligram per liter—a unit of concentration representing one milligram of solute in one liter of solution.

mining—the removal of ground water from an aquifer at a rate greater than the recharge rate of that aquifer.

municipal water use—water supplied through a centralized or municipal distribution system. Water supplied by the municipal system for domestic, commercial, and industrial uses are included in municipal water use.

non-contact cooling water—water used for cooling and condensing through heat exchange surfaces that separate the cooling water from the item to be cooled or condensed. Does not include water used for cooling and condensing in thermal electric generating plants.

planning subarea—group of counties whose area closely approximates the natural drainage limits of the decimally numbered subdivisions of the respective drainage areas (river basin groups) for each of the five Great Lakes.

process water use—all water, liquid or vapor, which comes into contact with the product being manufactured.

recirculation (reuse)—refers to the multiple use of intake water within a single establishment in which the water after one use is recycled with or without treatment for the same use, or is channelled to other stages of the plant for use in place of new intake water in a cascade system where water of diminishing quality is acceptable. Recirculation or reuse of water may be a deliberate measure for water conservation or may be a secondary benefit associated with recovery of materials, products, byproducts, heat, or pollution control.

recirculation (reuse) rate—ratio of the quantity of gross water used to the quantity of intake water.

regional water supply system—grouping of public water supply systems within a regional area for management purposes, and for physical connection and integration for supplementation of supply and services.

river basin—a term used to designate the hydrologic area drained by a river and its tributaries.

river basin group—two or more river basins or complexes combined for the purpose of reporting.

sandstone—a sedimentary rock consisting of sand, usually quartz, united by some cement, such as silica.

Standard Industrial Classification (SIC)—the Standard Industrial Classification was established by the Bureau of the Budget to facilitate the collection, tabulation, presentation, and analysis of data on establishments classified by the type of activity in which they are engaged. The classification covers the entire field of economic activities. It comprises a numerical system for classifying operating establishments by industry on a two-digit, three-digit, or four-digit basis, according to the degree of detail of information needed.

Standard Metropolitan Statistical Area (SMSA)—a county or group of counties containing at least one city of 50,000 inhabitants or contiguous cities with a combined population of 50,000 or more. In addition to the county containing such a city or cities, contiguous counties are included in an SMSA if they are metropolitan in character and are integrated socially and economically with the central city. The criteria of metropolitan character relate to the attributes of the outstanding county as a place of work or residence for a concentration of nonagricultural workers and stipulate that at least 75 percent of the labor force in a county must be nonagricultural and, usually, that the county must have 50 percent or more of its population living in contiguous minor civil divisions with a density of at least 150 people per square mile.

surface water—the water on the surface of the land, representing drainage from the land. Surface water is considered only as streamflow, regardless of source. Lakes and reservoirs are viewed as streamflow in storage.

thermal power cooling water—water used to condense steam and for other cooling purposes in steam electric generating facilities operated by a manufacturing plant.

treatment—water supply treatment by complete conventional means including coagulation, sedimentation, rapid granular filtration, and disinfection.

value added by manufacture—value added by manufacture is derived by subtracting the total cost of materials (including materials, supplies, fuel, electric energy, cost of resales and miscellaneous receipts) from the value of shipments (including resales) and other receipts, and adjusting the resulting amount by net changes in inventories between the beginning and end of the year. It is considered the best available value measure for appraising the relative economic importance of manufacturing activity between industrial and geographic areas and time periods.

water discharged—water that leaves plant premises, excluding steam or evaporative losses. It includes the quantity that is discharged from, but not into, the holding ponds.

water table—the upper surface of a zone of saturation except where surface is formed by an impermeable body.

wire-to-water efficiency—an expression of the combined electrical, mechanical, and hydraulic efficiencies of pumps and motors; could be expressed as:

$$\frac{\text{energy output of pump}}{\text{energy input to pump motor}} \times 100$$

