SPATIAL ASPECTS OF WATER RESOURCE PROBLEMS IN THE SAGINAW RIVER BASIN: A CASE STUDY

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ABSTRACT

SPATIAL ASPECTS OF WATER RESOURCE PROBLEMS IN THE SAGINAW RIVER BASIN: A CASE STUDY

by Stuart Otis Denslow

Through the centuries people have applied their creative imagination and utilized their skills and energies to develop facilities and methods through which they might better use the available water resources. The task of finding, developing, and maintaining suitable water supplies has become one of the great challenges of modern times and may well be one of the important keys to continued human advancement.

Fortunately, nature has provided natural boundaries creating river basins within which water resources can be measured, described, and in some cases controlled. The many roles which man has assigned to water in the process of settling and organizing the landscape of river basins is the basic source of multiple use conflicts which are expressed by polluted streams and lakes, falling water tables, empty reservoirs, and aesthetic losses of natural water bodies.

The Saginaw River Basin is the largest of sixty-three watersheds which make up the surface drainage system of the state of Michigan. The region consists of all or parts of twenty-one counties which include the semi-circular basin of four million acres drained by the Saginaw River and its four tributaries.

From the beginning of settlement, water problems of flooding, drainage, and water supply were an inherent part of basin development. The scope of the water problem was not, in most cases, restricted to the landholdings of a single individual or governmental jurisdiction. This fact tended to direct water management decisions and developments into the governmental arena. However, local self interest on the part of various units of government forestalled a comprehensive approach to water resource development.

Three separate and distinct forms of organization were recognized to exist in the basin. The first, a physical organization, is that which gradually evolved through the various physical processes. The second, is a governmental organization which was developed by society and superimposed on the physical fabric of the basin for ease in administering community functions. The third type of organization is functional, wherein the people used the tools of governmental organization and the resources of the physical environment to build facilities necessary to attempt solutions for water resource problems and requirements. Physical, governmental, and functional organizations exist and operate simultaneously within the study area.

Solution of water problems is an excellent example of the need to look at all impinging physical and cultural factors. The spatial approach, emphasizing areal or regional differences--physical character and cultural organization, is workable in identifying problems and suggesting certain solutions to them.

Occupants of the Saginaw River Basin face, in the near future, a crisis in water resources which will demand their collective action and participation. Greater attention must be focused upon subregional divisions of the watershed within the areal organization of the entire basin. Evolving solutions to the inherent water problems must recognize the areal organization of water-related features and facilities representing the accumulative water development decisions of over one hundred and thirty years.

Approved: L M Sommers

Date: Feb 24, 1966

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INTRODUCTION

Man's vital concern for water resources is written indelibly across the pages of history. His inability to adequately recognize the problems of intelligent water resource utilization has produced some of the greatent failures in the historical development of civilizations. Human advancement has been greatly facilitated by the technological progress in the use and development of water resources.

Through the centuries people have applied their creative imagination and utilized their skills and energies to develop facilities and methods through which they might better use the available water resources. Mr. Bernard Frank, in his article, "The Story of Water as the Story of Man,"[1] cites the ancient wells, aqueducts, and reservoirs of the old world--some still servicable after thousands of years--as attesting to the capacity for constructive thinking and cooperative ventures which had such an important part in human development. Despite man's dependence upon water for his very existence, he has not always been completely successful in properly utilizing this natural resource for his benefit.

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[1] Water, The Yearbook of Agriculture (Washington: U.S. Government Printing Office, 1955), p. 1.

Recent population growth and new developments in commerce, agriculture, and industry have multiplied many-fold the water requirements of a modern society. Current estimates indicate that future water needs will increase two to three hundred percent by 1975.[2] The imaginative development of water resources may well be one of the important keys to continued human advancement.

In this research it was necessary to select an area which was large enough to provide a variety of factors as an adequate sample. This study will be concerned with the development, organization, and problems of one of the most important areas of water resource management, that of the river basin. This thesis deals especially with the water resource problems in the Saginaw River Basin of Michigan which, more than any other portion of Michigan, symbolizes the complex pattern of water problems as expressed spatially.

Purpose

The task of finding, developing, and maintaining suitable water supplies has become one of the great challenges of modern times. No longer is water utilization a simple matter as increased demand has created conflicts of interest between domestic, industrial, agricultural, and recreational aspects of water resource use. Evidence

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[2] C. R. Humphrys, The Resource for the Future, Department of Resource Development, Michigan State University, 1958, p. 3.

of these difficulties is expressed in polluted streams and lakes, falling water tables, empty reservoirs, industrial waste effluent; and aesthetic losses of appearance and odor, or recreational usefulness of natural water bodies.

Despite Michigan's calling itself a "Water Wonderland," there exist water resource problems which are an important ingredient or deterrent in the economy of the state, counties, cities, local municipalities, and the lives of individuals. When man first occupied the Saginaw River Basin, the ubiquitous presence of water in its varying forms concealed the multiple use problems which were to face future generations. The many roles which man has assigned to water in the process of settling and organizing the Saginaw River Basin are the basic source of the conflicts which will be discussed in detail later in this study.

In attempts to resolve these use conflicts, man occasionally profits from mistakes. In so doing, he has developed methods of area organization designed to ease or eliminate the friction which developed as a result of the multiple roles of water in the evolving environment of the river basin.

Three separate and distinct forms of organization have been recognized within river basins. The first, a physical organization, is evolved through various physical processes over a period of time. The second is a political organization which was developed by man and superimposed on the physical fabric of the earth for ease in the administration of his activities. The third type of organization is the functional, wherein man uses the tools of the political organization and the resources of the physical environment to create workable facilities useful in developing the environment as a place in which to live, work, and seek recreational satisfaction. These three types of organization exist and function simultaneously in a given river basin during various stages of evolution. The study of the total "system" of a river basin is a relatively new conceptual approach in water resource analysis. The question which arises immediately from the examination of the organizational pattern is whether these three types of organization successfully resolve the conflicts of multiple use of water resources. Before such a question can be properly answered, it will be necessary to determine the present pattern of utilization, organization and natural environment which has and is being developed under the impact of present day problems and technology.

One might ask at this point, why is the study of water resources in a river basin significant to geography? Fundamentally the answer to such a question lies in the fact that the geographic method provides an effective means to approach the total spatial relationships of a water resource which is an important component of the geography of a region. The correlation between physical and cultural factors under the examination of a phenomenon such as water also provides a means of identifying areas where future conflicts in resource utilization can be anticipated.

Virtually every square mile of the continental Unites States (3,022,387 square miles) is included within one of the many river basins which make up the twenty-one water resource districts established by the Water Resource Division of the United States Geological Survey.[3] The exact number and area of the various river basins is subject to change as the peripheral boundaries of the river basins are revaluated through study of watershed activity.

The interest of geographers in the natural regions of the landscape has been extended into the subdivisions of the water realm. Resource geographers established an early interest in water policy. One of the major contributions of the discipline was the report of the Mississippi Valley Committee in 1934[4] in which geographers shared a notable responsibility. Another was the President's Water Resources Policy Commission whose report appeared in 1950.[5]

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[3] Kenneth A. MacKichan, Geological Survey Circular No. 398 (Washington, D. C.: United States Department of Interior, 1957), p. 2.

[4] U. S., Public Works Administration (Washington, U. S. Government Printing Office, Oct. 1, 1934).

[5] U. S., Office of the President (4 vols., Washington, U. S. Government Printing Office, 1950).

The Department of Geography at the University of Chicago is making a more recent concerted effort toward research in the water resource field. The department has research studies of flood plains and irrigation problems; however, broad coverage of water study has been related to policy and decision making in water related programs.[6]

While geographers have shown interest in water as a phenomenon, actual research has been limited in the study of those physical regions, river basins, which are an inherent and important part of the water regimen. The presence of various water problems has stimulated some interest in the study of river basins. Numerous writings have appeared in geographic publications which reflect nearly every associated aspect of water resource study. Despite increased interest in water research there have appeared only nine significant papers and articles on water resource study in the *Annals of the Association of American Geographers* since 1950. Considerable governmental research, with resulting technical reports, has been accomplished by forest and soil specialists. The complex and varied problems of river basins and the water resources lend themselves to geographic research. This study is an example as it examines the relationships of water resource phenomena as they exist in an area.

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[6]Communication from W. R. Derrick Sewell, Professor of Geography, University of Chicago, Chicago, Illinois, November 9, 1964.

The study of a river basin offers an excellent opportunity for examining the triumvirate of organization, physical, governmental and functional, as it relates to the use, development and problems of water resources.

River Basins Defined

The natural characteristics of a river basin such as soil, vegetative cover, rock strata, geomorphic forms, climate and water regime are interrelated and create a natural physical region of the landscape. An appraisal of the water regime of any watershed requires that one first acknowledge that efficient usability of water by man is dependent upon knowledge of the hydrologic cycle and ability to capture or control the movements of the mineral. Fortunately, nature has provided natural boundaries creating river basins within which water resources can be measured, described, and in some cases controlled.

Some confusion has developed as a result of the interchangeable use of the terms "watershed" and "river basin." A watershed, like a river basin, is a unit of land, the boundaries of which were originally defined by the natural action of geophysical forces on the land surface. According to Dr. Clifford Humphrys, "The term watershed or river basin may be used interchangeably to describe the extensive area of land drained by a river, or a slight depression in a 'back forty' that is drained by an intermittent stream." The terms "watershed" and "river basin" will be used in this manner throughout the remainder of this paper.[7]

Since water is a migratory mineral, it will move or flow from one location to another when influenced by gravitational forces or hydrologic pressure. This particular characteristic of water imposes many complex problems in the study and management of water resources, for geologists inform us that precipitation falling in one watershed may become the streamflow of an adjacent watershed via underground movement and the aforementioned forces of gravity and pressure.[8] As a consequence, there is always some question as to the exact subterranean boundary of a river basin.

Ground water must be appraised if the water regime of a watershed is to be completely analyzed.[9] The limitation of our knowledge of subterranean aquifers is the result of limited techniques of examination and the tremendous costs involved in collecting the necessary data for examination. As a result, many of the foremost water management specialists acknowledge readily the absence of accurage and definite data on underground water resources.

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[7] C. R. Humphrys, The Resource of the Future, Department of Resource Development, Michigan State University, 1958, p. 5.

[8] Ibid., p. 6.

[9] Ibid., p. 5.

Until more accurate techniques--at greatly reduced costs--are available to examine the subterranean water realm, river basins and watersheds will continue to be defined as natural units of land drained by a river or stream.

Reasons for Selecting the Saginaw River Basin as a Special Study Area

Early in the study it became evident that one individual could not adequately study all of the twenty-one water resource distrists of the United States. Further, it was impossible to complete an intensive study of all the sixty-three river basins of the State of Michigan. As a consequence of the number, size, and varied location factors of the Michigan river basins, it was decided to concentrate on a single one as a study area.[10]

There are several basic reasons for selecting the Saginaw River Basin as the study area. First, the Saginaw with its tributary system is the largest in Michigan, enclosing an area of 6,247 square miles. Uniquely, the Saginaw River, after which the basin is named, is barely twenty miles in length, the smallest stream within the area.

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[10] Several discussions with Dr. Lawrence Sommers, Chairman of the Department of Geography at Michigan State University and Dr. Allen Philbrick of the same Department, led to the selection of the Saginaw River Basin as meeting the criteria established.

Secondly, the Saginaw River Basin is characterized by a diversity of land use associations present. It lies across the transition zone separating the intensive southern and extensive northern land utilization of Michigan's lower peninsula.[11]

Thirdly, the northern reaches of the basin are oriented to forest and recreational use of low intensity while the southern sections are heavily populated and well developed both agriculturally and industrially. Each identifiable subregion within the watershed has a distinctive relationship to the water resource problem as a result of land utilization differences. The cultural organization pattern on the landscape is oriented in a south-north direction due to the gradual expansion of early settlement from south to north during the pioneering period and the subsequent economic and transportational flow-lines of development established in the 1800's.

No other river basin in Michigan has so great a contrast in land utilization pattern, population distribution, and the water resource relationships. The competing needs for water by agriculture, commerce, industry, and recreation offer the opportunity for observing the organization and use of the water resources under widely varying conditions. The functional connections of cultural organization

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[11] Robert K. Holz, <u>The Area Organization of National Forests</u>, A Case Study of the Manistee National Forest, Michigan (Ph.D. Dissertation, Michigan State University, East Lansing, Michigan, 1963, p. 53.

superimposed upon the physical fabric of the water resource realm provide areal patterns ideally suited for geographic analysis.

Approach

This study will focus on man's use of a resource, water, within the confines of a physical region and examine the appropriate phenomena and their interrelationships as they exist in space. A systematic examination of the water resources of the Saginaw River Basin will be made as they relate to the selected elements of the physical and cultural environment of the region in order to understand how man has organized the river basin into its present pattern of water resource utilization.

The Study Area and Its Historical Background

The Saginaw River Basin is located on the east central side of the lower peninsula of Michigan (Figure 1). It is the largest of sixty-three river basins which make up the surface drainage system of the State. The basin has been described as resembling a butterfly with outspread wings, with its head at the mouth of the Saginaw River.[12] The region consists of all or part of twenty-one

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[12] Gale H. Gibson, Executive Secretary, Saginaw Valley Regional Planning Commission (now dissolved), Proceedings of the Annual Meeting of American Society of Planning Officials, May 5th through 9th, 1947, p. 142.

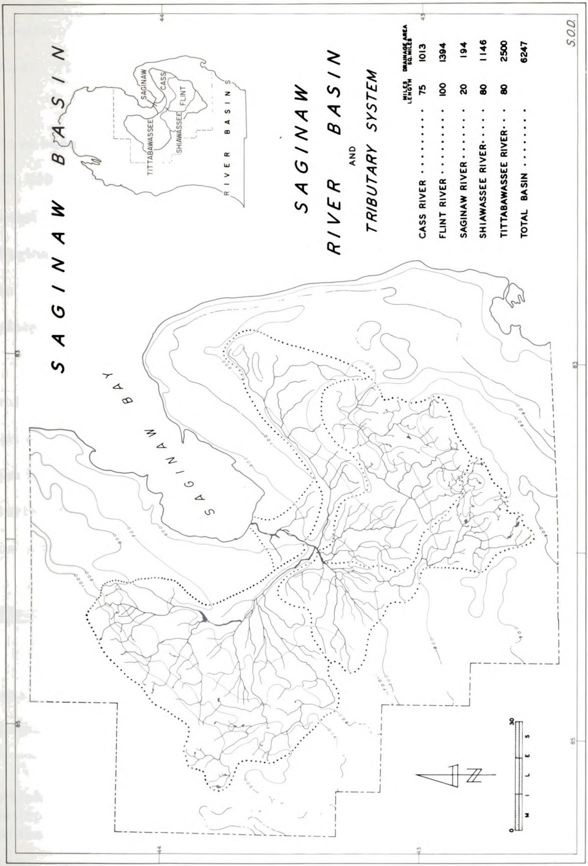
SAGINAW BASIN
SAGINAW BAY
SAGINAW RIVER BASIN AND TRIBUTARY SYSTEM
SAGINAW
CASS
FLINT
SHIAWASSEE
TITTABAWASSEE
RIVER BASINS
MILES LENGTH
DRAINAGE AREA SQ. MILES
CASS RIVER 75 1013
FLINT RIVER 100 1394
SAGINAW RIVER 20 194
SHIAWASSEE RIVER 80 1146
TITTABAWASSEE RIVER 80 2500
TOTAL BASIN 6247
MILES
0
30
S.O.D.

Fig. 1

counties drained by the Saginaw River and its four tributaries: the Cass, Flint, Shiawassee, and Tittabawassee.

Geologically, a major portion of the area is believed to have been part of Saginaw Bay until the late Pleistocene Period some 20,000 years ago. About one and one-half million acres of predominantly flat, fertile clay loam lands lie adjacent to the lower end of Saginaw Bay. This is surrounded by rolling to hilly clay loam land in the southern parts of the region, and sandy, forested hills and plains in the northern part.

With a population of 1,229,000 and an area of 6,247 square miles, the region is both large and economically varied over its 125 miles south-to-north extent.[13] The economic base and associated land uses change from south-to-north from predominantly manufacturing; to predominantly agriculture; to nearly complete dependence on tourist, resort, and recreation services.

Historical Background

Prior to settlement by the white man, the Saginaw Basin was the most important center of Indian population in the Middle Lakes Region.[14] An Indian village located at the present site of the city of

[13] The political boundaries of the twenty-one counties, which include the study area, enclose 13,200 square miles with a population of 1,849,000. About one half this total area and eighty percent of the population lie within the drainage basin described above.

[14] Maurice Edron McGaugh, The Settlement of the Saginaw Basin, Dissertation for Ph.D., University of Chicago. 1950, p. 1.

Saginaw had an Indian name meaning "The Gathering Place,"[15] an index of the importance placed upon the area by oboriginal settlers.

The Indians occupied the area under a semi-migratory settlement pattern, taking advantage of the focality of the Saginaw River drainage area and tributary system for the transportation media it provided. Indian population was supported by the available abundant forest, wildlife, and food resources.

The fur trade promoted by the European intruders prompted a complete alteration of the livelihood pattern of the Saginaw Basin area Indians. Fur trading posts and the associated commodity exchange were the first elements of permanent settlement.

A series of Indian treaties from 1807 to 1836 succeeded in transferring the ownership of all lower Michigan, including the study area, to the white man and ushered in a new wave of settlement. The next five decades witnessed the rapid growth of agricultural settlement, the rise of a booming lumber industry, and the introduction of railroads to support both lumbering and agriculture.

Beginning with the first major settlements about 1840, the reclamation by drainage of the flat and fertile clay loam lands adjacent to the lower end of Saginaw Bay developed the area into one of the rich agricultural regions of the United States. From the outset, water was

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[15] Ibid.

an outstanding factor in the area's economic status. Indians looked upon the swamps, channels and tributary systems which drained the area as an important transportation system, as well as a habitat for abundant fish and wildlife. These same characteristics were the fundamental basis of the fur trade which flourished until 1830. Lumbermen and settlers valued these streams and channels as a means of transportation and for the floatation of logs to downstream mills during the lumbering period. As permanent agriculture appeared, drainage and water control occupied the settlers and farmers during every season of the year. Thousands of miles of ditches were constructed, and the result was that rapid release of water runoff from upland areas produced simultaneously soil erosion at the head waters and flooding conditions on downstream lowlands. Some eighty square miles of rich delta land at the confluence of the four tributaries of the Saginaw River were inundated by flood water annually.

More recently industrialization has become important, as illustrated by the Dow Chemical Company at Midland, Michigan. This specific development is based on the sea of salt brine which underlies the area. Biproducts of this resource development resulted in increased phenol[16] pollution of the rivers and the other accompanying problems of sufficient fresh water to supply the people and industry.

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[16]Phenol--any of the aromatic hydroxl derivatives resulting from processing of the organic resource.

Because the salt brine is found at shallow depths, ninety feet at Saginaw, Michigan, only limited quantities of fresh water are available.[17]

At present, water resource problems in the study area are the cumulative result of settlement and development decisions made during the last one hundred thirty years. Consequently, all of the water resource problems--drainage, flooding, soil erosion, pollution, and limited fresh water supply--exist in association with the confines of the Saginaw River Basin. In the succeeding chapters these problems and related phenomena will be studied, individually and collectively, in order to analyze their impact and significance on the spatial character of a selected sample area.

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[17] Gibson, <u>Proceedings . . .</u>, p. 143.

II.

AN APPROACH TO STUDYING WATER RESOURCES WITHIN RIVER BASINS: WITH SPECIAL REFERENCE TO THE SAGINAW WATERSHED

Decisions to take comprehensive looks at the water resources of the United States have been repeated again and again throughout our national history. During the last fifty years alone, over twenty federal commissions or committees have looked into national water policies and problems.[1] The fundamental objective

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[1] Select Committee on National Water Resources, United States Senate; Water Resource Activities in the United States; Reviews of National Water Resources During the past Fifty Years; Committee Print Number 2, United States Government Printing Office, October 6, 1959, p. 111.

A partial list of commissions and committees which have worked to evolve water resources policy includes:

Inland Waterway Commission established by President Theodore Roosevelt, March 14, 1907.

National Conservation Commission established by President Theodore Roosevelt, June 8, 1908.

National Waterways Commission established by the Rivers and Harbors Act of March 3, 1909. (25 Stat. 815).

Waterways Commission created on August 8, 1917, by (40 Stat. 250).

"308" Reports resulting from Joint Resolution request of Congress March 3, 1925, and printed in House Document 308, 69th Congress, 1st Session.

President's Committee on Water Flow pursuant to Senate Resolution 164 and House Resolution 248, 73rd Congress, 2nd Session, of the commissions or committees in every case was to determine needs and evolve a policy framework within which legislative objectives, research, and action programs could be developed and implemented.

February 2, 1934.

Mississippi Valley Committee of the Public Works Administration, Report published by United States Government Printing Office, October 1, 1934.

National Resources Board established by Executive Order No. 6777 on June 30, 1934.

National Resources Committee established as a reconstitution of National Resources Board by Executive Order 7065, June, 1935.

Select Committee to Investigate the Executive Agencies of the Government, established by Senate Resolution 217, 74th Congress, February 24, 1936.

The Commission on Reorganization of the Executive Branch of the Government (First Hoover Commission) created July 7, 1947, by Public Law 162, (61 Stat. 246).

President's Water Resource Policy Commission (Cooke Commission) established by Executive Order 10095 on January 3, 1950.

The President's Materials Policy Commission (Paley Commission) created by President Truman on January 22, 1951.

Missouri Basin Survey Commission, created by Executive Order 10318, on January 3, 1952.

Commission on Intergovernmental Relations was established by Public Law 109, 83 Congress, (67 Stat. 145) July 10, 1953.

Commission on Organization of the Executive Branch of the Government, (Second Hoover Commission) established by Public Law 108, 83rd Congress, (67 Stat. 142) July 10, 1953.

Presidential Advisory Committee on Water Resources Policy, established by Presidential Order on May 26, 1954, and reported as House Document 315, 84th Congress, 2nd Session.

Select Committee on National Water Resources established by Senate Resolution 48, 86th Congress, April 20, 1959.

The Senate of the United States maintains four standing committees which have primary responsibility for national water resources.[2] From them legislation is introduced which ultimately directs the study and development of our water resources. Obviously, not all of the recommendations have been enacted into law; however, the basic policy framework has been established for studying, organizing and planning water resource utilization.

On April 20, 1959, the Eighty-sixth Congress, by Senate Resolution 48, established the Select Committee on National Water Resources. The Committee was directed to make studies of water resource activities and needs with projections to 1980 to enable the nation to satisfy water requirements for population, agriculture and industry.[3]

Senator Robert S. Kerr, Chairman of the Senate Select Committee on National Water Resources, in summarizing the past results of Congressional efforts in water resourse policy, indicated that the concensus of the many commissions and committees over the years produced two recommendations on organization which stood above all others. These recommendations included the placing of

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[2] Four standing United States Senate Committees which have responsibility for water resource study include: Public Works, Interior and Insular Affairs, Interstate Commerce, Agriculture and Forestry.

[3] Select Committee on National Water Resources, United States Senate, Eighty-Sixth Congress, 1st Session, Report of Hearing, Bismark, N. Dakota, October 7, 1959, p. 1.

all federal activities dealing with water resources in the Department of Interior and placing greater emphasis on the establishment of River Basin Commissions for planning and development of each basin area.[4]

Neither of these recommendations has been given complete formal adoptive recognition. However, this conceptual approach to organization has been informally adopted by the Congress and the Interior Department and by many states for both present and future programs of water resource study and organization.

In addition to the various Congressional actions, the Water Resource Division of Geological Survey, through the United States Department of Interior, has taken the recommendations of the various committees regarding organization under consideration and has established twenty-one water resource districts which correspond areally to major drainage regions of the United States. (Figure 2.)

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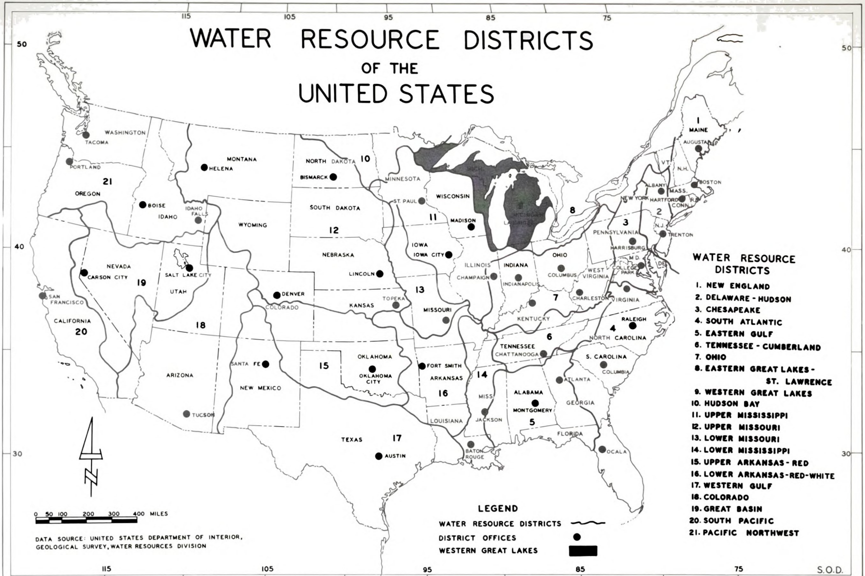
[4]Select Committee on National Water Resources, United States Senate, 86th Congress, 1st Session, Reviews of National Water Resources During the Past Fifty Years, Committee Print No. 2, October 6, 1959, p. 2.


WATER RESOURCE DISTRICTS
OF THE
UNITED STATES
WATER RESOURCE DISTRICTS
1. NEW ENGLAND
2. DELAWARE - HUDSON
3. CHESAPEAKE
4. SOUTH ATLANTIC
5. EASTERN GULF
6. TENNESSEE - CUMBERLAND
7. OHIO
8. EASTERN GREAT LAKES - ST. LAWRENCE
9. WESTERN GREAT LAKES
10. HUDSON BAY
11. UPPER MISSISSIPPI
12. UPPER MISSOURI
13. LOWER MISSOURI
14. LOWER MISSISSIPPI
15. UPPER ARKANSAS - RED
16. LOWER ARKANSAS-RED-WHITE
17. WESTERN GULF
18. COLORADO
19. GREAT BASIN
20. SOUTH PACIFIC
21. PACIFIC NORTHWEST
LEGEND
WATER RESOURCE DISTRICTS
DISTRICT OFFICES
WESTERN GREAT LAKES
0 50 100 200 300 400 MILES
DATA SOURCE: UNITED STATES DEPARTMENT OF INTERIOR, GEOLOGICAL SURVEY, WATER RESOURCES DIVISION
WASHINGTON
TACOMA
PORTLAND
OREGON
MONTANA
HELENA
BOISE
IDAHO
IDAHO FALLS
WYOMING
NORTH DAKOTA
BISMARCK
SOUTH DAKOTA
NEBRASKA
LINCOLN
KANSAS
TOPEKA
NEVADA
CARSON CITY
SALT LAKE CITY
UTAH
DENVER
COLORADO
SAN FRANCISCO
CALIFORNIA
ARIZONA
TUCSON
SANTA FE
NEW MEXICO
OKLAHOMA
OKLAHOMA CITY
TEXAS
AUSTIN
MINNESOTA
ST. PAUL
WISCONSIN
MADISON
IOWA
IOWA CITY
MISSOURI
FORT SMITH
ARKANSAS
LOUISIANA
BATON ROUGE
MISS.
JACKSON
ILLINOIS
CHAMPAIGN
INDIANA
INDIANAPOLIS
OHIO
COLUMBUS
KENTUCKY
TENNESSEE
CHATTANOOGA
ALABAMA
MONTGOMERY
GEORGIA
ATLANTA
FLORIDA
OCALA
S. CAROLINA
COLUMBIA
NORTH CAROLINA
RALEIGH
VIRGINIA
WEST VIRGINIA
CHARLESTON
M.D.
COLLEGE PARK
DE.
PENNSYLVANIA
HARRISBURG
N.J.
TRENTON
NEW YORK
ALBANY
VT.
N.H.
MASS.
BOSTON
HARTFORD
CONN.
R.I.
MAINE
AUGUSTA
115
105
95
85
75
50
40
30
S.O.D.

WATER RESOURCE DISTRICTS OF THE UNITED STATES

The drainage regions as shown in Figure 2 are described as follows:

New England--North Atlantic Slope Drainage from Maine to Connecticut.

Delaware-Hudson--Delaware River Basin; North Atlantic slope drainage Delaware River to Hudson River and the Hudson River Basin.

Chesapeake--North Atlantic slope drainage Chesapeake Bay to York River.

South Atlantic--Atlantic slope from James River to include peninsula of Florida.

Eastern Gulf--Gulf of Mexico drainage from the Suwanee River to the Pearl River.

Tennessee-Cumberland--Tennessee and Cumberland River Basins.

Ohio--Ohio River Basin exclusive of the Tennessee and Cumberland River Basins.

Eastern Great Lakes-St. Lawrence--St. Lawrence River Basin below the mouth of the St. Clair River.

Western Great Lakes--St. Lawrence River Basin above the mouth of the St. Clair River.

Hudson Bay--Portion of United States drained northward to Hudson Bay.

Upper Mississippi--Mississippi River Basin above the Ohio River and exclusive of the Missouri River Basin.

Upper Missouri--Upper portion of Missouri River Basin from the Big Sioux River westward.

Lower Missouri--Lower portion of Missouri River Basin to interception with Mississippi River.

Lower Mississippi--Mississippi River Basin below the Ohio River and exclusive of the Arkansas, White and Red River Basins.

Upper Arkansas-Red--Upper portion of Arkansas River Basin including the Red River Basin from Lake Texoma westward.

Lower Arkansas-Red-White--Lower portion of Arkansas River Basin including the Red and White Rivers.

Western Gulf--Gulf of Mexico drainage west of the Mississippi delta.

Colorado--Colorado River Basin.

Great Basin--The Great Basin (internal drainage).

South Pacific--Pacific slope drainage in California.

Pacific Northwest--Pacific slope drainage north of California. [5]

The Water Resources Division of Geological Survey, Department of Interior, has the unique role of providing a fund of basic information about water and water development in these water resource districts. To fulfill its function the Water Resources Division performs in accordance with the following broad objectives:

A. Collects facts concerning location, quantity, quality, movement and mode of occurrence of water resources.
B. Studies areas of existing or potential water problems.

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[5] Kenneth A. Mac Kichan, and J. C. Kammerer, Estimated Water Use in the United States 1960, Geological Survey Circular No. 456, United States Department of Interior, Washington, D. C., 1961, p. IV.

C. Conducts research to discover fundamental principles of hydraulics, hydrology and related fields of science.

D. Publishes the data it collects and the results of its investigation.[6]

One of the important continuing functions of the Water Resource Division is maintaining a surveillance over our national water supply. This responsibility is complicated by the wide areal variations in climate and precipitation conditions throughout the country. Rainfall variations are reflected in differences in both potential water supply and manageable water supply among the varied districts. United States Geological Survey indicates that the "long term average runoff of a river basin, with few exceptions, is the upper limit of possible production of the combined surface and ground water resources of the basin."[7]

The potential water supply is the total of all precipitation, in its various forms, within a specific drainage area. Unfortunately, not all precipitation is available for man's use. Evapotranspiration extracts a large toll from the total precipitation and the remainder, as percolation or runoff, becomes our manageable supply of water.

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[6] United States Geological Survey, Long Range Plan for Resource Surveys, Investigations and Research Programs, U. S. Department of Interior, Washington, D. C., 1964, p. 42.

[7] Kenneth A. Mac Kichan, Geological Survey Circular No. 398, United States Department of Interior, Washington, D. C., 1957, p. 16.

Table 1.--The nation's water supply.[a]

Region	Area (1,000 sq. mi.)	Inches Per Year	Est. Dependable Supply, Mgd[c]	1980 Mgd[b]
New England	59	24	67,000	22,000
Delaware-Hudson	31	21	32,000	24,000
Chesapeake	57	19	51,000	12,000
South Atlantic	170	14	110,000	
Eastern Gulf	109	19	99,000	75,000
Tennessee-Cumberland	59	21	59,000	22,000
Ohio	145	16	110,000	40,000
Eastern Great Lakes St. Lawrence	47	18	40,000	33,000
Western Great Lakes	81	11	42,000	
Hudson Bay	60	1.6	4,600	36,000
Upper Mississippi	182	7.2	62,000	31,000
Upper Missouri	458	1.0	24,000	
Lower Missouri	62	7.8	23,000	33,000
Lower Mississippi	64	16	49,000	25,000
Upper Arkansas-Red	153	1.6	11,000	
Lower Arkansas-Red-White	117	14	79,000	20,000
Western Gulf	341	3.2	52,000	20,000
Colorado	258	1.1	13,000	15,000
Great Basin	200	1.1	10,000	9,000
South Pacific	112	12	64,000	28,000
Pacific Northwest	257	13	159,000	70,000
United States	3,022		1,200,000	515,00

[a]Kenneth A. Mac Kichan, and J. C. Kammerer, Estimate Water Use in the United States 1960, Geological Survey Circular No. 456, United States Department of the Interior, Washington, D. C 1961, p. 26.

[b]D. R. Woodward, Availability of Water in the United States with Special Reference to Industrial Needs by 1980; Industrial College of Armed Forces, Washington, D. C., 1957, p. 49.

[c]Million gallons per day.

The average annual runoff in the United States varies from less than one-fourth inch in certain areas of the Southwest to more than eighty inches in some areas along the Pacific Coast.[8] This wide variation in runoff reflects in the manageable water supply of the water resource districts as shown in Table 1.

The Western Great Lakes Region

The Western Great Lakes Region, of which the study area is a part, includes that portion of the St. Lawrence River Basin lying above the mouth of the St. Clair River not far distant from Detroit, Michigan.

As a water resource region the streams of the Western Great Lakes provide plentiful supplies of fresh water which, if not used at the source, flow into Lake Michigan, Lake Superior, or Lake Huron. The thirteen million persons living and working in the Western Great Lakes water district have an industrial establishment using a thousand million gallons of water per day from public water supplies, a rate higher than any other region in the United States.[9] Simultaneously,

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[8] Ibid.

[9] Kenneth A. Mac Kichan, Geological Survey Circular No. 398, United States Department of Interior, Washington, D. C., 1957, p. 3., Table 1.

the per capita use of water is two hundred eleven gallons per day from public supplies, a rate exceeded only by residents of the Great Basin and the Pacific Northwest.[10]

The manageable supply of water in the Western Great Lakes Region is on the decline. D. R. Woodward has suggested that the water in the area may be reduced to thirty-six thousand million gallons per day by 1980 due to the depreciating effects of pollution, sewerage treatment irrigation requirements and other problems.[11] As was indicated earlier, future water needs may increase by two hundred percent by 1975, advancing withdrawals of ground and surface water to thirty-four thousand million gallons per day. As a result, water demands would actually exceed manageable supplies before 1980 in the Western Great Lakes Region.

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[10] Ibid.

[11] D. R. Woodward, Availability of Water in the United States with Special Reference to Industrial Needs by 1980, Industrial College of the Armed Forces, Washington, D. C., 1957, p. 49.

Table 2.--Manageable water supply.

Western Great Lakes Region[a] 1960-1980 Million Gallons per Day						
Region	Manageable Supply 1960		Est. Supply 1980	From Supply 1960	Est.[b] With-drawals 1980	Excess of Demand Over Supply 1980
	Runoff In./yr.	MGD				
Western Great Lakes	11 in.	42,000	36,000	16,830	40,000	4,000

[a]Kenneth A. Mac Kichan, and J. C. Kammerer, Estimated Use of Water in the United States, 1960, Geological Survey Circular 456, Washington, D. C., 1961, Table 18, p. 26.

[b]Estimates based upon data presented by C. R. Humphreys, entitled The Resource for the Future, Department of Resource Development, Michigan State University, 1958, p. 3.

The region was acknowledged as one of the water resource problem areas of the country by the Senate Select Committee on National Water Resources when selecting locations for hearings on water resource problems in 1959. The hearings in Detroit, Michigan, in October 1959 focused upon the Western Great Lakes Region, and expert testimony challenged the continued acceptance of the concept of "unlimited water supply" prevalent in the area.[12]

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[12]Hearings before the United States Congress Senate Select Committee on National Water Resources, Part Seven, Detroit, Michigan, Oct. 29, 1959, pp. 1101-1317.

United States Geological Survey water experts have shown that the manageable water supply of the Western Great Lakes is approximately forty-two thousand Mgd,[13] or the equivalent of eleven inches of runoff and/or percolation water per year.[14] Withdrawals from the supply totaled approximately sixteen thousand five hundred Mgd in 1960.[15] Thus, it appears that approximately thirty-eight percent of the manageable supply of surface and ground water is now in use in the Western Great Lakes Region.

The probability of a water deficit in the Western Great Lakes in the foreseeable future points up the need for a close look at our water resource management programs. Many water problems may be corrected through cultural modification of physical resources and human activities. Before corrective measures can be proposed, or accomplished, a careful description of the existing situation must be provided to understand the setting under which the water problems developed.

The study area, the Saginaw River Basin of Michigan, is part of the Western Great Lakes Region and exhibits both the advantages and disadvantages of the larger water realm. A careful description of the environment furnishes a necessary insight into the background of the water resource problems.

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[13] Mgd--Million Gallons per Day.

[14] Kenneth A. Mac Kichan, and J. C. Kammerer, Estimated Water Use in the United States 1960, Geological Survey Circular No. 456, United States Department of Interior, Washington, D. C., 1961, p. 26.

[15] Ibid.

The Saginaw River Basin

The Saginaw River Basin, the largest of sixty-three Michigan river basins, is located in the east central side of the lower peninsula. It consists of all or parts of twenty-one counties drained by the Saginaw River and its tributaries, the Cass, Flint, Shiawassee, and Tittabawassee.

The shape and boundaries of the basin are believed to have been determined by glacial activity in the late Pleistocene period which ended some twenty thousand years ago. As the Saginaw lobe of glacial ice retreated into Saginaw Bay, it left behind a vast lakebed of sand and clay lying adjacent to the lower end of the bay. This flat plain is surrounded by rolling morainic hill-land on the south and the west, and sandy hills and plains on the north. The watershed thus created resembles a butterfly with outspread wings with its head at the lower end of Saginaw Bay, as shown in Figure 3.

As the meltwater declined at the close of the glacial period, there was developed an internal drainage system which consisted of four tributary streams feeding the main arterial which flowed northeasterly into Saginaw Bay. The dendritic drainage system developed from the headwaters to the mouth in reverse of normal erosion patterns. The main arterial stream, the Saginaw River, is actually the youngest stream of the river system draining the area.

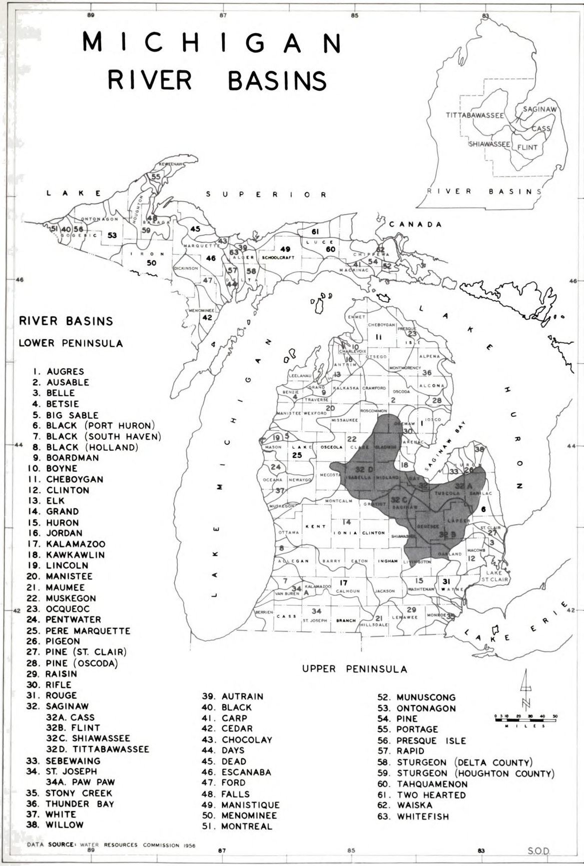
MICHIGAN
RIVER BASINS
LAKE SUPERIOR
CANADA
LAKE MICHIGAN
LAKE HURON
SAGINAW BAY
LAKE ERIE
LAKE ST. CLAIR
TITTABAWASSEE
SAGINAW
CASS
SHIAWASSEE
FLINT
RIVER BASINS
RIVER BASINS
LOWER PENINSULA
1. AUGRES
2. AUSABLE
3. BELLE
4. BETSIE
5. BIG SABLE
6. BLACK (PORT HURON)
7. BLACK (SOUTH HAVEN)
8. BLACK (HOLLAND)
9. BOARDMAN
10. BOYNE
11. CHEBOYGAN
12. CLINTON
13. ELK
14. GRAND
15. HURON
16. JORDAN
17. KALAMAZOO
18. KAWKAWLIN
19. LINCOLN
20. MANISTEE
21. MAUMEE
22. MUSKEGON
23. OCQUEOC
24. PENTWATER
25. PERE MARQUETTE
26. PIGEON
27. PINE (ST. CLAIR)
28. PINE (OSCODA)
29. RAISIN
30. RIFLE
31. ROUGE
32. SAGINAW
32A. CASS
32B. FLINT
32C. SHIAWASSEE
32D. TITTABAWASSEE
33. SEBEWAING
34. ST. JOSEPH
34A. PAW PAW
35. STONY CREEK
36. THUNDER BAY
37. WHITE
38. WILLOW
UPPER PENINSULA
39. AUTRAIN
40. BLACK
41. CARP
42. CEDAR
43. CHOCOLAY
44. DAYS
45. DEAD
46. ESCANABA
47. FORD
48. FALLS
49. MANISTIQUE
50. MENOMINEE
51. MONTREAL
52. MUNUSCONG
53. ONTONAGON
54. PINE
55. PORTAGE
56. PRESQUE ISLE
57. RAPID
58. STURGEON (DELTA COUNTY)
59. STURGEON (HOUGHTON COUNTY)
60. TAHQUAMENON
61. TWO HEARTED
62. WAISKA
63. WHITEFISH
MILES
DATA SOURCE: WATER RESOURCES COMMISSION 1956
S.O.D.

Fig. 3

Uniquely, the Saginaw is barely twenty miles in length and thus linearly the shortest of all the streams.

The hill lands which define the outer boundaries on the south, west and north were the moraines created at the glacial ice edge during various advances and retreats of the lobed ice front. Great variations exist in the drainage area of the several tributaries due to the complex of outwash and glacial channels and deltas as well as ground moraines which developed between the rows of morainic hills. Collectively these features create barriers and cause flowing streams to seek a circuitous route to the valley floor. The river system of the Saginaw Basin drains an area of 6,247 square miles.

Climate

Climate is important in determining the availability of water to the Saginaw Basin. The area, including the remainder of the northern one-half of the peninsula, is included in the humid mesothermal region of the North American continent which is generally characterized by cold winters, continuous snow cover, a long frost season, and large annual ranges of temperature with relatively short summers.[16]

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[16] Finch, et. al., Physical Elements of Geography, (New York: Mc Graw Hill Co. Inc., 1957), Appendix E, p. 529.