LIST OF ABBREVIATIONS

acre-ft—acre-feet

AWWA—American Water Works Association

BDC—Bureau of Domestic Commerce

bgd—billion gallons per day

cfs—cubic feet per second

EDA—Economic Development Administration

ERS—Economic Research Service

EPA—U.S. Environmental Protection Agency

FHA—Farmers Home Administration

gpcd—gallons per capita daily

gpm—gallons per minute

HUD—U.S. Department of Housing and Urban Development

IJC—International Joint Commission

mg/l—milligrams per liter

mgd—million gallons per day

NWWA—National Water Well Association

OBERS—Office of Business Economics—Economic Research Service

OMR—Operation, maintenance, and replacement costs

ppm—parts per million

RBG—River Basin Group

SIC—Standard Industrial Classification

SMSA—Standard Metropolitan Statistical Area

USDA—U.S. Department of Agriculture

USDC—U.S. Department of Commerce

USPHS—U.S. Public Health Service

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ADDENDUM

The Addendum contains a listing of the Standard Industrial Classification codes and their major industry groups, referred to in the text. This list has been reproduced from the *Standard Industrial Classification Manual.*

Code	
	Major Group 20—FOOD AND KINDRED PRODUCTS
201	Meat Products
2011	Meat packing plants
2013	Prepared meats
2015	Poultry dressing plants
202	Dairy products
2021	Creamery butter
2022	Natural cheese
2023	Condensed and evaporated milk
2024	Ice cream and frozen desserts
2025	Special dairy products
2026	Fluid milk
203	Canned and frozen foods
2031	Canned and cured seafoods
2032	Canned specialties
2033	Canned fruits and vegetables
2034	Dehydrated fruits and vegetables
2035	Pickles and sauces
2036	Fresh or frozen packaged fish
2037	Frozen fruits and vegetables
204	Grain mill products
2041	Flour and meal
2042	Prepared animal feeds
2043	Cereal preparations
2044	Rice milling
2045	Blended and prepared flour
2046	Wet corn milling
205	Bakery products
2051	Bread and related products
2052	Biscuit and crackers
206	Sugar
2061	Raw cane sugar
2062	Cane sugar refining
2063	Beet sugar
207	Candy and related products
2071	Confectionery products
2072	Chocolate and cocoa products
2073	Chewing gum
208	Beverages
2082	Malt liquors
2083	Malt
2084	Wines and brandy
2085	Distilled liquor except brandy

Code	
2086	Bottled and canned soft drinks
2087	Flavorings
209	Fats and oils
2091	Cottonseed oil mills
2092	Soybean oil mills
2093	Vegetable oil mills, n.e.c.
2094	Grease and tallow
2095	Roasted coffee
2096	Shortening and cooking oils
209	Other food preparations
2097	Manufactured ice
2098	Macaroni and spaghetti
2099	Food preparations, n.e.c
	Major Group 21—TOBACCO PRODUCTS
2111	Cigarettes
2121	Cigars
2131	Chewing and smoking tobacco
2141	Tobacco stemming and redrying
	Major Group 22—TEXTILE MILL PRODUCTS
2211	Weaving mills, cotton
2221	Weaving mills, synthetics
2231	Weaving, finishing mills, wool
2241	Narrow fabric mills
225	Knitting mills
2251	Full-fashioned hosiery mills
2252	Seamless hosiery mills
2253	Knit outerwear mills
2254	Knit underwear mills
2256	Knit fabric mills
2259	Knitting mills, n.e.c.
226	Textile finishing, except wool
2261	Finishing plants, cotton
2262	Finishing plants, synthetics
2269	Finishing plants, n.e.c.
227	Floor covering mills

Code	
2271	Woven carpets and rugs
2272	Tufted carpets and rugs
2279	Carpets and rugs, n.e.c.
228	Yarn and thread mills
2281	Yarn mills, except wool
2282	Throwing and winding mills
2283	Wool yarn mills
2284	Thread mills
229	Miscellaneous textile goods
2291	Felt goods
2292	Lace goods
2293	Padding and upholstery filling
2294	Processed textile waste
2295	Coated fabric, not rubberized
2296	Tire cord and fabric
2297	Scouring and combing plants
2298	Cordage and twine
2299	Textile goods, n.e.c.