Located in the heart of the Great Lakes Region, Michigan enjoys a climate moderated by them. Since large bodies of water are less responsive to rapid temperature change, they tend to exercise a stabilizing influence over adjacent land areas. The growing season in the study area ranges from one hundred forty to one hundred fifty days. The last killing frost may occur as late as May 20th to June 1st. In the fall the first frost can be anticipated from September 10th to as late as October 10th.[17]

Snowfall in the winter months averages forty inches per year. However, some of the northern counties in the Saginaw Basin have mean annual snowfalls up to fifty inches. Since temperatures during the snowfall months are generally below freezing, some of the accumulated snow cover can be anticipated as meltwater runoff during the spring warming period. This phenomenon produces annual flooding conditions at the confluence of the main tributaries of the Saginaw River.

The amount of water, although influenced by season and location, is determined chiefly by the amount of precipitation in the basin area. Mean annual precipitation totals thirty inches (including the water equivalent of snow). Variations in total mean annual

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[17] United States Department of Agriculture, 1941 Yearbook of Agriculture, Climate and Man, Washington, D. C., 1941, pp. 923-924.

precipitation range from twenty-eight to thirty-two inches with a noticeable decrease from west to east and from south to north. (Figure 4)

A. D. Ash has estimated that the evapotranspiration losses of plants, soils and surface waters total twenty inches annually in the basin.[18] These losses reduce the potential water supply of thirty inches to a manageable supply of ten inches or 271, 540 gallons of water per acre per year over the 6, 247 square mile area. It is this amount of water that can be manipulated to solve the water problems.

Seasonal variations are significant to produce fluctuations in runoff after evapotranspiration losses have occurred. The summer months (June, July, and August) are the "wet months" corresponding to increased convectional activity during that period. Brunnschweiler, in studying lower Michigan peninsula precipitation patterns over a twenty-two year period, noted that a conspicuous "dry belt" develops during July which centers in Saginaw Bay and extends diagonally north-west to south-east across the peninsula.[19]

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[18] C. R. Humphrys, Water Bulletin No. 5, Genesee County, Michigan, Department of Resource Development, Michigan State University, February 1960, p. 2.

Evapotranspiration includes the combined losses of water through evaporation from saturated soil, lakes and streams as well as transpiration of water vapor from living plants.

[19] Dieter Brunnschweiler, A Precipitation Regime in the Lower Peninsula of Michigan, Michigan Academy, Vol. XLVII, 1962, p. 368.

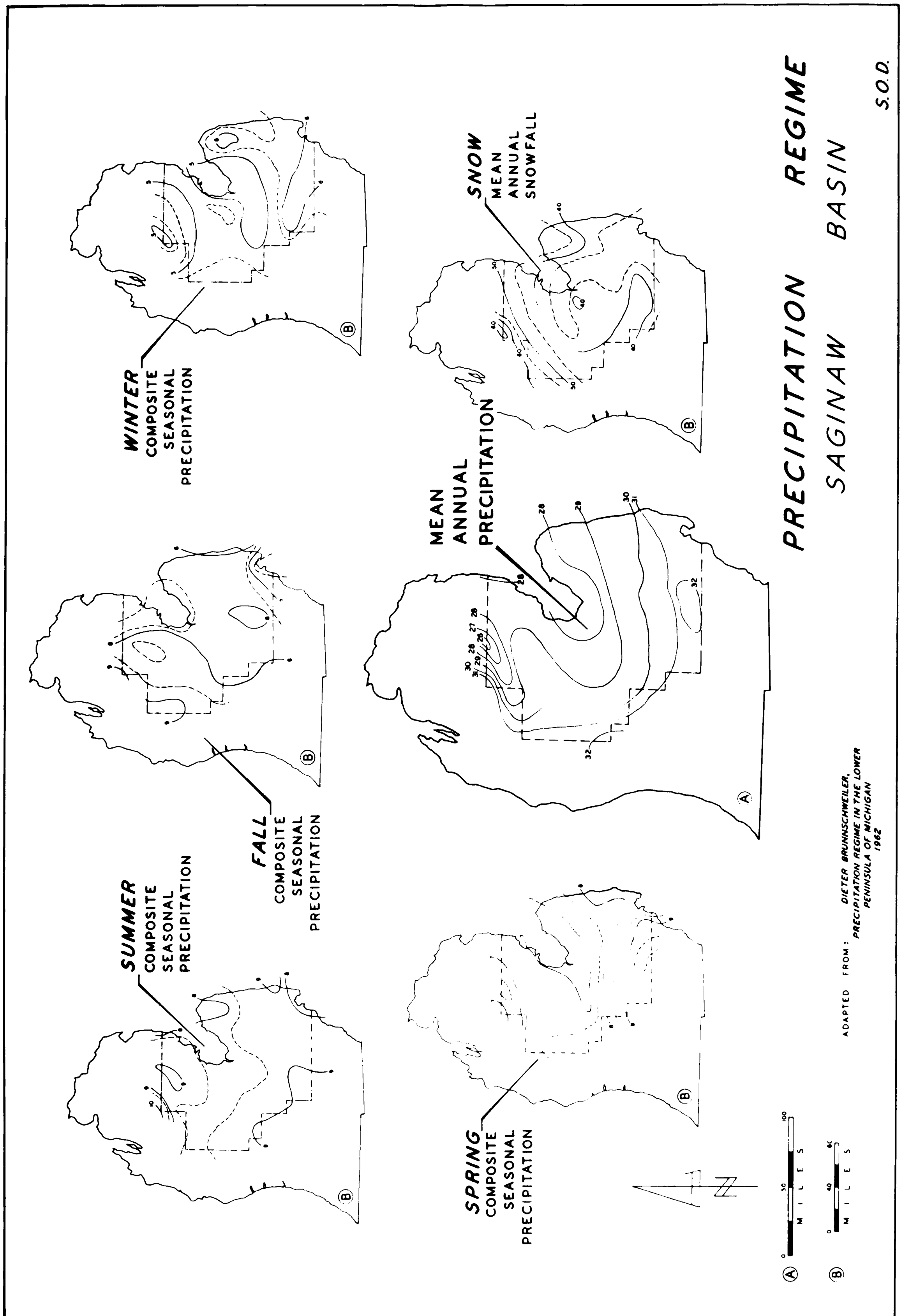
PRECIPITATION REGIME
SAGINAW BASIN
S.O.D.
SUMMER
COMPOSITE
SEASONAL
PRECIPITATION
FALL
COMPOSITE
SEASONAL
PRECIPITATION
WINTER
COMPOSITE
SEASONAL
PRECIPITATION
SPRING
COMPOSITE
SEASONAL
PRECIPITATION
MEAN
ANNUAL
PRECIPITATION
SNOW
MEAN
ANNUAL
SNOWFALL
ADAPTED FROM: DIETER BRUNNSCHWEILER,
PRECIPITATION REGIME IN THE LOWER
PENINSULA OF MICHIGAN
1962
A 0 50 100 MILES
B 0 40 80 MILES
N

Fig. 4

The slight decline in rainfall during July blends into the gradual decline of runoff values during the late summer and fall seasons and does not singly have a great importance on the runoff water supply.

The winter season (December, January, and February) has the driest months with a composite seasonal precipitation of five inches. It should be noted that approximately seventy percent of the forty-inch mean annual snowfall is deposited during the season. The resulting snow and ice accumulation is normally held in storage on the surface by below freezing temperature conditions with the effect of delaying normal runoff potential. As spring approaches (March, April, and May), rising temperatures and increased precipitation in the form of rainfall combine to amplify and hasten the release of runoff during this season, frequently producing flood conditions at the confluence of the four tributaries with the main stream at the so-called "Shiawassee Flats." Approximately eighty square miles of rich delta land southwest of Saginaw are thus annually inundated.

As precipitation decreases from south to north, so also do the watershed yields of the tributary system. The Flint River tributary on the south produces annually 11.01 inches of manageable water runoff. The Tittabawassee and Cass Rivers reflect their northern locations in the basin and have shown annual watershed yields of 9.48 and 9.08 inches respectively. The Shiawassee River

Basin indicates its transitional position between the Cass and Flint Rivers with 10.76 inches per annum.[20]

Long term average runoff of the basin marks the upper limit of possible production of both surface and ground water and is, therefore, a significant natural control over the limits of water supply and management alternatives toward solution of the various water problems of the Saginaw River Basin. Since man as yet has not learned to control climate, modification of conditions related to the water regime are limited to other elements of the physical landscape.

Subsurface and Surface Formations

Subsurface and surface formations, like climate, are not easily subject to cultural modification, yet they are significant to the nature of the water supply. Like most of Michigan, the Saginaw Basin area is covered with glacial drift.

Glaciers brought in rocks and soil, as well as grinding and mixing local rock types. Upon their retreat they left the basin covered with an assortment of glacial debris arranged as the surface formations of today. The nature of this glacial drift has a direct effect upon the quality of surface and ground water, the presence of

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[20] A. D. Ash, Annual Rainfall and Runoff in Inches, Surface Water Branch, Water Resources Division, United States Geological Survey, Lansing, Michigan, 1960.

lakes and streams, surface runoff, infiltration rates of water into the soil and other related factors. Before surface formations are examined in detail, the impact of the subsurface geology upon the water regime will be characterized.

a. Subsurface Geology

The subterranean strata of the Michigan peninsula are shaped similar to a vast saucer, with the lip at the outer shores and the depression in part beneath the Saginaw Basin. Rock structures below the basin are the Pennsylvanian series including both the Grand River and Saginaw groups. At the eastern edge, substrata of the Mississippian series emerge from beneath the Pennsylvanian deposit. (Figure 5.)

The Grand River group is characterized by both red and brown sandstone, sandy shales, and shales with clay.[21] These structures are aquifers for fresh water, but are susceptible to salt brine intrusion from other layers. The Saginaw Group is characterized by sandstone, clay shales and limestone with small deposits of low grade bituminous coal.[22] Fresh water supplies are very limited from this

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[21] Helen M. Martin, Geologic Map of the Southern Peninsula of Michigan (Pub. 39; Geo. Ser. 33; Lansing: Dept. of Conservation, Geo. Sur. Div., 1936).

[22] Ibid.

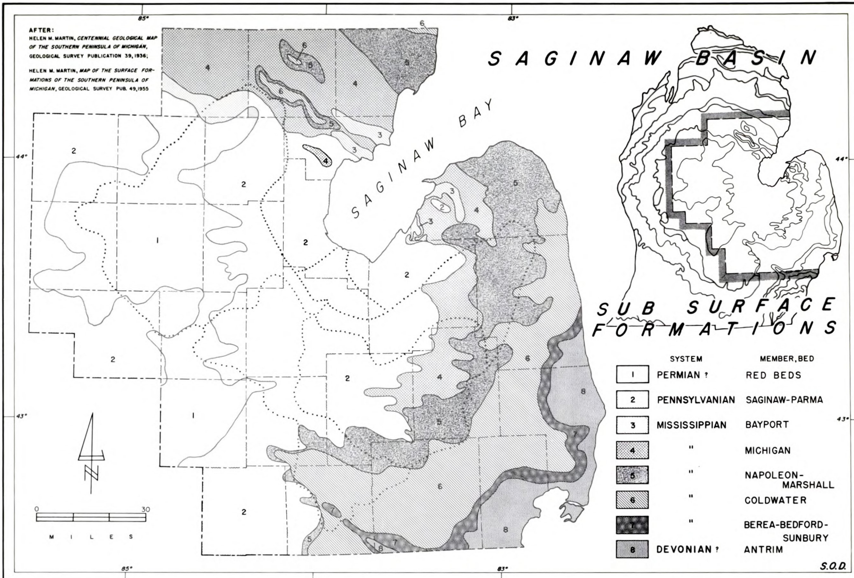
SAGINAW BASIN
SUB SURFACE FORMATIONS
AFTER:
HELEN M. MARTIN, CENTENNIAL GEOLOGICAL MAP OF THE SOUTHERN PENINSULA OF MICHIGAN, GEOLOGICAL SURVEY PUBLICATION 39, 1936;
HELEN M. MARTIN, MAP OF THE SURFACE FORMATIONS OF THE SOUTHERN PENINSULA OF MICHIGAN, GEOLOGICAL SURVEY PUB. 49, 1955
SAGINAW BAY
SYSTEM
MEMBER, BED
1 PERMIAN ? RED BEDS
2 PENNSYLVANIAN SAGINAW-PARMA
3 MISSISSIPPIAN BAYPORT
4 " MICHIGAN
5 " NAPOLEON-MARSHALL
6 " COLDWATER
7 " BEREA-BEDFORD-SUNBURY
8 DEVONIAN ? ANTRIM
0
30
MILES
85°
83°
44°
43°
S.O.D.

Fig. 5

group, but they produce economically valuable salt and sulphate brines at depths as shallow as ninety feet. Deeper drilling into the Mississippian series has tapped salt, brine, gas and oil of economically significant quantities.

The entire Saginaw River Basin has limited fresh water supplies at shallow depths, but has the problems of salt water intrusion into the aquifer as the fresh water is removed. As a result, fresh water production from sedimentary rock aquifers has a limited life expectancy. Other rock layers will continue to produce important salt water, sulphate brine, gas and oil to support petroleum and chemical industries throughout the region.

b. Surface Formations

The thickness and character of the glacial drift throughout the Saginaw River Basin has a profound effect upon water resource plans as it is the most extensively developed aquifer in the area, and offers some potential for future development. As salt water intrusion increases, however, ground water supplies must be either supplemented or substituted with surface supplies. The structure of the surface formations is a controlling factor in the gradient of streams, location of reservoirs, quantity of surface runoff, infiltration rates of precipitation into the soil, and the depth of producing water wells.

The Saginaw Basin surface is dominated by the vast one and one-half million acre predominantely flat glacial lakebed adjacent to the lower end of Saginaw Bay. This level and fertile clay loam land covers sixty percent of the area under consideration and is interrupted only by a relatively flat water laid moraine running northwest to southeast near the city of Saginaw. Surrounding this lakebed plain on the south, west, and north, is a series of moraines which developed at the edge of the glacial ice. (Figure 6.)

Till plains and outwash channels were created between the morainic hills from rock and soil debris and meltwater deposits at the glacial front. It is only in the moraine hill-land surrounding the lakebed plain that significant topographic variety exists. The depth of glacial drift varies from zero to five hundred feet with the average depth near two hundred feet.[23] The heavy clays and loams on the lakebed floor contrast with the sand, gravel, and boulders in the moraines. The valley floor changes in elevation only two hundred feet from the mouth of the Saginaw River to the west limit of the basin, a distance of seventy miles. At the southern and northern reaches, altitudes reach one thousand feet and provide an elevation difference of five hundred feet from tributary headwaters to the mouth of the Saginaw River.

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[23] Helen M. Martin, Surface Formations of the Southern Peninsula of Michigan (Lansing: Department of Conservation, Geo. Sur. Div., 1955).

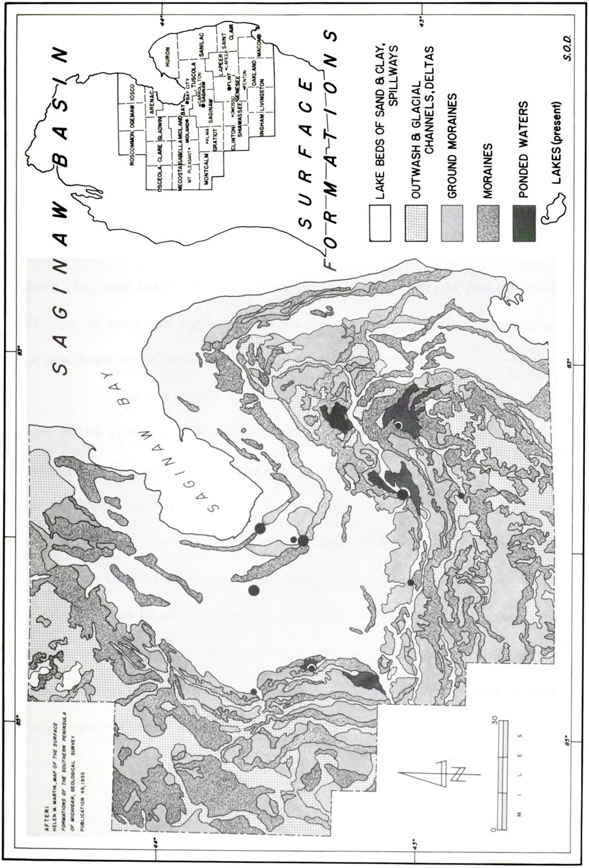
SAGINAW BASIN
SURFACE FORMATIONS
LAKE BEDS OF SAND & CLAY, SPILLWAYS
OUTWASH & GLACIAL CHANNELS, DELTAS
GROUND MORAINES
MORAINES
PONDED WATERS
LAKES (present)
S.O.D.
SAGINAW BAY
AFTER:
HELEN M. MARTIN, MAP OF THE SURFACE FORMATIONS OF THE SOUTHERN PENINSULA OF MICHIGAN, GEOLOGICAL SURVEY
PUBLICATION 49, 1955
0
30
MILES
44°
43°
83°
85°
ROSCOMMON
OGEMAW
IOSCO
ARENAC
OSCEOLA
CLARE
GLADWIN
MECOSTA
ISABELLA
MIDLAND
BAY
HURON
MT PLEASANT
MIDLAND
BAY CITY
TUSCOLA
SANILAC
MONTCALM
ALMA
GRATIOT
SAGINAW
CARROLLTON
SAGINAW
LAPEER
LAPEER
SAINT CLAIR
CLINTON
SHIAWASSEE
OWOSSO
FLINT
GENESEE
FENTON
INGHAM
LIVINGSTON
OAKLAND
MACOMB

Fig. 6

The headwater areas provide the topographic conditions for the natural lakes as well as for developed and potential reservoir sites. The sand and gravel soil at the surface of the drift in these moraine areas complements the topography by having high permeability as well as ground water flowage toward wells or river courses.

On the valley floor, the flat terrain complicates the drainage problem and provides no sites for reservoir development. The heavy clay and loam texture of the glacial drift retards the percolation and flow of water to wells and streams, causing low well production and the need for a vast network of drainage ditches.

The net effect of surface formations is reflected in several ways in the study area. Stream gradients are sufficient for good drainage in the headwater areas of the tributaries, but in turn complicate the flood problems on the valley floor. Ample natural lakes and reservoir sites are present in the headwater areas while nearly nonexistent on the valley floor. Drainage and water well production are excellent in the sand and gravel sections, while poor soil permeability and poor drainage are characteristic of the lakebed plain. Thus the importance of the surface formations to the water resources in the study area becomes clear.

Soil and Vegetation

Soil, like water and air, is one of the indispensable resources for human existence. The mineral and organic substances in soil which support plant life are the basis of much of our food and industrial raw materials. Soil and water have a dynamic relationship which becomes important when analyzing water resources. The nature and occurrence of various soil types affect land utilization, vegetation and crop production, surface runoff of precipitation, as well as infiltration rates of water into the soil.

Soils in the study area were developed under very poor natural drainage conditions from loam, clay loam, or silty clay loam parent material of the flat glacial lakebed adjacent to the lower end of Saginaw Bay. (Figure 7.) The near level topography and clay loam soil were conducive to wet, swampy conditions, which produced abundant natural vegetation and the resulting high levels of organic material. These soils are high in nitrogen and lime and with proper drainage are very productive for agriculture.[24]

Soil texture and structure are important factors in the movement of water from the surface into the ground water zone. Clay and silt are among the finest of textural classes within soils

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[24] E. P. Whiteside, I. F. Schneider, and R. L. Cook, Soils of Michigan, Soil Science Department, Michigan State University, Special Bulletin 402, December 1959, pp. 39-40.

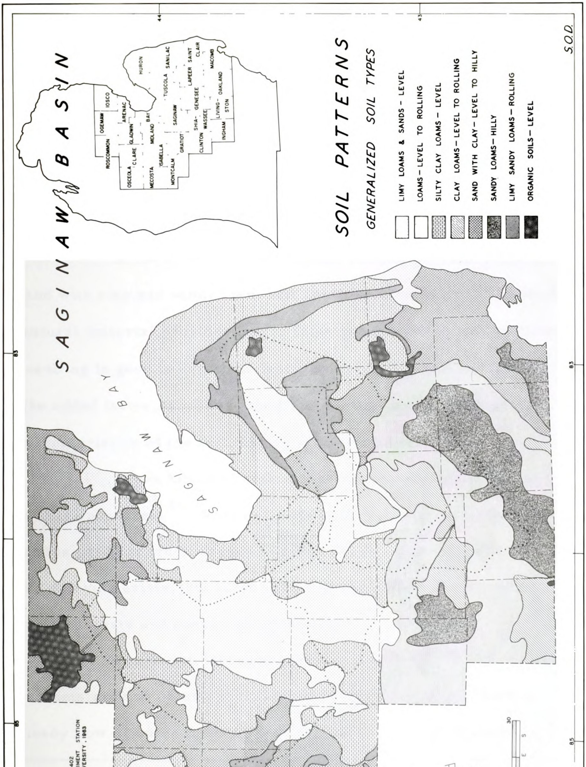
SAGINAW BASIN
SOIL PATTERNS
GENERALIZED SOIL TYPES
LIMY LOAMS & SANDS - LEVEL
LOAMS - LEVEL TO ROLLING
SILTY CLAY LOAMS - LEVEL
CLAY LOAMS - LEVEL TO ROLLING
SAND WITH CLAY - LEVEL TO HILLY
SANDY LOAMS - HILLY
LIMY SANDY LOAMS - ROLLING
ORGANIC SOILS - LEVEL
ROSCOMMON
OGEMAW
IOSCO
ARENAC
GLADWIN
CLARE
OSCEOLA
MECOSTA
ISABELLA
MIDLAND
BAY
MONTCALM
GRATIOT
SAGINAW
TUSCOLA
HURON
SANILAC
LAPEER
SAINT CLAIR
MACOMB
GENESEE
SHIA-WASSEE
CLINTON
INGHAM
LIVING-STON
OAKLAND
SAGINAW BAY
DATA SOURCE:
SOILS OF MICHIGAN,
SPECIAL BULLETIN 402
AGRICULTURAL EXPERIMENT STATION
MICHIGAN STATE UNIVERSITY, 1963
MILES
0
30
S.O.D.

Fig. 7

and thus provide the smallest pore spaces for the storage or movement of water. These characteristics cause water problems in the nature of low infiltration rates, slow movement of water within the ground water table, poor or limited well production and difficult surface drainage conditions. These features are characteristic of more than two and one-half million acres of basin area soil.

In the moraine sections surrounding the valley floor, sand with clay and sandy loam soil conditions dominate. The sandy textural material provides larger interstices between soil particles resulting in good to excellent drainage and infiltration conditions. The added factor of rolling topography complements the drainage characteristics of the soil texture and structure.

These hill-land soils are of medium value for agricultural purposes.[25] Where climate conditions are favorable the land is used for truck crops and small fruits. Some general farming and dairying exists, but large tracts of these soils are in second growth forests and conservation reserves.[26]

Vegetation increases the absorptive capacity of the soil, prevents erosion, slows surface runoff, and helps to maintain a steady flow of water to streams. Vegetation in the study area is

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[25] Ibid., p. 44.

[26] Elton B. Hill, and Russell G. Mawby, Types of Farming in Michigan, Michigan State University, Agricultural Experiment Station, Special Bulletin 206, September 1954, p. 35.

divided into two general categories: (1) cropland and grassland, and (2) forest land. On the valley floor, approximately two and one-half million acres of land are devoted to intensive agriculture producing row crops, such as beans and sugar beets, truck crops, and small grains. Since this is one of the productive agricultural regions of the country, the land was cleared of the original deciduous hardwood forest cover, with the exception of an occasional fenceline or farm wood lot. With the forest cover went fifty to eighty percent of the water retentive capacity of the vegetative cover.[27]

Barrett has shown that forest cover influences water supply conditions by reducing the erosion of violent rain, retarding the melting snow, increasing the absorptive capacity of soil, preventing erosion, and checking rapid surface runoff.[28] In the basin headwaters more than one million acres of partial to completely forested lands benefit the water inventory. The forest cover today is predominantly second growth stands of aspen, oak, and jack pine in the northern sections of the basin with ash, elm, and northern hardwood species in the South. (Figure 8.)

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[27] Leonard Barrett, Water and Its Relation to Forestry; paper delivered at Water Conservation Conference, Lansing, Michigan, January, 1944, pp. 16-18.

[28] Ibid., p. 18.

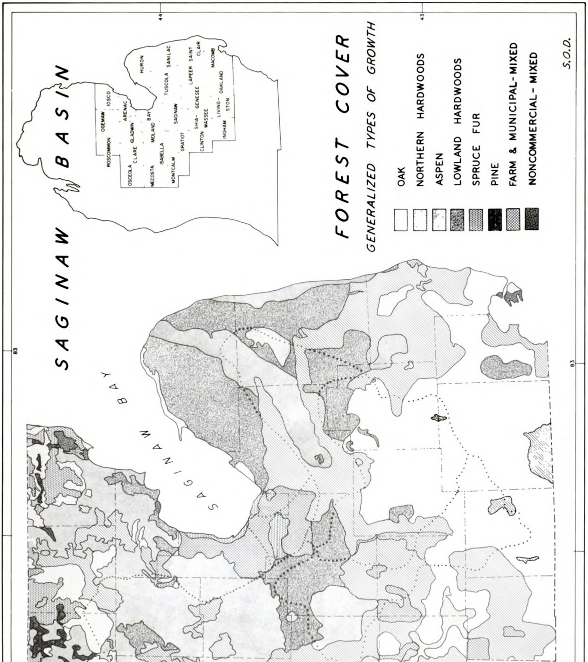
SAGINAW BASIN
SAGINAW BAY
FOREST COVER
GENERALIZED TYPES OF GROWTH
OAK
NORTHERN HARDWOODS
ASPEN
LOWLAND HARDWOODS
SPRUCE FUR
PINE
FARM & MUNICIPAL-MIXED
NONCOMMERCIAL-MIXED
S.O.D.
DATA SOURCE:
MICHIGAN FOREST SURVEY,
MICHIGAN DEPARTMENT OF
CONSERVATION, 1955-57
0
30
MILES
ROSCOMMON
OGEMAW
IOSCO
OSCEOLA
CLARE
GLADWIN
ARENAC
MECOSTA
ISABELLA
MIDLAND
BAY
HURON
MONTCALM
GRATIOT
SAGINAW
TUSCOLA
SANILAC
CLINTON
SHIA-WASSEE
GENESEE
LAPEER
SAINT CLAIR
INGHAM
LIVING-STON
OAKLAND
MACOMB
85
83
44
43

Fig. 8

The Michigan Department of Conservation has defined forest lands as those lands ten percent or more stocked by forest trees and land formerly forested, but now less than ten percent stocked if not developed for other purposes.[29] During the Michigan forest survey from 1955 to 1957, the areas of commercial forest under this definition were found to be extensive. (Table 3.) Within the basin area the significant forested sections were the hill-land areas in the south and north. It is in these areas where the nature of soil and forest help stabilize the lakes, streams, ponds, and underground water supplies. Flooding, drainage, and surface pollution problems rarely occur. Salt water intrusion into underground aquifers is nearly an unknown phenomena. Forests, lakes, streams, and ponds provide some of the finest recreational environment in the State. On the valley floor, many of these elements of the water regime are in utter conflict, frequently because the balance of soil and vegetative cover has been ignored.

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[29] Michigan Department of Conservation, Michigan Forest Survey, Mio Block, Lower Peninsula of Michigan, 1957 Appendix 11, p. 49.

Table 3.--Forest resources of the Saginaw River Basin.[a]

County	Land Area[b] Acres	Nonforest Acres	Forest Land[c]: Total Area Acres	Forest Land[c]: Total Percent Forest	Forest Land[c]: Non-Commercial[d] Acres	Forest Land[c]: Commercial Forest Acres
Arenac	235,500	137,400	98,100	41.7	11,700	86,400
Bay	285,400	232,300	53,100	18.6	100	53,000
Clare	366,100	124,900	241,200	65.9	4,900	236,300
Clinton	365,400	332,700	32,700	8.9	0	32,70C
Genesee	412,200	352,400	59,800	14.5	0	59,800
Gladwin	321,900	137,800	184,100	57.2	22,700	161,400
Gratiot	362,200	305,500	56,700	15.7	0	56,700
Huron	526,100	413,300	112,800	21.4	1,100	111,700
Ingham	357,800	319,700	38,100	10.6	0	38,100
Iosco	350,100	101,200	248,900	71.1	13,300	235,600
Isabella	366,100	260,500	105,600	28.8	0	105,600
Lapeer	421,800	314,900	106,900	25.3	3,100	103,800
Livingston	365,400	268,600	96,800	26.5	10,100	86,700
Macomb	307,800	272,200	35,600	11.6	800	34 800
Mecosta	360,300	195,100	165,200	45.8	200	165,000
Midland	332,800	141,200	191,600	57.6	7,500	184,100
Montcalm	455,700	346,800	108,900	23.9	400	108,500
Oakland	561,300	434,100	127,200	22.7	23,600	103,600
Ogemaw	367,300	93,460	273,900	74.6	2,200	271,700
Osceola	371,800	182,500	189,300	50.9	1,200	188,100
Roscommon	333,440	28,540	304,900	91.4	800	304,100
Saginaw	519,700	409,200	110,500	21.3	0	110,500
St. Clair	473,600	367,000	106,600	22.5	1,500	105,100
Sanilac	615,000	526,000	89,000	14.5	0	89,000
Shiawassee	345,600	306,800	38,800	11.2	0	38,800
Tuscola	522,200	399,700	122,500	23.5	e	122,500

[a]Michigan Forest Survey. Timber Resources (Michigan Department of Conservation: 1955-1957.)

[b]From areas of the Unites States, 1950 Bureau of the Census.

[c]Land at least 10 per cent stocked by forest trees and land formerly forested but now less than 10 per cent stocked if not developed for other use.

[d]Includes reserved land.

[e]Signifies less than 1/2 of 1 recognizable unit.

Population

Among the cultural characteristics, the distribution and density of population has more problem-creating potential for water resources than any other factor. Growth of population and the industrial and service establishments designed to serve the people create multiple demands upon the manageable water supply of the basin area. The Saginaw River Basin contains one-fifth the area and nearly one-fifth the population of the State of Michigan. Of the one and one-quarter million residents, more than half are included in the Detroit to Bay City population corridor which follows generally the Flint River. (Figure 9.)

The cities of Flint, Saginaw, and Bay City are the major urban complexes which anchor the corridor, within the confines of the study area. Population has spilled out from these urban centers to adjacent suburban townships. Population densities vary from six thousand five hundred per square mile in Flint to townships nearly devoid of population in the northern reaches of the basin. Eight hundred sixty thousand people live in the Flint and Saginaw watersheds along with the accompanying major water-using industrial concentrations.

The distribution of population in the study area indicates some development characteristics of subregions within the basin. The smaller towns and villages are mostly market centers for the agricultural areas on the east and west of the urban-industrial corridor.

Tl

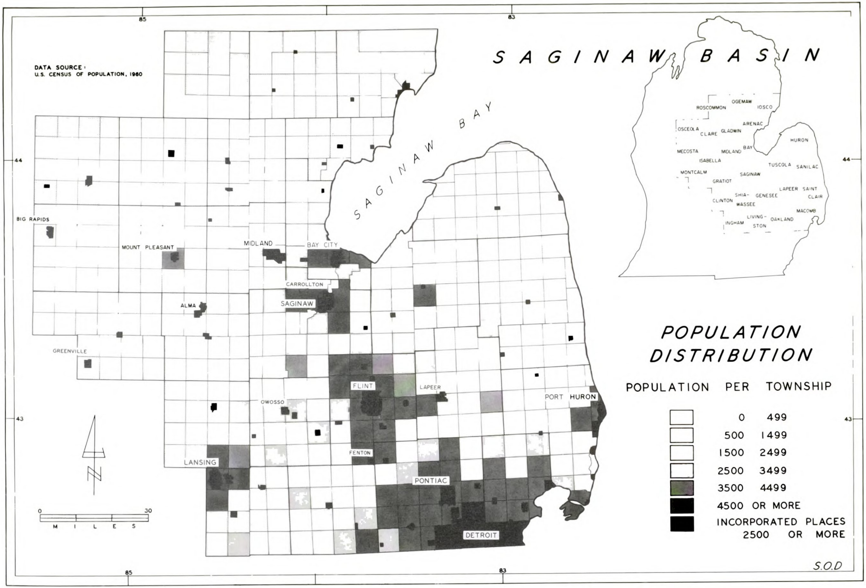
SAGINAW BASIN
DATA SOURCE:
U.S. CENSUS OF POPULATION, 1960
SAGINAW BAY
BIG RAPIDS
MOUNT PLEASANT
MIDLAND
BAY CITY
CARROLLTON
SAGINAW
ALMA
GREENVILLE
OWOSSO
FLINT
LAPEER
FENTON
LANSING
PONTIAC
DETROIT
PORT HURON
ROSCOMMON
OGEMAW
IOSCO
OSCEOLA
CLARE
GLADWIN
ARENAC
HURON
MECOSTA
MIDLAND
BAY
ISABELLA
TUSCOLA
SANILAC
MONTCALM
SAGINAW
GRATIOT
LAPEER
SAINT CLAIR
SHIA-WASSEE
GENESEE
CLINTON
MACOMB
LIVING-STON
OAKLAND
INGHAM
POPULATION DISTRIBUTION
POPULATION PER TOWNSHIP
0 499
500 1499
1500 2499
2500 3499
3500 4499
4500 OR MORE
INCORPORATED PLACES 2500 OR MORE
0
30
MILES
85
83
44
43
S.O.D

Fig. 9

Tl

In the north the towns and villages serve both as agricultural centers and service centers for recreation resources. In the population corridor, however, small towns are satellite communities whose residents are economically oriented to the large industrial cities nearby.

The Cass River watershed reflects its dominately rural pattern with a population of fifty-four thousand spread thinly over the one thousand square mile area. The Shiawassee River basin has similar rural characteristics with a population of only one hundred twenty-two thousand and an area of over eleven hundred square miles. In the Saginaw River portion seventy percent of the population are residents of cities and towns, emphasizing its urban characteristics. (Table 4.)

In the urban-industrial corridor all major urban centers have been forced to seek water supplies from outside the basin. Since 1948, Bay City, Saginaw, and Midland have been tapping Lake Huron for their water supply. Flint was connected to the Detroit system and Lake St. Clair in 1964. The demands of population and industrial uses have outrun the surface and ground water supplies in the Flint and Saginaw watersheds and have forced communities to look elsewhere for adequate water supply.

TI

Table 4.--Population of the Saginaw Basin by tributary area, 1960.

River	Rural and Rural Nonfarm	Cities and Towns	1960 Total	1980 Projection
Cass	49,686	4,901	54,587	81,098
Flint	425,348	217,128	642,476	956,261
Saginaw	65,058	156,459	221,517	329,706
Shiawassee	91,295	29,862	121,157	181,820
Tittabawassee	123,480	63,319	186,799	278,031
TOTAL	754,867	471,669	1,226,536	1,826,916

Source: United States Census, 1960.

Population projections indicate that future water demands will extend this trend for "seeking external water supplies" to communities in the other tributary watersheds. By 1980 the Saginaw Basin will include a population base of 1.8 million with a water demand exceeding the manageable supply by some four thousand million gallons per day.

Land Utilization

The surface of the land is the principal recipient of precipitation which in turn creates surface and ground water. The use of the land thus has a major role in water resource management. Land and the cultural uses and facilities in and upon it determine to a great extent the amount of precipitation intercepted, water infiltration into the aquifer, water quality, as well as erosion and flood problems.

Despite Michigan's industrial economy, land utilization in the study area continues to be predominantly agricultural. Nearly forty-eight hundred square miles, or seventy-six percent of the Saginaw Basin area, is devoted to agriculture. (Figure 10.)

Urban land uses, which contain the bulk of the population and generates much of the water demand, cover little more than four hundred square miles. These urban uses are distributed mainly along the Detroit to Bay City industrial corridor. Midland, Mt. Pleasant,

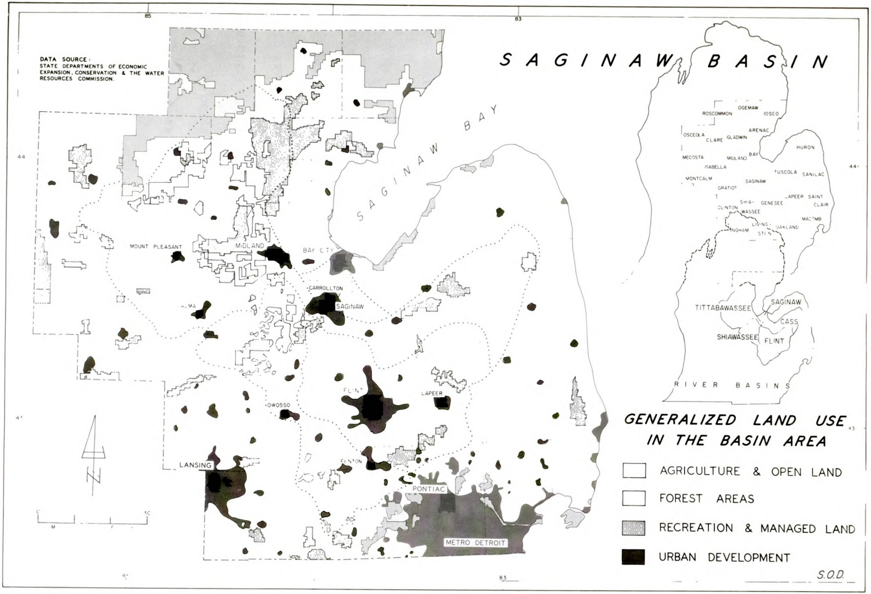
SAGINAW BASIN
DATA SOURCE:
STATE DEPARTMENTS OF ECONOMIC EXPANSION, CONSERVATION & THE WATER RESOURCES COMMISSION.
SAGINAW BAY
MOUNT PLEASANT
MIDLAND
BAY CITY
CARROLLTON
SAGINAW
OWOSSO
FLINT
LAPEER
LANSING
PONTIAC
METRO DETROIT
ROSCOMMON
OGEMAW
IOSCO
OSCEOLA
CLARE
GLADWIN
ARENAC
HURON
MECOSTA
MIDLAND
BAY
ISABELLA
TUSCOLA
SANILAC
MONTCALM
SAGINAW
GRATIOT
LAPEER
SAINT CLAIR
CLINTON
GENESEE
TITTABAWASSEE
SAGINAW
CASS
SHIAWASSEE
FLINT
RIVER BASINS
GENERALIZED LAND USE IN THE BASIN AREA
AGRICULTURE & OPEN LAND
FOREST AREAS
RECREATION & MANAGED LAND
URBAN DEVELOPMENT
S.O.D.

Fig. 10

Alma, and Lapeer are the nuclei for the remaining cells of urban land outside this corridor. (Table 5.)

Forest and recreation uses are concentrated in the central to northern sections of the Saginaw Basin, primarily in the Shiawassee and Tittabawassee watersheds. More than a thousand square miles of forest and recreation lands provide the setting for natural water features such as lakes and ponds in the headwaters area. On the valley floor swamplands, unusable for agriculture, have been developed into conservation reserves. Recreation land utilization has been intensively developed within the marginal and sub-marginal area in the northern sections. As much as sixty percent of the land in the northern counties is in state ownership for recreation purposes.[30]

The functional structure of the Saginaw River Basin is closely tied to the physical basis of settlement, particularity the utilization of land and water resources. Water problems are the product of both areal differences in the physical environment and the cultural decisions regarding the use of that environment. An examination of the spatial aspects of water resource problems may reveal the areas of conflict between human activity and the natural environment of water resources.

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[30] Maurice Edron McGaugh, The Settlement of the Saginaw Basin (Dissertation for Ph.D., University of Chicago, 1950), p. 374.

Table 5.--Land utilization in the Saginaw River Basin by tributary areas.

Rivers	Land Uses in Square Miles[b] Agriculture	Forest[a]	Recreation	Urban	Total Area
Cass	903	0	80	30	1,013
Flint	1,147	0	80	167	1,394
Saginaw	133	0	6	67	194
Shiawassee	891	106	74	75	1,146
Tittabawassee	1,712	330	338	70	2,500
Land Use Totals	4,786	436	628	409	6,247

[a]Definition of forest land is that used by Michigan Department of Conservation--land at least 10% stocked by forest trees and land formerly forested but now less than 10% stocked if not developed for other use.

[b]Compiled from data provided by Michigan State Conservation Department and Michigan Water Resources Commission.

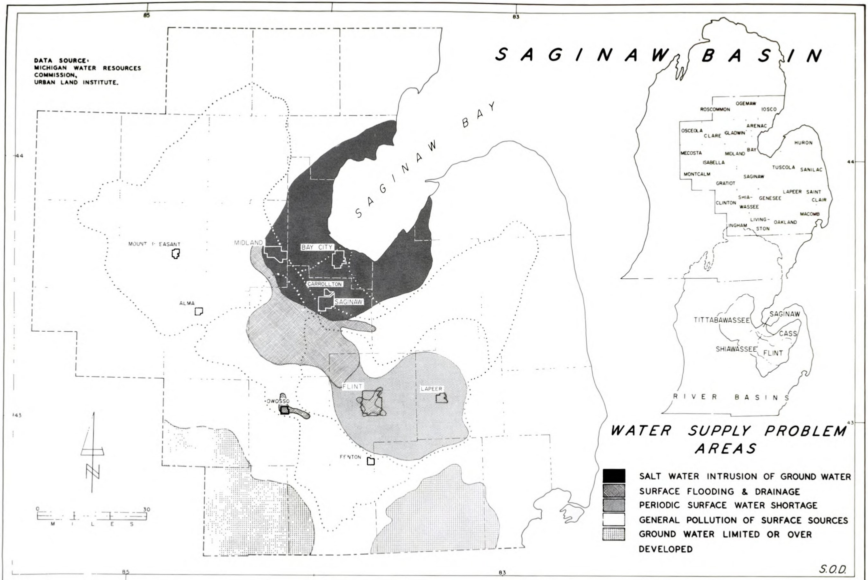
III

SPATIAL CHARACTERISTICS OF WATER RESOURCE PROBLEMS IN THE SAGINAW RIVER BASIN

The water resource, as a spatial factor in a drainage basin, is the result of such variables as the underlying geologic structure of the region and the activities of man which modity the quality, quantity, or movement of water at any point. The total character of the water resource at any location is a product of the interaction of all factors affecting it. Saginaw Basin's water problems are the product of areal differences in the physical environment and in the human use and management of the water resource therein.

Water Resource Problem Areas

Several kinds of water resource problems occur in the Saginaw Basin. Some are the result of actions by its occupants. The generalized patterns of water supply problem areas are shown on Figure 11. The problem pattern is more complex than is first apparent. Thus, while salt water intrusion appears to be the dominant problem in the lower portion of the basin, it is also true that surface flooding and drainage problems exist, and that general surface water pollution occurs in this particular portion as well as throughout the basin.