Major Group 23—APPAREL AND RELATED PRODUCTS

Code	
2311	Men's and boys' suits and coats
232	Men's and boys' furnishings
2321	Men's dress shirts and nightwear
2322	Men's and boys' underwear
2323	Men's and boys' neckwear
2327	Separate trousers
2328	Work clothing
2329	Men's and boys' clothing, n.e.c.
233	Women's and misses' outerwear
2331	Blouses
2335	Dresses
2337	Women's suits, coats, and skirts
2339	Women's outerwear, n.e.c.
234	Women's undergarments
2341	Women's and children's underwear
2342	Corsets and allied garments
235	Millinery, hats and caps
2351	Millinery
2352	Hats and caps
236	Children's outerwear
2361	Children's dresses
2363	Children's coats
2369	Children's outerwear, n.e.c.
2371	Fur goods
238	Miscellaneous apparel
2381	Fabric dress and work gloves
2384	Robes and dressing gowns
2385	Waterproof outer garments
2386	Leather and sheeplined clothing
2387	Apparel belts
2389	Apparel, n.e.c.
239	Fabricated textiles, n.e.c.
2391	Curtains and draperies
2392	Housefurnishings, n.e.c.
2393	Textile bags
2394	Canvas products
2395	Trimmings and stitching
2397	Schiffli machine embroideries
2399	Textile products, n.e.c.

Major Group 24—LUMBER AND WOOD PRODUCTS

Code	
2411	Logging camps and contractors
242	Sawmills and planing mills
2421	Sawmills and planing mills
2426	Hardwood dimension and flooring
2429	Special product sawmills, n.e.c.
243	Millwork and related products
2431	Millwork plants
2432	Veneer and plywood plants
2433	Prefabricated wood products
244	Wooden containers
2441	Nailed wooden boxes and shook
2442	Wirebound boxes and crates
2443	Veneer and plywood containers
2445	Cooperage
249	Miscellaneous wood products
2491	Wood preserving
2499	Wood products, n.e.c.

Major Group 25—FURNITURE AND FIXTURES

Code	
251	Household furniture
2511	Wood furniture, not upholstered
2512	Wood furniture, upholstered
2514	Metal household furniture
2515	Mattresses and bedsprings
2519	Household furniture, n.e.c.
252	Office furniture
2521	Wood office furniture
2522	Metal office furniture
2531	Public building furniture
254	Partitions and fixtures
2541	Wood partitions and fixtures
2542	Metal partitions and fixtures
259	Furniture and fixtures, n.e.c.
2591	Venetian blinds and shades
2599	Furniture and fixtures, n.e.c.

Major Group 26—PAPER AND ALLIED PRODUCTS

Code	
2611	Pulp mills
2621	Paper mills, except building
2631	Paperboard mills
2661	Building paper and board mills
264	Paper and paperboard products
2641	Paper coating and glazing

Code	
2642	Envelopes
2643	Bags, except textile bags
2644	Wallpaper
2645	Die cut paper and board
2646	Pressed and molded pulp goods
2649	Paper and board products, n.e.c.
265	Paperboard containers and boxes
2651	Folding paperboard boxes
2652	Set-up paperboard boxes
2653	Corrugated shipping containers
2654	Sanitary food containers
2655	Fiber cans, tubes, drums, etc.