SAGINAW BASIN
DATA SOURCE:
MICHIGAN WATER RESOURCES
COMMISSION,
URBAN LAND INSTITUTE.
SAGINAW BAY
MOUNT PLEASANT
MIDLAND
BAY CITY
CARROLLTON
SAGINAW
ALMA
OWOSSO
FLINT
LAPEER
FENTON
ROSCOMMON
OGEMAW
IOSCO
ARENAC
OSCEOLA
CLARE
GLADWIN
HURON
MECOSTA
MIDLAND
BAY
ISABELLA
TUSCOLA
SANILAC
MONTCALM
SAGINAW
GRATIOT
LAPEER
SAINT CLAIR
SHIA-WASSEE
GENESEE
CLINTON
MACOMB
LIVING-STON
OAKLAND
INGHAM
TITTABAWASSEE
SAGINAW
CASS
SHIAWASSEE
FLINT
RIVER BASINS
WATER SUPPLY PROBLEM AREAS
SALT WATER INTRUSION OF GROUND WATER
SURFACE FLOODING & DRAINAGE
PERIODIC SURFACE WATER SHORTAGE
GENERAL POLLUTION OF SURFACE SOURCES
GROUND WATER LIMITED OR OVER DEVELOPED
0
30
MILES
85
83
44
43
S.O.D.

The ground water immediately adjacent to Saginaw Bay has been extensively intruded by salt. This contamination is the result of penetration of the aquifers by salt wells and coal mining exploration holes.[1] Failure to adequately seal off these openings upon abandonment has allowed leakage into the aquifer. This is an example of an area where lack of knowledge and consequent lack of regulation have caused deterioration of the resource as a result of human activity.

Drainage and flooding of surface areas is another problem which affects the southern portions of the basin. The natural geologic and topographic conditions which make this portion of the basin the most valuable agriculturally also cause it to be the most susceptible to accumulations of run-off water. Stream gradients tend to be very small and the result is a two-fold problem. Drainage of the flat, fertile plains areas is generally poor, with water tables near the surface, causing problems for agriculture.[2] Relatively small amounts of precipitation produce local surface flooding and cause damage to crops which are not water tolerant. Further, runoff waters from the upper portions of the basin move through the several tributary streams which join southwest of Saginaw to form the Saginaw River. This juncture

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[1] Max S. Wehrly, Water for Industry, Urban Land Institute Technical Bulletin 17 (Washington: Nov. 1951), p. 25.

[2] Michigan Water Resources Commission, Water Resource Conditions and Uses in the Shiawassee River Basin (Lansing: 1960), pp. 60 & 69.

area consists of a broad, flat, flood plain extending southwestward from Saginaw to the vicinity of the village of St. Charles and is sometimes referred to as the "Shiawassee Flats." During periods of heavy runoff this area is habitually flooded. Since a portion of the area consists of developed agricultural fens and urban land, any excessive flooding can be expected to cause heavy damage, both to property and crops.[3]

The desire of man to best utilize land has resulted in two major efforts in the area of water controls. The efforts, unfortunately, are not always compatible. On the one hand, agricultural users need to have excess water drained from the soil in order to successfully and consistently produce crops. This need has resulted in extensive programs to improve natural drainage channels, construct artificial ditch drains, and lay closely spaced grids of drainage tile throughout the fields. These drainage works have the desired effect of moving surface water from the fields and lowering water tables so that crops can sucessfully be produced. However, the same works contribute to a somewhat intensified flooding problem downstream by assisting in the rapid release of surface water. The exact role of artificial drainage in relation to flooding is still not definitely settled, according to

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[3] _Ibid._, p. 91.

the Michigan Water Resources Commission.[4] However, sufficient concern about flooding has been evidenced in several of the lower basin communities to result in court injunctions against further drainage projects at upstream locations.[5]

Surface water is much more responsive to fluctuations in the precipitation pattern than is ground water. Since the water appearing in the streams is largely the result of runoff from precipitation, any variations from month to month are reflected in streamflow patterns. All of the streams in the basin display similar flow patterns. The typical pattern shows a minimum flowage during the months of June, July, August, and September. Some increase in flow rates will occur during the fall and winter months. Strong peaks in rate of flow occur during the month of March as a result of melting of the winter snows coupled with spring precipitation. Then flow tapers off rapidly during April and May.[6]

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[4]Michigan Water Resources Commission, Water Resource Conditions & Uses in the Tittabawassee River Basin (Lansing: 1960), p. 19.

[5]C. R. Humphrys, Water Bulletin No. 5, Water Resource Analysis of Genessee County (East Lansing: Michigan State University, 1960), p. 9.

[6]U. S. Department of the Interior, Geological Survey, Surface Water Records of Michigan 1962 (Lansing, Michigan), pp. 144-150.

This strong cylical pattern of runoff is reflected in periodic surface water shortages in some parts of the basin. The pattern which appears in Figure 11 indicates those portions of the basin most affected by this condition. Two factors help explain the pattern. First, there is little tributary area in the headwaters to collect precipitation. Second, the heavy demand of the highly urbanized and industrialized southern part containing the cities of Flint and Lapeer. This combination or urban needs and restricted supply area results in general shortages at times.

Pollution of surface water sources in general throughout the basin. Pollution will be defined here as any factor which causes any type of reduction in the quality of water for any desired use. Using this guide line, it may be seen that factors of the natural environment such as the erosional processes and wildlife are the first contributors to decrease in surface water quality. Agricultural activities contribute to the quality reduction process in the form of pesticides and fertilizers in runoff water, and by increases in erosional activities. Proceeding from the rural to the urban areas, the quality of water is subject to further decline by the addition of sanitary and industrial wastes. An extra element adding to the complexity of the situation is the need of industry for water for cooling purposes. This category of surface pollution must be seen therefore as a composite of a variety of factors, and as a summation of a variety of conditions existing at various points in the basin. The monolithic surface pollution pattern recorded in Figure 11 is in reality a concensus of a broad variety of quality reducing characteristics.

One other potential problem concerning the water resource remains to be considered. In urbanized areas immediately to the south of the basin region, evidence exists of over development of available water supplies. In the Pontiac and Lansing urbanized areas increasing demands for water have resulted in decline of water table levels of ground water sources.[7] Extended periods of water table drawdown in these adjacent areas may have latent ground water effects in the Saginaw River Basin.

In metropolitan Flint, limits have been reached for use of the Flint River and added sources of water must be obtained for further development of the region.[8]

Sources of Water Supply

The water which is found in the basin at any time in any of its varying forms, is inextricably bound to the hydrologic cycle. The amount of water received by the region is substantial. Average annual

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[7] Max S. Wehrly, Water for Industry, Technical Bulletin No. 17 (Washington: Urban Land Institute, Nov., 1951), p. 25.

[8] Michigan Water Resources Commission, Water Resource Conditions and Uses in the Flint River Basin (Lansing, Michigan: 1956), pp. 61 & 62.

precipitation varies from 28 inches in the northern portion of the basin to 32 inches in the southern.[9] Not all of the water which is precipitated reaches the streamflow stage. Some portions of it are intercepted by vegetation and other surfaces and lost to evaporation. Of that which infiltrates, a large portion is utilized by plants and subsequently transpired to the atmosphere. Still other amounts are lost from the surface water areas by direct evaporation.

The net result of these processes of evapotranspiration is that perhaps two-thirds of the precipitation is dissipated before it can leave the basin. The tributary watershed yields shown in Figure 12 illustrate that no more than 11.5 inches of water are yielded by any portion of the basin watersheds. This is not a net loss, however, since that portion of the losses attributed to plant transpiration has served its purpose prior to being given up to the atmosphere.

That portion of the precipitation which reaches the surface either becomes a part of overland runoff or infiltrates and becomes part of the ground water resource. Some of the overland runoff becomes a part of streamflow and proceeds to follow the descending gradient out of the basin. Another part enters the inland lakes and becomes a part of the surface water resource. In like manner that portion which

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[9] A. D. Ash, Annual Rainfall and Runoff in Inches for Michigan (Lansing, Michigan: Geological Survey, Surface Water Branch), as reported by C. R. Humphrys, Michigan State University, in a paper prepared for Michigan Week, 1958.

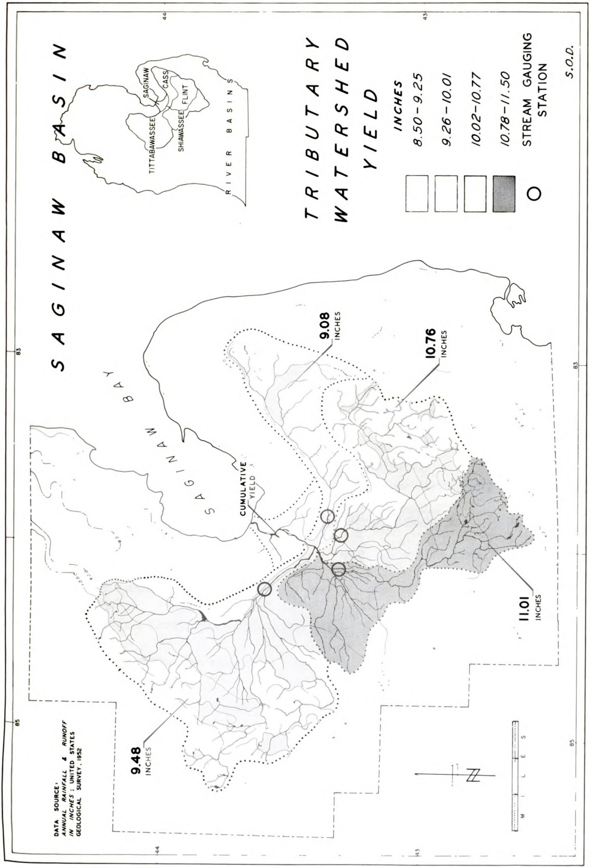
SAGINAW BASIN
TRIBUTARY WATERSHED YIELD
INCHES
8.50 – 9.25
9.26 – 10.01
10.02 – 10.77
10.78 – 11.50
STREAM GAUGING STATION
S.O.D.
SAGINAW
CASS
FLINT
SHIAWASSEE
TITTABAWASSEE
RIVER BASINS
SAGINAW BAY
CUMULATIVE YIELD
9.08 INCHES
10.76 INCHES
11.01 INCHES
9.48 INCHES
DATA SOURCE: ANNUAL RAINFALL & RUNOFF IN INCHES; UNITED STATES GEOLOGICAL SURVEY, 1952
MILES

Fig. 12

percolates into the ground continues to move, at a slower rate, and contributes to the maintenance of the inland lake levels and to streamflow during all seasons of the year.

Thus, there are several elements of the water resource supply of the basin. Moisture exists in the atmosphere as potential water; within the lithosphere as ground water; and as surface water, both standing and flowing. The water which is available but stored within the ground is to some extent an unknown quantity. It has been determined, however, that the potential capacity of the aquifers is exceedingly large. Within the basin in 1961 at least one hundred ninety-two communities, including subdivisions and villages, were reported using ground water sources, with wells either into the glacial drift or bedrock, for public water supplies.[10] An inventory of surface water features by C. R. Humphrys shows that fifteen classifications of surface water exist in the study area varying from natural lakes to fish breeding ponds.[11] The various categories of surface water total over one hundred forty-four thousand acres and are an important part of the water resource inventory. (Table 6.)

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[10] P. P. Giroux, Summary of Ground Water Conditions in Michigan, 1961 (Lansing, Michigan: Michigan Department of Conservation, 1962), p. 6.

[11] C. R. Humphrys, Michigan Lake Inventory Bulletins, (East Lansing, Michigan: Michigan State University, Department of Resource Development, 1962).

Table 6.--Surface water areas of the Saginaw River Basin by county.[a]

County	Natural Lakes & Ponds		Natural Lake with a Dam		Artificial Pond		Hydro-Electric Reservoir	
	No.	Acres	No.	Acres	No.	Acres	No.	Acres
Arenac	22	295.1			20	28.1		
Bay	18	328.3			30	53.4		
Clare	344	4,158.5	4	734.5	24	29.8		
Clinton	161	793.4			18	22.5		
Genesee	146	3,304.4	2	543.0	46	77.4		
Gladwin	47	1,032.3			28	40.1	7	5,111.0
Gratiot	244	288.3			18	40.9		
Ingham	100	911.5	1	453.0	61	58.2	2	310.0
Isabella	174	1,188.7			36	28.9	1	65.0
Lapeer	301	3,682.1	8	549.3	180	170.7		
Livingston	496	7,172.3	11	1,766.7	91	100.6	2	49.1
Macomb	138	275.0	1	15.0	87	70.3		
Midland	5	29.9			4	9.8	2	1,578.0
Mecosta	322	3,989.3	6	754.7	55	22.9	5	1,723.0
Montcalm	463	5,438.9	8	2,102.7	40	50.8	1	149.0
Oakland	1,486	15,313.7	23	3,939.5	220	322.5	1	92.0
Osceola	405	3,134.2	1	5.7	65	97.0	1	18.0
Roscommon	109	2,042.8	3	31,900.0	2	.2		
Saginaw	69	754.8			21	32.9		
Shiawassee	95	440.0			39	81.8	1	50.0
St. Clair	601	7,640.4	6	1,816.0	67	87.7	1	4.0
Tuscola	27	299.8	1	203.0	14	14.3	1	200.0
TOTAL	5,773	62,513.7	75	44,783.1	1,166	1,440.8	25	9,349.1

[a]Michigan Department of Conservation, Institute of Fisheries Research, Pamphlet No. 24, 1953, and, C. R. Humphry's, Michigan Lake Inventory Bulletins, Department of Resource Development, Michigan State University, 1962.

Table 6.--Continued

County	Municipal Water Supply Reservoir		Fish & Wildlife Flooding		Mill Pond		Gravel Pit or Quarry Pond	
	No.	Acres	No.	Acres	No.	Acres	No.	Acres
Arenac							3	2.6
Bay								
Clare			1	263.0	1	32.0	2	0.4
Clinton			2	5.5	1	21.0		
Genesee	4	815.0			6	129.2	1	0.8
Gladwin			7	1,091.0				
Gratiot			18	719.0	1	5.0		
Ingham			34	150.7	1	60.0	3	3.0
Isabella					2	39.0		
Lapeer			26	236.9	2	77.2		
Livingston			3	68.7	4	98.8		
Macomb					3	47.8	28	124.4
Midland			1	590.0			2	9.5
Mecosta			5	2,255.0	2	31.0		
Montcalm			17	110.2	2	17.1		
Oakland			1	9.4	8	222.6	67	327.2
Osceola								
Roscommon			8	4,258.0	1	8.0		
Saginaw			1	648.0				
Shiawassee			1	60.0			3	0
St. Clair			6	8.5	11	1,114.3	2	0.8
Tuscola			46	1,076.5				
TOTAL	4	815.0	177	11,550.4	45	1,903.0	111	468.7

Table 6.--Continued

County	Fish Hatchery		Underwater Borrow Pit		Settling Pond		Beaver Pond		Sewage Disposal Pond	
	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres
Arenac										
Bay			7	25.0						
Clare							1	10.0		
Clinton			2	8.0						
Genesee			3	11.0						
Gladwin							1	20.0		
Gratiot			2	14.0						
Ingham			2	11.5	1	18.0				
Isabella			2	22.0						
Lapeer										
Livingston			2	31.0						
Macomb			1	.7						
Midland										
Mecosta	1	2.1								
Montcalm			1	1.0						
Oakland	13	56.0	10	9.8					10	5.5
Osceola										
Roscommon			1	20.0						
Saginaw										
Shiawassee			2	40.0			1	8.0		
St. Clair	1	12.6	1	2.0					2	1.7
Tuscola										
TOTAL	15	70.7	36	196.0	1	18.0	3	38.0	12	7.2

Table 6.--Continued

County	Fish Breeding Pond No.	Fish Breeding Pond Acres	Artificial Lakes No.	Artificial Lakes Acres	Total Area (Acres) of Water Surface
Arenac					325.8
Bay	1	5.3	2	22.5	434.5
Clare	2	5.5	7	482.6	5,716.3
Clinton	1	1.0	2	460.0	1,311.4
Genesee			5	255.0	5,135.8
Gladwin					7,294.4
Gratiot			3	51.1	1,118.3
Ingham					1,975.9
Isabella					1,343.6
Lapeer			8	292.1	5,008.3
Livingston			9	1,284.7	10,571.9
Macomb			4	734.4	1,267.6
Midland			1	33.0	2,250.2
Mecosta	1	1.5	2	47.0	8,826.5
Montcalm			2	34.0	7,903.7
Oakland			36	5,206.1	25,504.3
Osceola			5	227.0	3,481.9
Roscommon	1	3.0	1	900.0	39,132.0
Saginaw			2	43.8	1,479.5
Shiawassee			5	135.0	814.8
St. Clair			5	833.0	11,521.0
Tuscola	1	5.0	1	0.0	1,798.6
TOTAL	7	21.3	100	11,041.3	144,216.3

Flooding

The capacity of a stream to carry water is a function of its channel depth within banks; its channel width; and its slope, or gradient.[12] This basic capacity is then subject to temporary or permanent modification by constrictions or improvements in the channel. Ice or other natural blockages may constrict, while channel straightening and other clearance projects may increase the capacity to carry water away. Whenever the capacity of a stream to carry water is exceeded, the water surface level rises above bank level and the excess spreads beyond the channel limits onto the adjoining flood plain.

The relief of a major portion of the Saginaw Basin is such that gravity assists little in the movement of water. The profile of the Shiawassee tributary shows it to have an average gradient of only 3.5 feet per mile.[13] Comparatively, an analysis of topographic profiles shows the gradient of the Cass River to be only 2.2 feet per mile and the Tittabawassee 3.3 feet per mile respectively. These low gradient streams all flow into the Shiawassee Flats area. Downstream from this point the Saginaw River exhibits a near zero gradient to its outlet at Saginaw Bay.

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[12] Arthur N. Strahler, Physical Geography, 2nd ed. (New York: John Wiley & Sons, Inc., 1960), p. 334.

[13] Michigan Water Resources Commission, Water Resource Conditions and Uses in the Shiawassee River Basin (Lansing, Michigan: October, 1963).

The area of confluence is essentially a flat plain. When the right combination of conditions occurs to send water downstream faster than it can be carried away, the excess tends to crest in the Shiawassee Flats and spread over the plain and into the village of St. Charles.

In addition to this flooding, other problems exist along the tributaries. Inadequate channel capacity and encroachments upon the natural flood plain cause periodic problems at several locations, and occasionally such combinations as frozen soil, heavy rains, and channel ice jams result in excesses severe enough to cause damage.[14] At Midland, in the Tittabawassee Basin, a persistent problem exists due to the juncture of two tributaries, the Chippewa and Pine Rivers, with the Tittabawassee; coupled with the existence of a broad, flat flood plain which is subject to overflowing. Consequently, Midland has experienced periodic flooding damage whenever those combinations of conditions favorable to production and retention of water have occurred. Recently the Midland area has been free of serious floods. During the 1940's, however, flooding stages occurred nine times, with

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[14] The U.S. Geological Survey reports that on February 16-17, 1954, an ice jam, coupled with rains and meltwater, which formed in the Cass River channel immediately below the village of Frankenmuth, caused water to be impounded and overflow into the Central Business District. Summary of Floods; 1954; Water Supply Paper 1370-C, (Washington, D. C.: 1959), p. 207.

a reported annual damage of $69,000.[15] Further partial records indicate at least thirty-eight additional instances of flood flow, several exceeding the magnitudes of those of the forties, in the period of record from 1904 through 1957.[16]

Similar flood conditions to those at Midland prevail at Owosso and Corunna in the Shiawassee Basin. Inadequate channel capacity at both locations results in overflow of low areas. This channel inadequacy has been increased by construction of dams with inadequate spillways, and buildings and bridges with foundations jutting into the channel.[17] Similar encroachments have occurred on the flood plain of the Flint River Basin with resultant possibilities of heavy damage from severe flooding. A record flood on this tributary in 1947 caused an estimated four million dollars damage.[18] As might be expected, much of the flooding within the basin is primarily a springtime phenomenon resulting from combinations of equinoctial

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[15] Michigan Water Resources Commission, Water Resource Conditions and Uses in the Tittabawassee River Basin (Lansing, Michigan: 1960), p. 105.

[16] Ibid., p. 106.

[17] Michigan Water Resources Commission, Water Resource Conditions and Uses in the Shiawassee River Basin (Lansing, Michigan: 1963), pp. 90 & 91.

[18] Michigan Water Resources Commission, Report on Water Resource Conditions and Uses in the Flint River Basin (Lansing, Michigan: 1956), p. 35.

rains and melting snow. Records on all tributaries confirm, however, that severe summer storms can and have produced substantial flooding.[19]

The flood problems of the basin have been recognized for some time. Professors Wisler and King of the University of Michigan reported on "Floods in Saginaw County" in 1920.[20] The Corps of Engineers of the United States Army began, at Congressional authorization, to study the basin in 1937.[21] The results of the exhaustive Corps studies were finally approved by Congress, and federal support of improvement projects was authorized in 1958. The participation depended, however, upon the conclusion of agreements with local units of government and these agreements have not been forthcoming.[22] Colonel R. C. Pfeil, District Engineer of the Corps of Engineers, Detroit, Michigan, reported to Mr. Milton Adams, Executive Secretary of the Michigan State Water Resource Commission, on June 28, 1961, that the Saginaw Basin watershed program had not received the local cooperation necessary for its implementation.[23] Flint and Frankenmuth were the

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[19] Michigan Water Resources Commission, Flint, p. 35; Shiawassee, pp. 35 & 94; Tittabawassee, pp. 100 & 102.

[20] Michigan Water Resources Commission, Shiawassee, p. 91.

[21] Ibid.

[22] Ibid., p. 92.

[23] L. M. Reid, Dis-Integrated Resource Development, A Case Study of the Saginaw Valley Watershed Development Plan (Ann Arbor, Michigan: University of Michigan, March, 1962), p. 10.

only communities expressing a positive interest in a comprehensive water resource development program. In the Midland area, subsequent to Corps of Engineer studies, some diking has been provided by the City and by the Dow Chemical Company to protect special high value areas against moderate flooding.[24] Humphrys points out that in many areas the problem is not yet severe enough to force action. Only when danger to life or crippling economic costs mount will the proposed solutions be accepted and implemented.[25]

Drainage

The record of the settlement of the Saginaw Valley is replete with reference to water problems. As indicated in the previous discussion of topography and resulting flooding on the flat plain, the low gradient produced swampy conditions where agriculture was virtually impossible.[26] Gradually, as the value of the fertile plain

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[24]Michigan Water Resources Commission, Water Resource Conditions and Uses in the Tittabawassee River Basin (Lansing, Michigan: 1960), p. 107.