Major Group 27—PRINTING AND PUBLISHING

2711	Newspapers
2721	Periodicals
273	Books
2731	Books, publishing and printing
2732	Book printing
2741	Miscellaneous publishing
275	Commercial printing
2751	Printing: letterpress
2752	Printing: lithographic
2753	Engraving and plate printing
2761	Manifold business forms
2771	Greeting cards
278	Bookbinding and related work
2782	Blankbooks: looseleaf binders
2789	Bookbinding and related work
279	Printing trades services
2791	Typesetting
2793	Photoengraving
2794	Electrotyping and stereotyping

Major Group 28—CHEMICALS AND ALLIED PRODUCTS

Code	
281	Basic chemicals
2812	Alkalies and chlorine
2813	Industrial gases
2814	Cyclic (coal tar) crudes
2815	Intermediate coal tar products
2816	Inorganic pigments
2818	Organic chemicals, n.e.c.
2819	Inorganic chemicals, n.e.c.
282	Fibers, plastics, rubbers
2821	Plastics materials
2822	Synthetic rubber
2823	Cellulosic man-made fibers
2824	Organic fibers, noncellulosic
283	Drugs
2831	Biological products
2833	Medicinals and botanicals
2834	Pharmaceutical preparations
284	Cleaning and toilet goods
2841	Soap and other detergents
2842	Polishes and sanitation goods
2843	Surface active agents
2844	Toilet preparations
285	Paints and varnishes
2851	Paints and varnishes
2852	Putty and calking compounds
2861	Gum and wood chemicals
287	Agricultural chemicals
2871	Fertilizers
2872	Fertilizers, mixing only
2873	Agricultural pesticides
2879	Agricultural chemicals, n.e.c.
289	Other chemical products
2891	Glue and gelatin
2892	Explosives
2893	Printing ink
2894	Fatty acids
2895	Carbon black
2899	Chemical preparations, n.e.c.

Major Group 29—PETROLEUM AND COAL PRODUCTS

2911	Petroleum refining
295	Paving and roofing materials
2951	Paving mixtures and blocks
2952	Asphalt felts and coatings
299	Petroleum and coal products, n.e.c.
2992	Lubricating oils and greases
2999	Petroleum and coal products, n.e.c.

Major Group 30—RUBBER AND PLASTICS PRODUCTS, N.E.C.

3011	Tires and inner tubes
3021	Rubber footwear
3031	Reclaimed rubber
3069	Fabricated rubber products, n.e.c.
3079	Plastics products, n.e.c.

Major Group 31—LEATHER AND LEATHER PRODUCTS

3111	Leather tanning and finishing
3121	Industrial leather belting
3131	Footwear cut stock
314	Footwear, except rubber
3141	Footwear, except rubber
3142	House slippers
3151	Leather gloves

Code	
3161	Luggage
317	Purses and small leather goods
3171	Handbags and purses
3172	Small leather goods
3199	Leather goods, n.e.c.

Major Group 32—STONE, CLAY, AND GLASS PRODUCTS

3211	Flat glass
322	Pressed and blown glassware
3221	Glass containers
3229	Pressed and blown glass, n.e.c.
3231	Products of purchased glass
3241	Cement, hydraulic
325	Structural clay products
3251	Brick and structural tile
3253	Ceramic wall and floor tile
3255	Clay refractories
3259	Structural clay products, n.e.c.
326	Pottery and related products
3261	Vitreous plumbing fixtures
3262	Vitreous china food utensils
3263	Earthenware food utensils
3264	Porcelain electrical supplies
3269	Pottery products, n.e.c.
327	Concrete and plaster products
3271	Concrete block and brick
3272	Concrete products
3273	Ready-mixed concrete
3274	Lime
3275	Gypsum products
3281	Cut stone and stone products
329	Nonmetallic minerals
3291	Abrasive products
3292	Asbestos products
3293	Gaskets and insulations
3295	Minerals: ground or treated
3296	Mineral wool
3297	Nonclay refractories
3299	Nonmetallic minerals, n.e.c.