[25]C. R. Humphrys, Water Bulletin No. 5, Water Resource Analysis of Genessee County, Michigan (East Lansing, Michigan: Michigan State University, February 1960), p. 9.

[26]In 1815 the Commissioner of the General Land Office is reported to have said that there "would not be more than one acre out of a hundred, if there would be one out of a thousand . . . suitable for cultivation."--George Nowman Fuller, "An Introduction to the Settlement of Southern Michigan from 1815 to 1835," Michigan

came to be recognized, effort was expended to reclaim it for productive uses. The first attempts were individual projects involving surface ditching. By 1839, legislation had been passed to allow public participation in drainage projects.[27] It was not until after the Civil War, however, when real activity began on organized programs, and subsurface methods were developed.[28]

The bulk of the Saginaw Basin is now interwoven with drainage improvement projects. Natural channels have been improved and supplemented with constructed ditches, to act as a collector system for excess water. Small ditches and/or networds of subsurface tile, constructed of clay or concrete sections, lead the water from individual fields to the collection system. The drainage program has been in progress for more than a century now, and the results are reflected in the extensive network of drains. Records of the Michigan Water Resources Commission reveal that a large portion of the land within the Shiawassee Basin has been modified by artificial drainage improvements,[29] while in the Tittabawassee Basin, some fifty percent

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Pioneer and Historical Collections, Vol. XXXVIII (1912), p. 546. (Reported by Maurice Edron McGaugh), The Settlement of the Saginaw Basin, Dissertation for Ph.D., University of Chicago, 1950, p. 40.

[27] Ibid., pp. 85 & 86.

[28] Ibid., p. 87.

[29] Michigan Water Resources Commission, Water Resource Conditions and Uses in the Shiawassee River Basin (Lansing, Michigan: 1960), p. 70.

of the land is served by a drainage system.[30] Renewal of existing drains and expansion of the system is continuing.

Drainage of the land was the key to settlement of the basin. Without artificial control of the water level, agriculture would have been impossible over much of the region. Drainage technology has been a boon to the agricultural industry. Outside the sphere of agriculture, however, some doubts still remain about the effect of drainage programs. Not all of the questions concerning the role of drainage in relation to flooding have been answered. With increasing amounts of urbanization concentrated along the rivers, some resistance is occurring to any additional projects.[31] Drainage works may also lower the water level of nearby lakes and marshes, as well as that of the area they were intended to drain. Thus conflicts arise between wildlife, recreation, urban and agricultural interests. Detailed study and coordinated plans for the whole of the basin will be required in order to reconcile the conflicting interests.

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[30] Michigan Water Resources Commission, Water Resource Conditions and Uses in the Tittabawassee River Basin (Lansing, Michigan: 1960), p. 21.

[31] C. R. Humphrys, Water Bulletin No. 5, Water Resource Analysis of Genesee County, p. 9.

Land Utilization and Relation to Natural Characteristics

The patterns of distribution which have been previously examined indicate the variety of conditions existing within the basin. Large quantities of water are available, and if properly utilized can meet much of the foreseeable need. In practice, it is found that the actual distribution of water is such that supply and demand do not coincide areally. Water utilization will now be examined to determine some factors affecting the natural state of basin developments.

Irrigation

Augmentation of the natural precipitation supply for agricultural and other purposes is not an activity widely recognized in Michigan. However, supplemental water for agricultural use is commonly accepted and the amount of acreage under irrigation is rapidly increasing. (Table 7.) In addition to agriculture there are a number of municipal irrigation uses for water to maintain cemeteries, parks and golf courses. In the beginning, irrigation was provided only as a supplement to correct any deficiencies in the natural rainfall. Now, however, there is some tendency for a pattern of regularly scheduled irrigation to be followed with the natural rainfall

Table 7.--Growth of irrigation in the Saginaw River Basin (by county).[a]

County	Acres Irrigated (By Yr.) Prior to 1930	1944	1958	1930 - 1958 Percent Increase
Arenac			170	Total[b]
Bay	64	64	1,192	1,763
Clare	6	7	16	167
Clinton	0	0	0	0
Genesee	52	52	450	765
Gladwin	0	0	0	0
Gratiot	1	3	515	51,400
Huron	36	36	41	14
Ingham	250	251	995	298
Iosco	0	0	92	Total[b]
Isabella	24	31	528	2,100
Lapeer	44	139	819	1,761
Livingston	126	141	564	348
Macomb	333	444	1,864	460
Mecosta	0	33	590	Total[b]
Midland	0	65	325	Total
Montcalm	167	187	2,866	1,616
Oakland	1,356	1,576	1,990	47
Ogemaw	0	3	3	Total[b]
Osceola	0	5	118	Total
Roscommon	3	3	9	200
Saginaw	130	264	398	206
Sanilac	6	6	40	567
Shiawassee	3	3	216	7,100
St. Clair	212	229	745	251
Tuscola	3	3	328	10,833
TOTAL	2,818	3,550	15,224	551

[a]Adapted from Mich. Water Res. Comm., Water Use for Irrigation, Lan., 1959, App. A. Table 3.

[b]No Acreage recorded at beginning period.

being viewed as supplemental.[32] It is not necessary to apply the large amounts of supplemental water for crops in this climate as is required for crops in the arid regions. The survey conducted by the Water Resources Commission indicated that the average rate of application was about 4.3 inches per acre per season.[33]

Much of the water for irrigation purposes in Michigan is withdrawn from the many sources of surface water which are available. Within the Saginaw Basin this pattern is also followed. The data in Table 8 indicates that some seven times as much land is irrigated from surface sources as from ground water. Since it is typically cheaper to pump directly from a surface source than to dig wells and pump the water up from an underground aquifer, it was to be expected that most of the original irrigators would draw on available surface water. So long as the amount of water withdrawn from a source was insignificant there was little possibility of complaints from other riparians. Now that the amount of irrigated land is increasing, however, there is beginning to be some question about the potential effects of diversion. This is a valid concern since most of the water utilized for irrigation purposes is not returned to the watershed, but is lost to the atmosphere. As a result of these concerns and because of uncertainties about the

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[32] Michigan Water Resources Commission, Water Use for Irrigation (Lansing, Michigan: 1959), p. 8.

[33] Ibid., p. 3.

Table 8.--Saginaw Basin irrigation water withdrawals by river basin.[a]

Basin	Surface		Ground		Combined		City		Total	
	Systems	Acres	Systems	Acres	Systems	Acres	Systems	Acres	Systems	Acres
Cass	9	121	3	48	1	105	1	3	14	277
Flint	28	712	7	143	-	-	2	24	37	878
Saginaw	4	61	2	15	-	-	11	180	17	256
Shiawassee	13	324	7	30	1	5	2	2	23[b]	361[b]
Tittabawassee	36	1,415	5	193	-	-	5	155	46	1,762
TOTAL	90	2,633	24	428	2	110	21	364	137	3,535

[a] Water Use For Irrigation, Water Resources Commission 1959, App. A., Table 4.

[b] Later data collected in 1961 shows 780 acres irrigated by 40 systems, a 116.1 percent increase of acreage from 1957 -- Water Res. Comm., Water Resource Conditions & Uses in the Shiawassee River Basin, Lansing, 1963, p. 62.

rights of the irrigator if his diversion were to be challenged, many operators are now taking steps to secure their future supplies by converting to ground water sources.[34]

The patterns appearing on Figure 13 indicate widespread irrigation. Most of the municipalities are irrigating where desirable to maintain public facilities, and other operators have begun to irrigate where it appeared advantageous to do so. The data presented in Table 9 indicates quantitively the amount of land involved in irrigation projects for each county which is represented within the Saginaw Basin. More than fifteen thousand acres of land are served by five hundred twelve irrigation systems in the study area. Several counties are only partially within the basin; therefore, these figures must be used as a relative indicator of the amount of irrigated land within the basin compared to the balance of the state.

As was noted in the first portion of this chapter, many Michigan streams experience wide variation in flow--from flooding in the early spring to extremely low water in the late summer. Where these conditions exist in the basin, and where suitable sites are available, it would be possible to construct storage facilities to conserve and utilize water for irrigation which is now lost during floods. Conversely, some portions are well supplied with water from lakes or

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[34] Michigan Water Resource Commission, Water Use for Irrigation (Lansing, Michigan: 1959), pp. 10 & 13.

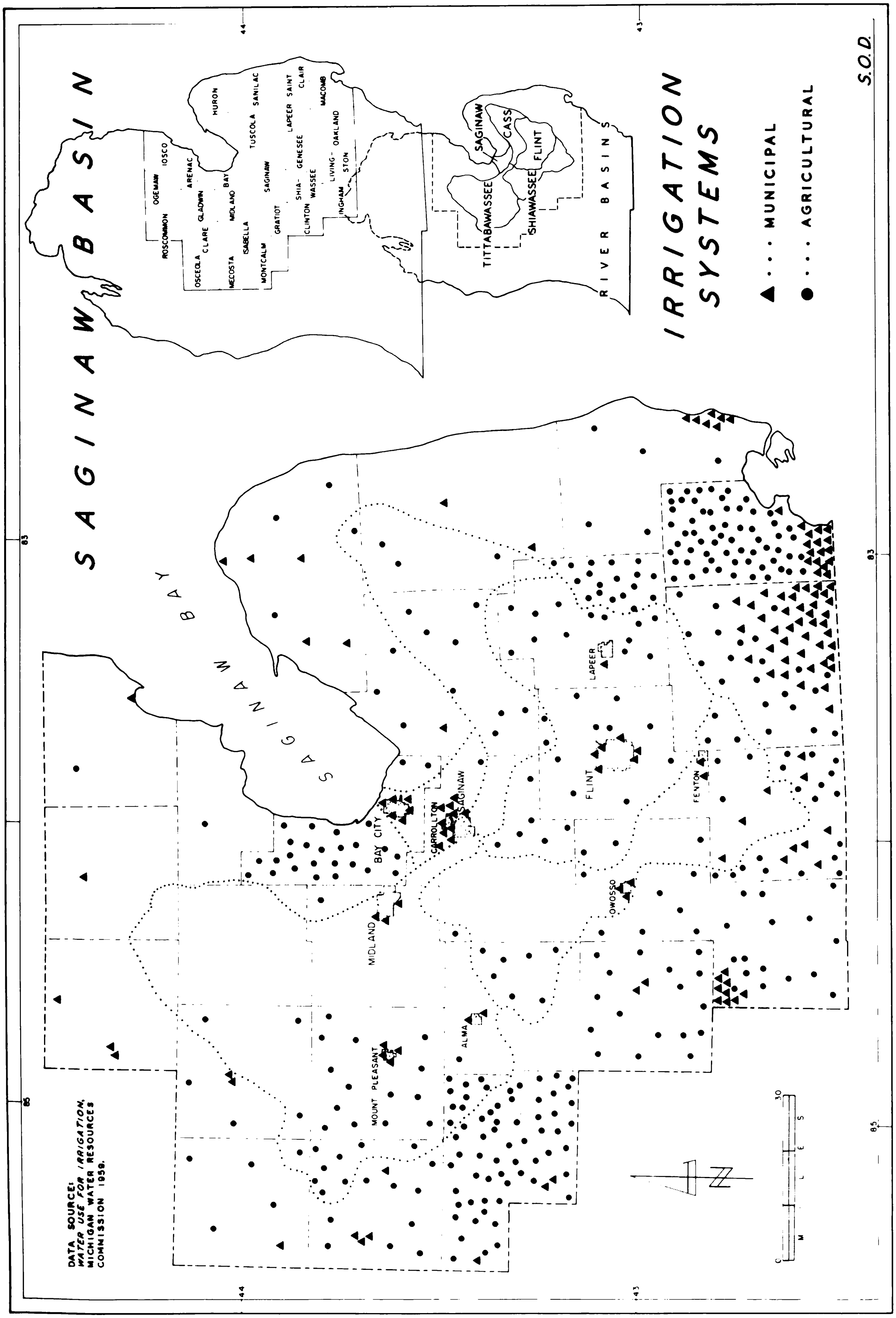
SAGINAW BASIN
IRRIGATION SYSTEMS
▲ . . . MUNICIPAL
● . . . AGRICULTURAL
DATA SOURCE:
WATER USE FOR IRRIGATION,
MICHIGAN WATER RESOURCES
COMMISSION 1959.
S.O.D.
SAGINAW BAY
RIVER BASINS
TITTABAWASSEE
SHIAWASSEE
FLINT
CASS
SAGINAW
BAY CITY
CARROLLTON
MIDLAND
MOUNT PLEASANT
ALMA
OWOSSO
FLINT
LAPEER
FENTON
MILES

Fig. 13

Table 9.--Saginaw River Basin irrigation activity by county.[a]

County	SYSTEM						ACRES			
	Total	Muni.	Agri.	Percent of State Total	Total Irrig.	Percent of State Total	Muni. Irrig.	Agri. Irrig.	Cropland in County	Percent of Cropland Irrigated
Arenac	1	0	1	.040	170	.248	0	170	70,832	.240
Bay	32	6	26	1.292	1,192	1.741	76	1,116	159,166	.701
Clare	7	2	5	.283	16	.023	6	10	51,625	.019
Clinton	19	2	17	.767	651	.951	5	646	222,931	.289
Genesee	19	8	11	.767	450	.657	109	341	193,155	.176
Gladwin	0	0	0	0	0	0	0	0	70,477	0
Gratiot	10	2	8	.404	515	.752	4	511	226,531	.225
Huron	9	5	4	.363	41	.060	15	26	364,410	.007
Ingham	25	9	16	1.010	996	1.454	252	744	183,989	.404
Iosco	2	1	1	.081	92	.134	2	90	41,648	.216
Isabella	18	4	14	.727	528	.771	38	490	176,473	.277
Lapeer	32	1	31	1.292	819	1.196	3	816	220,735	.369
Livingston	31	10	21	1.252	564	.824	124	440	150,845	.291
Macomb	79	17	62	3.191	1,864	2.722	568	1,296	134,448	.963
Mecosta	21	4	17	.848	590	.861	34	556	113,378	.490
Midland	4	3	1	.162	325	.474	315	10	87,128	.011
Montcalm	67	3	64	2.706	2,866	4.185	55	2,811	198,495	1.416
Oakland	66	42	24	2.666	1,990	2.906	1,592	398	160,313	.248
Ogemaw	1	1	0	.040	3	.004	3	0	59,279	0
Osceola	6	1	5	.242	118	.172	5	113	104,163	.108
Roscommon	3	3	0	.121	9	.013	9	0	5,418	0
Saginaw	18	10	8	.727	398	.581	258	140	279,984	.050
Sanilac	5	2	3	.202	40	.058	6	34	405,767	.008
Shiawassee	13	3	10	.525	217	.317	7	210	209,752	.100
St. Clair	12	7	5	.485	745	1.088	519	226	227,493	.099
Tuscola	12	1	11	.485	328	.479	3	325	290,749	.111

[a]Michigan Water Resources Commission, Water Use for Irrigation, 1959.

larger streams and foresee no shortage of water. One factor does appear certain: the use of water for irrigation purposes will increase, along with other competing demands for water. Wherever and whenever these conflicting demands begin to present a problem, it is to be expected that operators will become interested in storage of the excess surface water for use during the dry season, or in developing their own sources of water from ground resources.

Recreation

Abundant opportunities for outdoor recreation occur within the basin. These facilities, located throughout the region, range from relatively highly developed spots designed to serve the metropolitan communities to streams and forest areas which have undergone little or no development. The type of recreation available within the area is a direct function of the type of physical facilities available. Recreation activities range from family picnicing at one end of the scale to primitive camping and large game hunting at the other.

The pattern which appears in Figure 14 and which is identified in greater detail in Table 10 gives an indication of the variety of locations and recreation activities which the region provides. The names of the facilities do not always reveal the involvement of the water resource. In point of fact, however, the value of water is implicit in practically every recreational use. Water for swimming, boating, or mere viewing

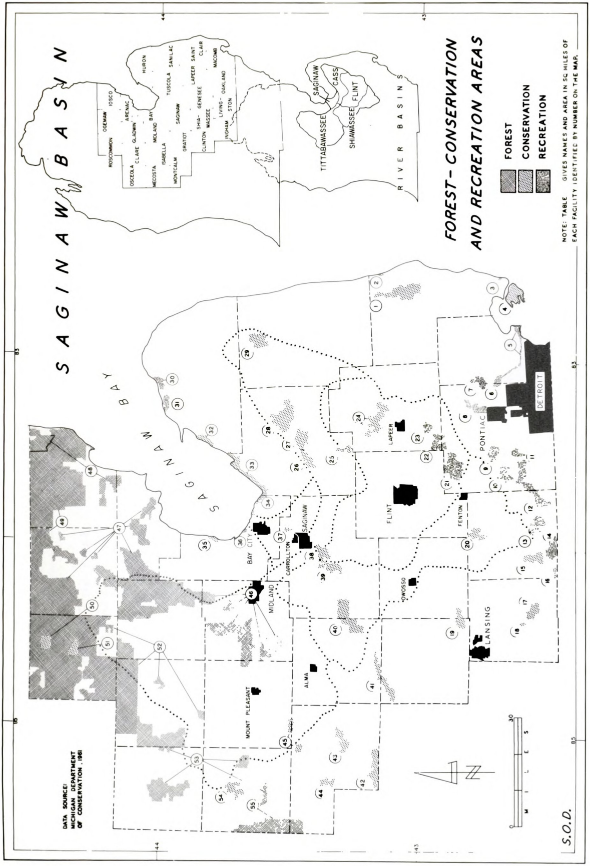
SAGINAW BASIN
FOREST-CONSERVATION AND RECREATION AREAS
FOREST
CONSERVATION
RECREATION
NOTE: TABLE GIVES NAMES AND AREA IN SQ MILES OF EACH FACILITY IDENTIFIED BY NUMBER ON THE MAP.
DATA SOURCE: MICHIGAN DEPARTMENT OF CONSERVATION, 1961
SAGINAW BAY
RIVER BASINS
TITTABAWASSEE
SHIAWASSEE
SAGINAW
CASS
FLINT
ROSCOMMON
OGEMAW
IOSCO
ARENAC
GLADWIN
CLARE
OSCEOLA
MECOSTA
ISABELLA
MIDLAND
BAY
HURON
TUSCOLA
SANILAC
SAGINAW
GRATIOT
MONTCALM
SHIA-WASSEE
GENESEE
LAPEER
SAINT CLAIR
MACOMB
OAKLAND
LIVING-STON
INGHAM
CLINTON
DETROIT
PONTIAC
LAPEER
FLINT
FENTON
OWOSSO
LANSING
SAGINAW
CARROLLTON
BAY CITY
MIDLAND
MOUNT PLEASANT
ALMA
MILES
0
30
S.O.D.

Fig. 14

Table 10.--Forest, conservation, and recreation areas of the Saginaw River Basin.[a]

Map No.	Name of Facility	Area in Acres	Area in Sq. Mi.
1.	Port Huron State Game Area	6,079.09	9.50
2.	Lake Port State Park	371	.58
3.	Algonac State Park	981	1.53
4.	St. Clair State Wildlife Area	6,556.45	10.24
5.	Metropolitan Park Way - 18 3/4 mi., Variable Width	-	-
6.	Rochester-Utica Recreation Area	903	1.41
7.	Stony Creek Metropolitan Park	2,856	4.46
8.	Bald Mountain Recreation Area	2,499	3.90
9.	Pontiac Lake Recreation Area	3,604	5.63
10.	Highland Recreation Area	5,407	8.45
11.	Proud Lake Recreation Area	3,321	5.19
12.	Kensington Metropolitan Park	4,200	6.56
13.	Brighton Recreation Area	4,470	6.98
14.	Pinckney Recreation Area	9,481	14.81
15.	Gregory State Game Area	2,441.54	3.81
16.	Unadilla Wildlife Area	810.90	1.27
17.	Dansville State Game Area	4,141.89	6.47
18.	State Game Farm Area	201.48	.31
19.	Rose Lake Wildlife Experiment Station	3,261.11	5.10
20.	Oak Grove State Game Area	1,796.37	2.81
21.	Holly Recreation Area	6,066	9.48
22.	Ortonville Recreation Area	3,982	6.22
23.	Metamora Recreation Area	683	1.07
24.	Lapeer State Game Area	6,736.26	10.53
25.	Murphy Lake State Game Area	2,600.02	4.06
26.	Vassar State Game Area	2,793.10	4.36

[a]Source: Michigan Department of Conservation, 1961 & 1965.

Table 10.--Continued.

Map No.	Name of Facility	Area in Acres	Area in Sq. Mi.
27.	Tuscola State Game Area	8,143.29	12.72
28.	Deford State Game Area	9,438.04	14.74
29.	Minden City State Game Area	5,863.90	9.16
30.	Port Crescent State Park	164	0.26
31.	Albert E. Sleeper State Park	922	1.44
32.	Wildfowl ¢ Wildlife Bay Area	1,542.48	2.41
33.	Fishpoint Wildlife Area	3,048.99	4.76
34.	Quanicassee Wildlife Area	217.87	0.34
35.	Navanquing Point Wildlife Area	832.44	1.30
36.	Bay City State Park	196	0.31
37.	Crow Island State Game Area	1,108.25	1.73
38.	Shiawassee National Wildlife Refuge	6,352.79	9.93
39.	Shiawassee River State Game Area	7,449.57	11.64
40.	Gratiot-Saginaw State Game Area	12,738.62	19.90
41.	Maple River State Game Area	5,745.62	8.98
42.	Plat River State Game Area	9,527.66	14.89
43.	Stanton State Game	3,505.71	5.48
44.	Livingston State Game Area	1,796.37	2.81
45.	Edmore State Game Area	2,388.66	3.73
46.	Chippewa River State Forest	60,981.49	95.28
47.	Ogemaw State Forest	183,180.02	286.22
48.	Alpena State Forest	74,210.50	115.95
49.	Huron National Forest	413,595	646.24
50.	Conservation Regional Headquarter Experiment Station	(Part of Shiawassee River State Game Area)	
51.	Backus Creek State Game Area	3,427.62	5.36
52.	Houghton Lake State Forest	327,079.06	511.06
53.	Chippewa River State Forest	(Part of Number 46.)	
54.	Haymarsh Lake State Game Area		
55.	Manistee National Forest	456,674	713.55

is an essential part of most picnic situations. It is absolutely essential, of course, for those whose recreation goal is fishing, boating, or swimming; and water is needed even in the hunting areas if the game sought is to reproduce and thrive.