Major Group 33—PRIMARY METAL INDUSTRIES

Code	
331	Steel rolling and finishing
3312	Blast furnaces and steel mills
3313	Electrometallurgical products
3315	Steel wire drawing
3316	Cold finishing of steel shapes
3317	Steel pipe and tubes
332	Iron and steel foundries
3321	Gray iron foundries
3322	Malleable iron foundries
3323	Steel foundries
333	Primary nonferrous metal
3331	Primary copper
3332	Primary lead
3333	Primary zinc
3334	Primary aluminum
3339	Primary nonferrous metals, n.e.c.
3341	Secondary nonferrous metals
335	Nonferrous rolling and drawing
3351	Copper rolling and drawing
3352	Aluminum rolling and drawing
3356	Rolling and drawing, n.e.c.
3357	Nonferrous wire drawing, etc.
336	Nonferrous foundries
3361	Aluminum castings
3362	Brass, bronze, copper castings
3369	Nonferrous castings, n.e.c.
339	Primary metal industries, n.e.c.
3391	Iron and steel forgings
3392	Nonferrous forgings
3399	Primary metal industries, n.e.c.

Major Group 34—FABRICATED METAL PRODUCTS

3411	Metal cans
342	Cutlery, hand tools, hardware
3421	Cutlery
3423	Edge tools
3425	Hand saws and saw blades
3429	Hardware, n.e.c.
343	Plumbing and nonelectric heating
3431	Plumbing fixtures
3432	Plumbing fittings, brass goods
3433	Nonelectric heating equipment
344	Structural metal products
3441	Fabricated structural steel
3442	Metal doors, sash, and trim
3443	Boiler shop products
3444	Sheet metal work
3449	Miscellaneous metal work, n.e.c.
345	Screw machine products and bolts
3451	Screw machine products
3452	Bolts, nuts, washers, and rivets
3461	Metal stampings
347	Metal services, n.e.c.
3471	Plating and polishing
3479	Metal coating, engraving, etc.
3481	Fabricated wire products, n.e.c.
349	Fabricated metal products, n.e.c.
3491	Metal barrels, drums and pails
3492	Safes and vaults
3493	Steel springs
3494	Valves and pipe fittings
3496	Collapsible tubes
3497	Metal foil and leaf
3498	Fabricated pipe and fittings
3499	Fabricated metal products, n.e.c.

Code	
	Major Group 35—MACHINERY, EXCEPT ELECTRICAL
351	Engines and turbines
3511	Steam engines and turbines
3519	Internal combustion engines
3522	Farm machinery and equipment
353	Construction and like equipment
3531	Construction machinery
3532	Mining machinery and equipment
3533	Oil field machines and equipment
3534	Elevators and moving stairways
3535	Conveyors
3536	Hoists, cranes, and monorails
3537	Industrial trucks and tractors
354	Metalworking machinery
3541	Metal-cutting machine tools
3542	Metal-forming machines tools
3544	Special dies and tools
3545	Machine tool accessories
3548	Metalworking machinery, n.e.c.
355	Special industry machinery
3551	Food products machinery
3552	Textile machinery
3553	Woodworking machinery
3554	Paper industries machinery
3555	Printing trades machinery
3559	Special industry machinery, n.e.c.
356	General industrial machinery
3561	Pumps and compressors
3562	Ball and roller bearings
3564	Blowers and fans
3565	Industrial patterns
3566	Power transmission equipment
3567	Industrial furnaces and ovens
3569	General industry machinery, n.e.c.
357	Office machines, n.e.c.
3571	Computing and related machines
3572	Typewriters
3576	Scales and balances
3579	Office machines, n.e.c.
358	Service industry machines
3581	Automatic vending machines
3582	Commercial laundry equipment
3584	Vacuum cleaners, industrial
3585	Refrigeration machinery
3586	Measuring and dispensing pumps
3589	Service industry machines, n.e.c.
3599	Miscellaneous machinery
	Major Group 36—ELECTRICAL MACHINERY
361	Electric distribution products
3611	Electric measuring instruments
3612	Transformers
3613	Switchgear and switchboards
362	Electric industrial apparatus
3621	Motors and generators

Code	
3622	Industrial controls
3623	Welding apparatus
3624	Carbon and graphite products
3629	Electric industrial goods, n.e.c.
363	Household appliances
3631	Household cooking equipment
3632	Household refrigerators
3633	Household laundry equipment
3634	Electric housewares and fans
3635	Household vacuum cleaners
3636	Sewing machines
3639	Household appliances, n.e.c.
364	Lighting and wiring devices
3641	Electric lamps
3642	Lighting fixtures
3643	Current carrying devices
3644	Noncurrent carrying devices
365	Radio, TV, receiving equipment
3651	Radios and TV receiving sets
3652	Phonograph records
366	Communication equipment
3661	Telephone; telegraph apparatus
3662	Radio, TV communication equipment
367	Electronic components
3671	Electron tubes, receiving type
3672	Cathode ray picture tubes
3673	Electron tubes, transmitting
3679	Electronic components, n.e.c.
369	Electrical products, n.e.c.
3691	Storage batteries
3692	Primary batteries, dry and wet
3693	X-ray and therapeutic apparatus
3694	Engine electrical equipment
3699	Electrical products, n.e.c.
	Major Group 37—TRANSPORTATION EQUIPMENT
371	Motor vehicles and equipment
3713	Truck and bus bodies
3715	Truck trailers
3717	Motor vehicles and parts
372	Aircraft and parts
3721	Aircraft
3722	Aircraft engines and parts
3723	Aircraft propellers and parts
3729	Aircraft equipment, n.e.c.
373	Ships and boats
3731	Ship building and repairing
3732	Boat building and repairing
374	Railroad equipment
3741	Locomotives and parts
3742	Railroad and street cars
3751	Motorcycles, bicycles, and parts
379	Transportation equipment, n.e.c.
3791	Trailer coaches
3799	Transportation equipment, n.e.c.