Fortunately, water is well supplied to the basin, and most of the wildlife and recreation areas shown have been selected because the necessary water was present. Approximately twenty-four thousand acres of lentic water surface exist within the defined watershed of the Saginaw River, while more than one hundred forty-four thousand acres are found within the total area of the twenty-one counties situated wholly or partly within the basin.

Some of the surface water bodies are entirely natural in character, while some are partly or completely artificial. The watershed of the Saginaw River is the only area of the basin totally without natural or artificial lakes. (Table 11.) Hydro-electric reservoirs are the largest class of impounded surface water available for recreation use in the study area. Nearly ten thousand acres of surface water are created by hydro dams primarily on the Tittabawassee River.

Unfortunately, nature did not evenly distribute the available features and facilities for water-related recreation. Aside from the main tributaries and their feeder systems, large sections of the basin are nearly devoid of such natural resources. The East Michigan Tourist and Resort Association indicates that the superb highway system of the

Table 11.--Surface water areas in the Saginaw River Basin by tributary.

Types of Surface Water	Cass Acres	Flint Acres	Saginaw Acres	Shiawassee Acres	Tittabawassee Acres	Total Acres
Natural Lakes with Dams	123	2,504	0	1,859	815	5,301
Artificial Lakes	640	468	0	1,408	526	3,042
Hydro-Electric Reservoirs	98	0	0	81	9,170	9,349
Fish & Wildlife Flooding	1,347	301	0	843	2,431	4,922
Municipal & Industrial Water Supply Reservoirs	0	1,204	0	0	0	1,204
Mill Ponds	0	152	0	49	67	268
Gravel Pits & Quarries	2	0	0	0	0	2
Fish Breeders	5	0	5	5	1	16
Underwater Borrow Pits	0	68	35	0	46	149
TOTAL	2,215	4,697	40	4,245	13,056	24,253

basin enables the population centers to distribute water-oriented recreation demand over a wide area both within and outside the basin. The highway system is the single organization thread which ties the forest, conservation, and recreation areas into a network of facilities.

Some surface waters have been developed primarily for commercial purposes, such as power production; some for improved wildlife habitat, and some with recreation directly in mind. In most cases recreation has been a by-product of natural and artificial surface water, whether intended or not. In southeastern Michigan, including the study area, the water-oriented activities of fishing, swimming, boating, or hunting are given higher opportunity values which apparently reflect the desirability of the available water-related recreation facilities.[34] It is anticipated that the use of these waters will continue to increase in ratio to the expected increase in population and income and resultant increases in demand for recreation.[35]

Water Quality

Contamination of water supplies is a factor which exists to varying degrees at locations throughout the basin. Contamination for this purpose will be defined as anything which exists naturally or

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[34] Outdoor Recreation Resources Review Commission, Prospective Demand for Outdoor Recreation, Study Report 26 (Washington, D. C.: 1962), p. 23.

[35] *Ibid.*

is introduced into the water to reduce its quality for a specified purpose. Using this criterion, it is possible to classify waters as contaminated which have been merely warmed above temperatures which will support game fish. Other water exists naturally with high saline content in strata underlying portions of the region. Conversely, some waters are polluted by introduction of residential, industrial, or agricultural wastes. This latter type of contamination is what is commonly envisioned when the word pollution is mentioned. Since introduction of waste products is only a part of the total water quality problem, the word pollution-contamination will be used in all references to water quality.

In studying the quality of water resources of the basin, it is helpful to consider the several factors in relation to both surface waters and to ground water. Several problems exist within the ground water, some of which are natural and others are caused or intensified by man's activities. Within the Saginaw lowlands, saline, highly mineralized water is found at shallow depths. This mineralized water occupies some shallow aquifers and sometimes discharges into surface streams.[36] Man, as he has explored, settled, and intensified his use of the region, has compounded this problem. During exploration for coal, oil, and

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[36]Morris Deutsch, Ground Water Contamination and Legal Controls in Michigan, U.S.G.S. Water Supply Paper 1691 (Washington, D. C.: U.S. Government Printing Office, 1963, p. 49.

other minerals which are found in the study area, a great number of holes have been drilled. These holes have been sunk to appreciable depths in many cases, and have penetrated successive layers of the underlying geological strata. The drilling of these holes, and their subsequent abandonment, left channels through which waters could move vertically from one stratum to another. Before the problem came to be recognized, and legislation was passed to control it, many of these test holes were left without being sealed. The result has been that a considerable amount of pollution-contamination of the fresh water aquifers has occurred due to upward migration of the saline waters which were tapped. This upward migration has been hastened by over-pumping from the upper aquifers in some cases. In the Flint area, for instance, increasing chlorides in the fresh water aquifers are attributed to this action.[37] Penetration and withdrawal of brines from the deep aquifers has developed into an important industry at Midland and other locations within the basin. However, it has been subsequently found necessary to go back and plug many of the wells which had been abandoned without being properly sealed to protect the integrity of the aquifer.[38] Legislation now requires sealing of abandoned holes, but the virtual impossibility of finding and

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[37] Ibid., p. 58.

[38] Ibid., p. 53.

capping all abandoned wells will be a great detriment to reclamation of the aquifer.

Drilling, mining, and lagoon storage of surface wastes are the principal culprits of ground water pollution-contamination and quality reduction in the Saginaw Basin. Such lessor factors as hardness or taste which reduce quality are normally related to subterranean conditions over which man has no control except through artificial processing, with special equipment, at surface locations. Surface seepage of undesirable substances together with saline water intrusion may, over a period of time, destroy the ground water aquifer beneath much of the lowland areas of the basin, placing great limitations on local water supplies.

Surface waters in the study area suffer some pollution-contamination due to such factors as temperature increases, turbidity, discoloration, acidity, or bacterial infestation. Examples of each of these problems may be found which reduce water quality in the basin.

Industrial cooling activity has reduced oxygen content and increased temperature levels in streams at Flint, Saginaw, Midland, Mt. Pleasant, Alma, Owosso, and Bay City. These temperature increases destroy fish habitat, but more importantly, reduce the sewage dilution capacity of the stream. Secondarily, the water supply value of the stream is reduced by the increased content of undigested solids due to lack of oxygen to support decay bacteria.

Turbidity of surface waters caused by material in suspension is related primarily to clay and silt resulting from soil erosion conditions. The introduction of extensive tile and ditch drainage systems has increased the turbidity factor of all surface streams in the basin. The Tittabawassee, Cass, and Flint Rivers are cited by the Michigan Water Resources Commission as streams with turbidity conditions, particularly during the spring season. Suspended material will settle out if the water is impounded in a reservoir or pond for a period of time. Flint's Holloway Reservoir is an excellent example of successful turbidity control of a surface water supply.

Discoloration, acidity, and bacterial infestation are problems introduced by human activities. Many industrial processes or waste disposal techniques produce undesirable side effects which reduce water quality. Industrial activity in Flint, Saginaw, Bay City, and Midland produce dyes which are not easily removed from the disposed water. Sugar beet processing establishments at several locations in the downstream areas of the Saginaw River add discoloration and objectionable odors simultaneously into the surface water at points of disposal. Acidity in the surface water has resulted from the use of stream waters as a universal solvent or for dilution of toxic liquids of an acidic nature. The petro-chemical industries in Mt. Pleasant, Alma, Midland, and Bay City have faced problems of dilution to neutralize acidic conditions resulting from chemical processes. The Tittabawassee River and its tributaries which pass through these urban communities do not have sufficient flow to absorb the acid conditions which continue to plague the watershed.

Infestation of surface waters by pathogenic bacteria is a constant threat in high density population areas where water supplies may actually become disease carriers. Water processing through public water supply systems has reduced this problem in recent years. The exposed nature of surface supplies, however, greatly increases the possibilities for infection under uncontrolled conditions. Testing of water supply sources by the Michigan State Health Department has reduced to a minimum the threat of spreading infestation.

Contamination of surface or underground water supplies exists to varying degrees throughout the study area. Though the problems vary, the collective impact reduces the quality of the total water supply available to the residents of the basin. Salt water intrusion of ground water aquifer and general pollution-contamination of surface sources are the greatest reducers of water quality at this time.

Multiple Use of Water Resources Within the Basin

A spatial analysis of water resource problems in the Saginaw River Basin indicates an increasing amount of interaction between problem-producing factors and expanding water demands. Since the total amount of manageable water available within the basin cannot exceed the long term average annual runoff of the basin, the concept of using the same water in several ways can serve to expand the usable capacity of the fixed supply.

The multiple use of water resources has been an espoused theory for many years; however, as a management practice it has been difficult to execute.[39] To maintain a sustained yield of manageable water resources in the study area requires that no particular utilization overuse the resource to the extent of impairing uses for other water demands. Multiple use of the water resources for the greatest benefit of all concerned is only possible with full cooperation of water-using groups. Thus far, the water resource users of the Saginaw River Basin have not created a viable water management program to implement the conceptual form of multiple use of the water resource.

In 1960, the Michigan State Water Resources Commission sponsored a meeting at Frankenmuth for purposes of reviewing local interests in a comprehensive water management program for the basin.[40]

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[39] Credit for the theory of multiple use management is given to Mr. Carl Schurz, Secretary of the Interior in the early 1870's, who publicly espoused the now established theory of optimum use for the greatest public benefit--Multiple Use of Land and Water Areas, A Report of the Outdoor Recreation Resources Review Commission (Washington, D. C.: 1962), p. 1.

[40] Leslie M. Reid, Dis-Integrated Resource Development, A Case Study of the Saginaw Valley Watershed Development Plan (Ann Arbor: University of Michigan, March, 1962), p. 20.

During this session, numerous local communities reported they were not interested in participation.[41] Apparently, individual communities within the basin have great difficulty in comprehending the relationship of their water problems with those of other communities in the watershed.

The various water problems previously discussed are the results of conflicting demands upon the water resources of the study area. Since collective action for resource management on a basin-wide basis has not evolved, the separate communities throughout the basin have sought individual action. The resulting pattern of developing water-related facilities and features by the separate communities has created an areal organization which utilizes both the natural water resources and man-made facilities.

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[41] Ibid., p. 21.

IV

AREAL ORGANIZATION OF WATER-RELATED FUNCTIONS AND FACILITIES IN THE SAGINAW RIVER BASIN

In an earlier chapter, it was noted that three separate and distinct forms of organization exist in the Saginaw River Basin which relate to the water resources therein. The first, a physical organization, is that which evolved through various physical processes such as climate, topography, soils and vegetation over a period of time.

Second is a political organization which was developed by man and superimposed on the physical fabric of the basin for ease in administration. The governmental organization and responsibilities assumed under such organization are simple enough in concept; however, the complex network of governmental units results in a jurisdictional morass burdened by invisible boundaries and inflexible structures. On charts or tables of organization the relationship of federal, state, county, township, city, village, special district or ad hoc agency, all seem amazingly clear cut with logical lines of authority and responsibilities. However, from the everyday operational world, one finds more discords than harmony and the problem solving needs of water resource management in the Saginaw River Basin are entwined in a governmental maze.

The study area contains more than five hundred and seventy units of government which have water resource management responsibilities of one form or another. These include twenty-one counties, four hundred and fifty-eight townships, ninety-one cities, twenty-seven villages, thirty special districts and nine ad hoc agencies. These groupings do not include the federal government through the Corps of Engineers or the Interior Department; Michigan State Government through the Water Resources Commission, the Conservation Department, or the Department of Health. The net result of this organizational pattern is an institutional handicap preventing an integrated approach to the water resource needs of the area. Under this confusing governmental organization, areas of the basin with no immediate local water problems are reluctant to cooperate in planning or financing projects in other areas of the watershed which do not provide direct or obvious benefits to them. As a result, the spatially varying organization of type of government becomes part of the problem rather than a means of solution.

The third type, functional organization, emerges from the relationships between cultural facilities and natural features coupled to satisfy water needs. The encumbrances placed upon known water management procedures to solve water problems in the Saginaw River Basin reflect the several subregional divisions in the basin area and the diverse demands placed upon the water resource inventory within these subregions. Water needs are generally based upon cultural and economic patterns of development and the smaller the area of consideration, the greater uniformity in problem characteristics. Although watersheds are natural units of land area, the development of cultural features and facilities frequently ignores the natural boundaries and follows economic and transportation trend lines, thus creating a functional organization of facilities to satisfy water resource needs.

Such is the case with the Saginaw River Basin. Development during the 1800's grew from southeast to northwest diagonally across natural divisions of the watershed. As the settlements increased in size and number, and roads and railroads were established, the patterns of land utilization developed divisions in the basin area quite distinct from the natural boundaries of the watershed.[1]

Subregional Divisions of the Basin

Examination and classification of characteristic development patterns and associated water problems indicate that four subregional divisions can be identified. Each such subregional division has distinctive characteristics in water needs which are expressed in various combinations and intensities in the areal arranagment of water-related facilities and features.

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[1]An excellent discussion of this settlement pattern in the Saginaw Basin is presented by Maurice E. McGaugh in his doctoral dissertation from the University of Chicago entitled: The Settlement of the Saginaw Basin, 1950.

The subregional areas are defined by land use and water use characteristics unique to particular sections of the basin through a series of interconnections between unlike water-related activities and facilities. The first subregion includes urban-industrial dominant areas where agricultural activity is subordinate, but together create the greatest water-using portion of the study area. In the second subregion agriculture is dominant with minor service subcenters of urban-industrial growth. A third northern subregion consists of forest, recreation, and agricultural area where the least intensive water uses are identified. (Figure 15.) Each subregional division is discussed separately to clarify the areal variations and interconnections and relationships of water-oriented features.

a. Eastern Subregion

Agricultural activity interspersed with subcenters of urban-industrial development dominates the eastern subregion of the study area. Level to rolling fertile loam soils facilitate an agricultural focus. The large industrial centers to the south provide market demands which encourage dairying and general farming, yet as employment centers, they are not close enough to encourage large numbers of farmers to engage in non-farm industrial employment.[2]

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[2] Elton B. Hill & Russell G. Mawley, Special Bulletin No. 206, Types of Farming in Michigan (East Lansing, Michigan: Michigan State University, Agricultural Experiment Station, 1954), p. 34.

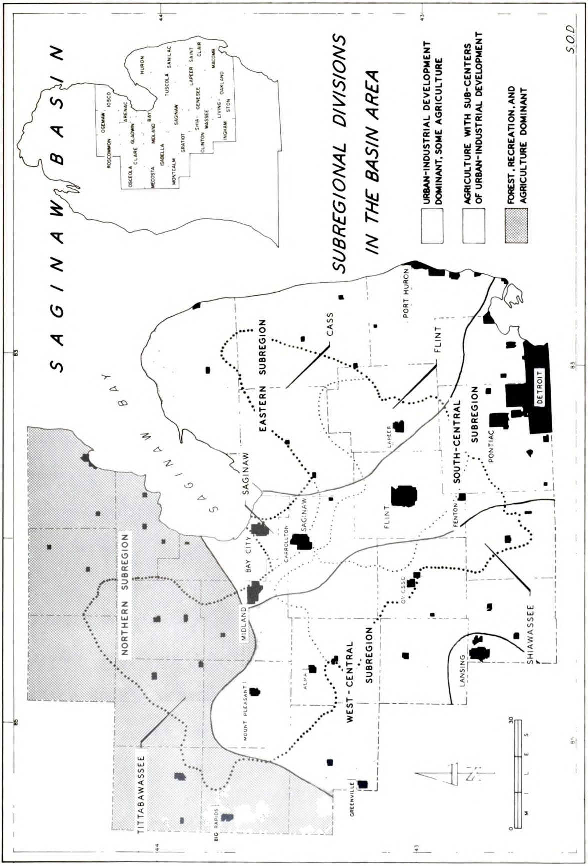
SAGINAW BASIN
SUBREGIONAL DIVISIONS IN THE BASIN AREA
URBAN-INDUSTRIAL DEVELOPMENT DOMINANT, SOME AGRICULTURE
AGRICULTURE WITH SUB-CENTERS OF URBAN-INDUSTRIAL DEVELOPMENT
FOREST, RECREATION, AND AGRICULTURE DOMINANT
S.O.D.
ROSCOMMON
OGEMAW
IOSCO
OSCEOLA
CLARE
GLADWIN
ARENAC
MECOSTA
ISABELLA
MIDLAND
BAY
HURON
MONTCALM
GRATIOT
SAGINAW
TUSCOLA
SANILAC
CLINTON
SHIA-WASSEE
GENESEE
LAPEER
SAINT CLAIR
INGHAM
LIVING-STON
OAKLAND
MACOMB
SAGINAW BAY
NORTHERN SUBREGION
EASTERN SUBREGION
SOUTH-CENTRAL SUBREGION
WEST-CENTRAL SUBREGION
TITTABAWASSEE
SAGINAW
CASS
FLINT
SHIAWASSEE
PORT HURON
DETROIT
PONTIAC
LAPEER
FLINT
FENTON
SAGINAW
CARROLLTON
BAY CITY
MIDLAND
OWOSSO
LANSING
ALMA
MOUNT PLEASANT
GREENVILLE
BIG RAPIDS
M I L E S
0
30
44
43
83
85

Fig. 15

Agricultural activity includes dairying and truck gardening with the additional major cash crop products being dry field bean, wheat and sugar beets.[3]

Water uses in this region are associated primarily with the livestock needs of agriculture and the domestic requirements of small urban service centers. Water supplies are generally based upon ground water sources, including both glacial drift and bedrock aquifers. The rainfall, aided by the moisture retentive quality of the soils is sufficient to meet crop demands and as a result irrigation is rarely used. The largest water problems are created by drainage needs of agricultural lands together with surface water pollution. Artificial drainage is necessary in much of the eastern subregion resulting in interconnected drainage systems. Chemical pollution of surface waters from agricultural chemicals and light industrial activity pervail.

Some areas where drainage has been a prolonged problem have been converted to fish and wildlife floodings and conservation reserves. The Vassar State Game Area, near Caro in the Cass River tributary, and the Lapeer State Game Area, near Lapeer in the Flint River tributary, are major examples of this approach to insolvable drainage problems. Conservation of this type provides a recreation

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[3] _Ibid_.

use of water which is compatible with other land use patterns in the eastern subregion.

b. South-Central Subregion

Urban-industrial development and its concentrated water needs in the Detroit to Bay City corridor distinguish the south-central subregion of the study area from that of other divisions of the basin. The industrial facilities centered in the cities of Flint, Saginaw, Bay City, and Midland set the pattern and focus for this subregion. Though agricultural land uses cover the greatest areal portion of the landscape, part-time or residential farms exceed fifty percent of this land area throughout this subregion, emphasizing the importance of non-farm employment.

Water demands for domestic and industrial needs have outstripped local surface and ground water supplies with the result that all major urban areas in the corridor have tapped surface water supplies from sources outside the basin. Drainage problems are very acute in the northern section of the subregion and artificial drainage facilities are necessary in most areas. Extensive storm and sanitary sewerage treatment facilities have been constructed at nineteen locations fronting on streams ultimately flowing into Saginaw Bay.

Irrigation has become an important element of the truck farming operations in the corridor area near Bay City. Yields of vegetables, fruits and berries are greater in this agricultural area when supplemental irrigation has been provided from drainage ditches or groundwater.

The major stimulus creating water problems in the total study area evolve from the heavy population and industry concentrations in this south-central subregion. More than half the people of the entire basin reside here, creating slightly over two-thirds the total water demand or the equivalent of 130 mgd not including such non-withdrawal uses as hydro power or recreation needs. Much of the population in this subregion uses water recreation features and facilities in other subregions, particularly to the north, thus, transferring these water demands outside the region.

c. West-Central Subregion

Great similarity exists between the eastern subregion and the west-central subregion, for in the west agriculture again dominates the landscape interspersed with small nodes of urban-industrial development. A strong farming economy is based upon loam soils of medium to high fertility, a relatively long growing season and good markets for whole milk. The feed crops of hay, pasture, corn, and oats are important. Where soil conditions are favorable, wheat, white field beans, and sugar beets are important cash crops.[4]

The industrial nodes are small urban communities which serve also as market and trading centers for the surrounding agricultural area. Cities such as Owosso, Alma, and Mt. Pleasant are small industry-service centers with the economy balanced between industry, agricultural services and commerce.

Water needs in the subregion are, once again, primarily domestic and livestock requirements. Ground water sources are supplemented with minor surface supplies from streams. Well water sources tap both glacial drift and bedrock aquifers. Irrigation is rare; however, programs of supplemental irrigation of pastures during "dry spells" have increased in recent years due to improved flexibility in the irrigation techniques.[5]

Drainage continues to be a problem in the northern portion of the Shiawassee Basin as well as the southern portion of the Tittabawassee Basin. Artificial drainage is necessary in both areas and flooding of lowlands is an annual spring event. Ten public and institutional storm and sanitary sewerage treatment facilities have

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[4] Ibid., p. 33.

[5] Marvin R. Shearer, and C. R. Humphrys, Water Resource Development Cost for Irrigation, Art. 44-39 (East Lansing, Michigan: Michigan State University, Agricultural Experiment Station, February 1962), p. 14.

been constructed in the region with outflow water reaching principal streams in every case. Pollution of streams from untreated wastes, agricultural chemicals, and wastes from various light industrial activity is an increasing problem.