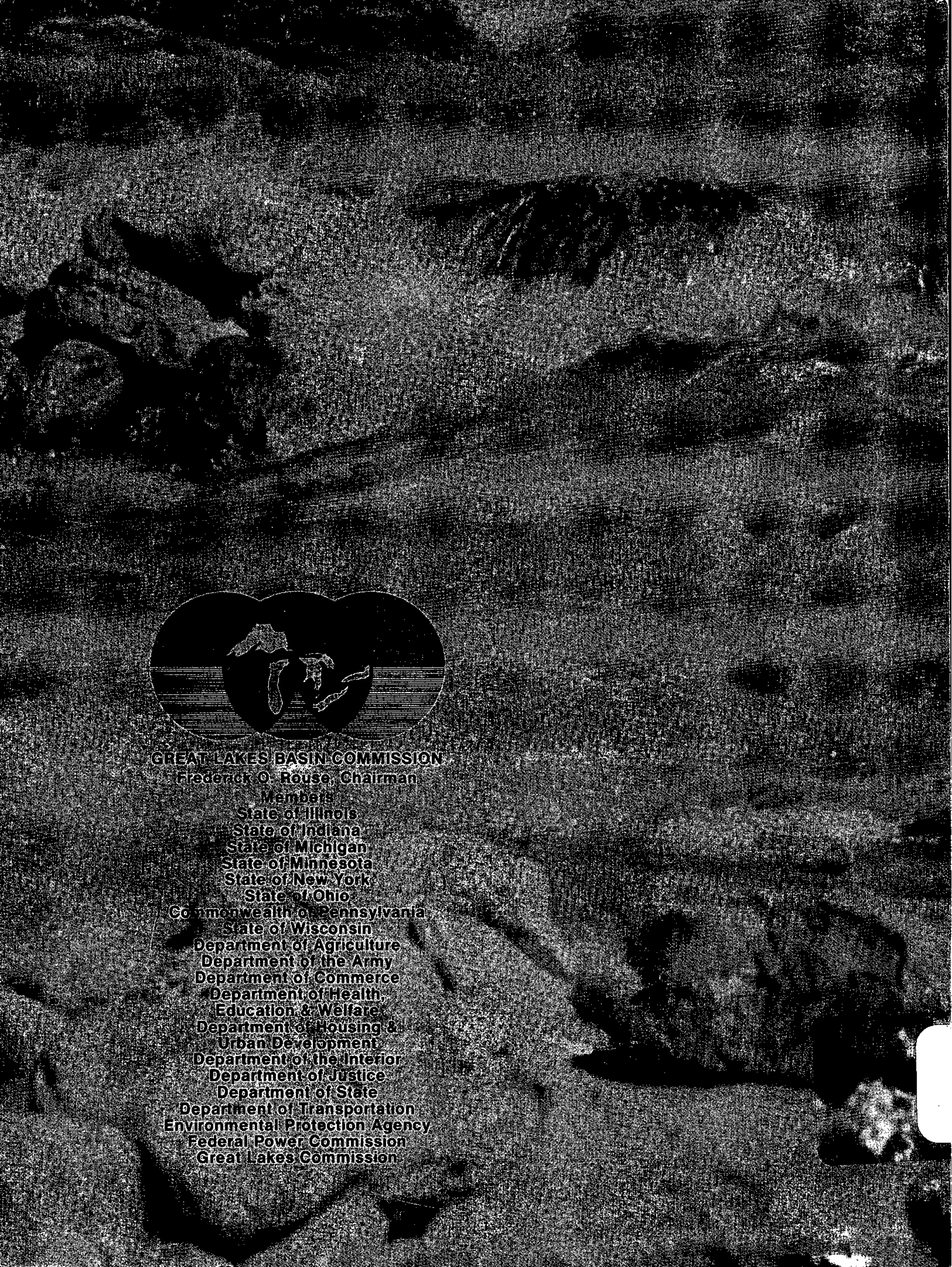
Code	
	Major Group 38—INSTRUMENTS AND RELATED PRODUCTS
3811	Scientific instruments
382	Mechanical measuring devices
3821	Mechanical measuring devices
3822	Automatic temperature controls
3831	Optical instruments and lenses
384	Medical instruments and supplies
3841	Surgical and medical instruments
3842	Surgical appliances and supplies
3843	Dental equipment and supplies
3851	Ophthalmic goods
3861	Photographic equipment
387	Watches and clocks
3871	Watches and clocks
3872	Watchcases
	Major Group 39—MISCELLANEOUS MANUFACTURING
391	Jewelry and silverware
3911	Jewelry, precious metal
3912	Jewelers' findings and materials
3913	Lapidary work
3914	Silverware and plated ware
3931	Musical instruments and parts
394	Toys and sporting goods
3941	Games and toys, n.e.c.
3942	Dolls
3943	Children's vehicles
3949	Sporting and athletic goods, n.e.c.
395	Office supplies

Code	
3951	Pens and mechanical pencils
3952	Lead pencils and art goods
3953	Marking devices
3955	Carbon paper and inked ribbons
396	Costume jewelry and notions
3961	Costume jewelry
3962	Artificial flowers
3963	Buttons
3964	Needles, pins, and fasteners
398	Miscellaneous manufactures
3981	Brooms and brushes
3982	Hard surface floor coverings
3983	Matches
3984	Candles
3987	Lamp shades
3988	Morticians' goods
399	Miscellaneous manufactures
3992	Furs, dressed and dyed
3993	Signs and advertising displays
3995	Umbrellas, parasols and canes
3999	Miscellaneous products, n.e.c.
1911	Guns, howitzers, and mortars
192	Ammunition; guided missiles
1921	Artillery ammunition
1922	Ammunition loading and assembling
1925	Guided missiles, complete
1929	Ammunition, n.e.c.
1931	Tanks and tank components
1941	Sighting and fire control equipment
1951	Small arms
1961	Small arms ammunition
1999	Ordnance and accessories, n.e.c.

AUTHOR

TITLE GREAT LAKES BASIN FRAMEWORK STUDY - APPENDIX 6

DATE DUE	BORROWER'S NAME
GAYLORD 45	



GREAT LAKES BASIN COMMISSION

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