Limited water recreation is available in the southern portion of this region where hill-land areas provide some natural lakes and several artificial lakes have been constructed. In the northern portion of the region the short distance by convenient highways to recreation lakes and forests in the northern subregion of the basin effectively satisfy these water demands.

d. Northern Subregion

Large acreages of state-owned land dedicated to forestry, parks, and other recreation uses characterize the northern subregion of the Saginaw Basin. Numerous natural lakes and several artificial lakes dot the surface, providing some of the finest water recreation in the entire basin. More than one-half the land in this area is devoted to forest and recreation uses. The remaining land is devoted to general livestock or part-time farming. Since good local markets do not exist for whole milk products, many livestock farms feed animals for beef production. E. B. Hill indicates that half the farms in this region are part-time or residential farms.[6]

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[6]Elton B. Hill, and Russell G. Mawley, Special Bulletin

Water needs of this region are directly related to recreation or conservation. Domestic uses are satisfied by adequate ground water supplies from wells primarily in glacial drift aquifers. Drainage is not considered to be a problem, for the soils are purous and the topog-graphy gently rolling to hilly. Swamplands are retained for their rec-reation value as a habitat for wildlife and as natural water recharge areas feeding stream flow during low rainfall periods. The balance between agricultural land, water, and forest is here more nearly ideal than in any other portion of the study area. Low population density and limited cultural facilities of an urban nature restrict the water resource problems and needs to a minimum in this subregion.

The needs and uses of water resources in the four sub-regions have stimulated development decisions which have created the areal arrangement of water-related features and facilities. Intercon-nections of the water features and facilities provide an areal organization to satisfy water resource requirements. The elements of this functional organization are described in the following portions of the study.

206, Types of Farming in Michigan (East Lansing, Michigan: Michigan State University, Agricultural Experiment Station, 1954), p. 35.

Areal Arrangement of Water-Related Features and Facilities

The areal arrangement of water-related features and facilities is the product of human decisions during various phases of sequent occupance as to utilization of the natural environment including water resources in the Saginaw Basin. Since most natural water features are closely related to such natural conditions as rainfall and topography, the random nature of their distribution has not been greatly modified by cultural developments. Glacial hill-land in the southern and northern sections of the basin provides two broad belts of natural terrain wherein lakes, swamplands, wildlife floodings, and reservoirs have been developed. These arc-shaped belts of hills vary from twelve to thirty miles in width and extend up to one hundred twenty-five miles in length. This terrain contains natural storage reservoirs for ninety percent of the surface water in the study area. The Saginaw River Basin is dominated by the two and one-half million acre lake bed plain which is nearly devoid of surface water features other than swamplands, river courses, or small artificially created water bodies of limited use for water supply. Added to this natural limitation are water supply demands which exceed available ground water supplies, thus requiring major urban concentrations to seek surface supplies from outside the basin.

In the headwaters of the tributary basins are concentrated the greater portion of natural water features available in the study area. More than twenty-four thousand acres of surface water in nine distinct classifications are distributed in the moraine hill-lands in both the southern and northern reaches of the basin. (Figure 16.) These water features contribute to the stability of streamflow and to the maintenance of an adequate ground water table. Natural water bodies have been supplemented by the addition of twenty-three lake level control dams which stabilize some fifty-three hundred acres of surface water. Thirty-three artificial lakes with a total area exceeding three thousand acres had been constructed by late 1964 with numerous others proposed or planned. Fish and wildlife floodings developed by the State Conservation Department have added a new element in surface water supply stabilization. Nearly five thousand acres of surface water have been added to the surface water inventory through the installation of eighty-six flooding sites for fish and game habitat. Such features as mill ponds, gravel pits and quarries, and underwater borrow pits add fewer than five hundred acres to the surface water inventory in the basin.

In the Tittabawassee River watershed, the natural terrain features have contributed to the largest area of surface water, namely, hydro-electric reservoirs. More than nine thousand acres of surface water have been created by the installation of dams designed to produce

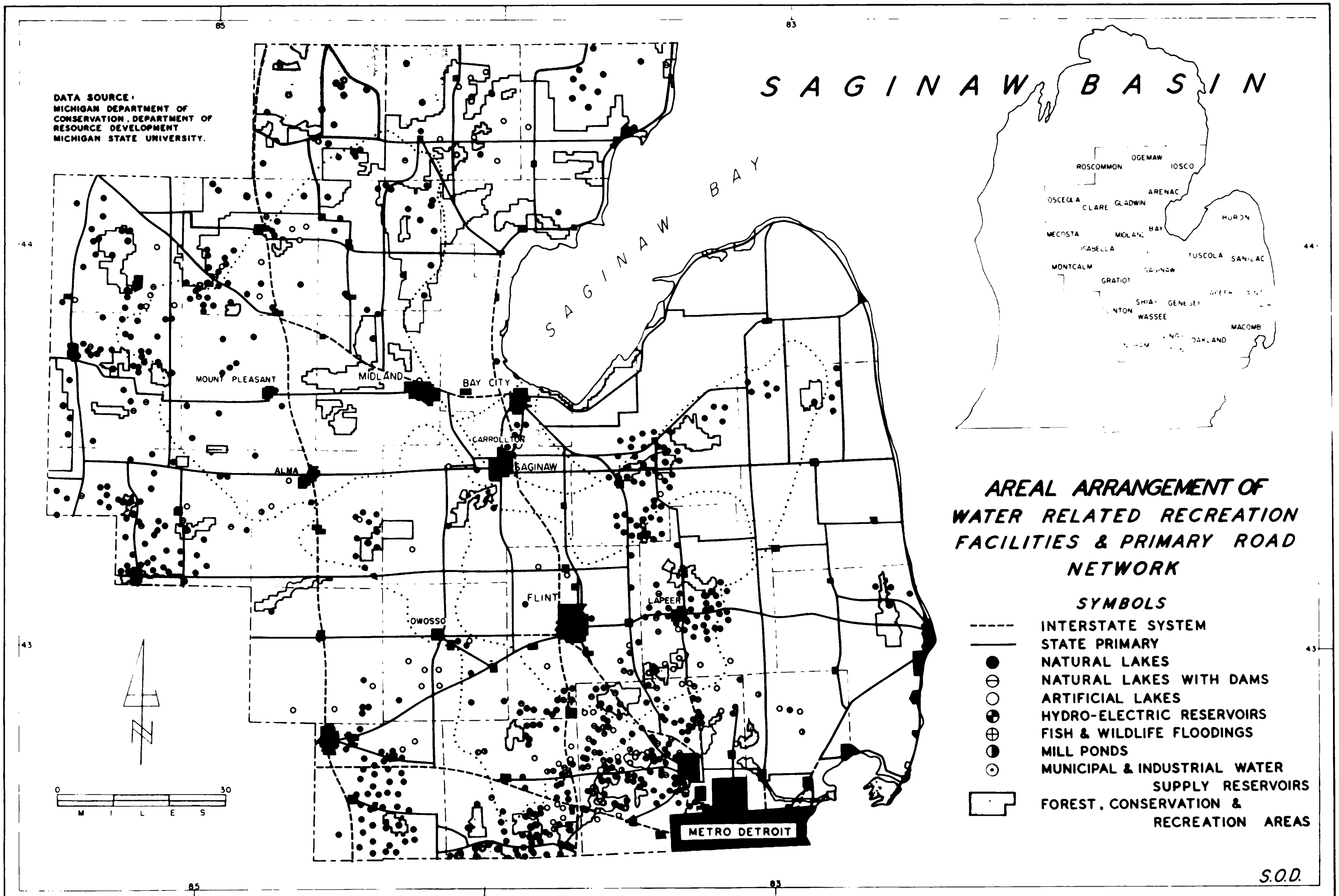
SAGINAW BASIN
AREAL ARRANGEMENT OF WATER RELATED RECREATION FACILITIES & PRIMARY ROAD NETWORK
SYMBOLS
INTERSTATE SYSTEM
STATE PRIMARY
NATURAL LAKES
NATURAL LAKES WITH DAMS
ARTIFICIAL LAKES
HYDRO-ELECTRIC RESERVOIRS
FISH & WILDLIFE FLOODINGS
MILL PONDS
MUNICIPAL & INDUSTRIAL WATER SUPPLY RESERVOIRS
FOREST, CONSERVATION & RECREATION AREAS
S.O.D.
SAGINAW BAY
METRO DETROIT
BAY CITY
SAGINAW
CARROLLTON
MIDLAND
MOUNT PLEASANT
ALMA
FLINT
LAPEER
OWOSSO
ROSCOMMON
OGEMAW
IOSCO
ARENAC
GLADWIN
CLARE
OSCEOLA
MECOSTA
ISABELLA
MIDLAND
BAY
HURON
TUSCOLA
SANILAC
MONTCALM
GRATIOT
SHIAWASSEE
GENESEE
MACOMB
OAKLAND
DATA SOURCE:
MICHIGAN DEPARTMENT OF CONSERVATION, DEPARTMENT OF RESOURCE DEVELOPMENT
MICHIGAN STATE UNIVERSITY.
0
30
MILES
85
83
44
43

Fig. 16

hydro-power at four sites in the Tittabawassee watershed. Unlike many other uses of water, hydro-power does not change the natural physical properties of water to diminish its value or usefulness. Simultaneously, with the production of hydro-power are the associated benefits which dam facilities provide in reducing flooding and erosion problems.

The relationship between these surface water features and the ground water supply is, at first glance, not too self-evident. Lakes and streams are basically depressions in the surface of the landscape that are filled with ground water. The voids and pore spaces of the soil beneath the land surface are saturated with water which has either percolated from the surface or flowed there from another location where surplus water was temporarily available. Although this saturated zone is commonly referred to as ground water, certain geologic depressions in the form of lakebeds and streams may extend downward intersecting the ground water zone to appear as a surface water source. This concept emphasizes the fact that surface and ground water are closely related.

Many wells have been drilled to utilize the available ground water of the Saginaw Basin. The rates of ground water withdrawals by wells have exceeded the rates of water flow from the upland recharge areas to replace those quantities removed. Salt brines from lower levels have migrated upward to replace the removed water, thus destroying the value of some of the natural ground water. To overcome this problem, collective action has been necessary to develop public water supplies from sources that are not affected by these physical limitations.

Public Water Supplies

An "adequate water supply" is a relative term which underlines the necessity to provide enough water of the right quality and at a reasonable price to meet the needs of citizens for both domestic and economic purposes. If water supplies cannot be provided from local sources, or made satisfactory by appropriate treatment, then a supplementary supply must be provided from more distant sources by pipeline or aqueduct. The quest to provide an adequate water supply for population clusters in the Saginaw River Basin has resulted in the creation of more than two hundred and twenty-seven public water supply systems with water sources ranging from wells to the Great Lakes. Approximately eighty percent of the basin population is served by public water supply systems, as are nearly all industrial facilities. (Figure 17.)

During the course of the study, the writer made numerous field trips into the basin to inventory public water supply systems and to examine various natural and cultural features related to the water regime. Combined with information provided by the Michigan

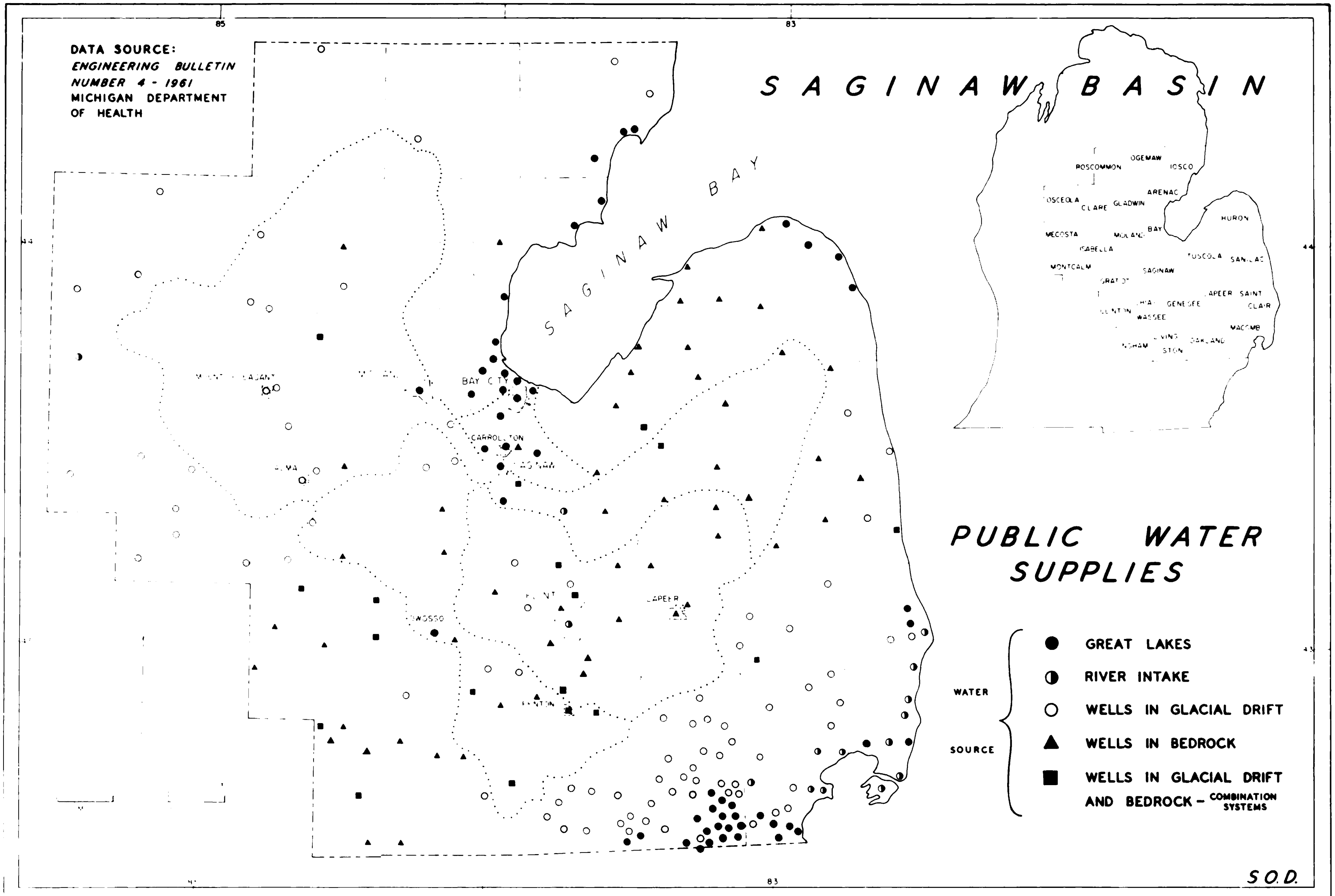
DATA SOURCE:
ENGINEERING BULLETIN
NUMBER 4 - 1961
MICHIGAN DEPARTMENT
OF HEALTH
SAGINAW BASIN
SAGINAW BAY
BAY CITY
CARROLLTON
SAGINAW
FLINT
LAPEER
OWOSSO
FENTON
ALMA
ROSCOMMON
OGEMAW
IOSCO
OSCEOLA
CLARE
GLADWIN
ARENAC
HURON
MECOSTA
MIDLAND
BAY
ISABELLA
TUSCOLA
SANILAC
MONTCALM
SAGINAW
GENESEE
SAINT
CLAIR
WAS SEE
MACOMB
OAKLAND
PUBLIC WATER
SUPPLIES
WATER
SOURCE
GREAT LAKES
RIVER INTAKE
WELLS IN GLACIAL DRIFT
WELLS IN BEDROCK
WELLS IN GLACIAL DRIFT
AND BEDROCK - COMBINATION SYSTEMS
S.O.D.
85
83
44
43

Fig. 17

Department of Health, the tabular results of the water supply inventory are provided as important supplemental information in Appendix A.

One very important feature resulting from the inventory is that the total of used and unused capacity of water supply equipment and storage facilities exceed the present estimated potential of surface and ground water supplies available in the Saginaw Basin.[7] Significant amounts of the equipment have design capacity to handle water supply needs for some years in the future. The actual source of supply, however, is not clearly determined and must be assumed to be from a source presently outside the basin.

Despite the vast quantity of well water surving private and public systems in the study area, (Appendix A) an important trend has developed in the use of surface water to satiffy needs. The larger urban complexes such as Saginaw and Bay City have developed water supply facilities to tap the great surface sources of Lake Huron and Lake St. Clair. Both Flint and Mt. Pleasant, on the other hand, are using some local river supplies to supplement water production; however, the recent low rainfall cycle reduced stream flows to levels which rendered them undependable as supplementary sources and caused these urban complexes to look toward the Great Lakes for future supplies.

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[7] D. R. Woodward, Availability of Water in the United States with Special Reference to Industrial Needs by 1980, Industrial College of Armed Forces (Washington, D. C.: 1957), p. 49.

Public water supply systems are oriented to the local water source, be it wells, rivers, or lake. Improved technology of pumps, pipes, filter systems and storage facilities has expanded the alternatives for securing adequate water supplies from further distant sources. The resulting functional organization creates four levels of responsibility in supplying water needs. The first level is at the source of supply, where measures must be taken to insure that there are no conflicts in the use of the water at the source. This may involve legal activities to secure the supply at the source or may merely represent an engineering problem to construct water intake equipment and facilities. At the second level a transportation system is required to move the supply of water from the source to the processing and distribution system. This function may involve the acquisition of rights-of-way for pipeline or adueducts, or their construction over already available rights-of-way. Third level functions include processing and treatment of the supply and the development of an adequate distribution system to serve the water users of all types. Such facilities may include standard filtration, chlorination, fluoridation, and softening equipment in connection with pumping and storate equipment and an intricate system of distribution mains connecting the water users.

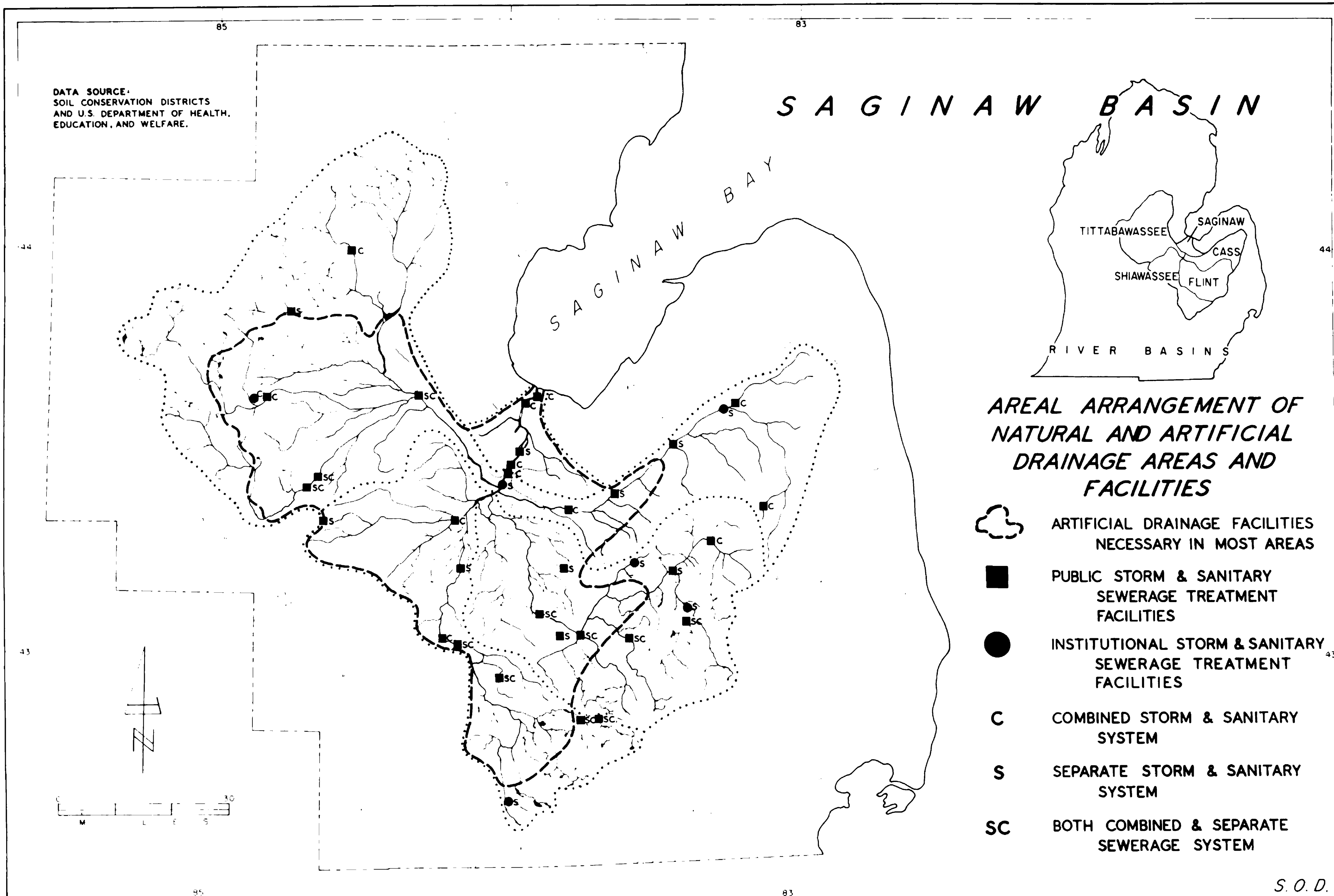
The final level of organization introduces the problem of disposing of large quantities of "used water" through an equally complex system of collection, treatment, and disposal facilities. Since water is the vehicle commonly used to get rid of waste matter, the methods and order for disposing of water become as important as was the organization for supplying the water in the first instance.

Areal Arrangement of Natural and Artificial Drainage Areas and Facilities

Drainage and sewerage treatment are an aspect of water resource study that is seldom included as relevant to the water regime. In the study area, nearly two-thirds of the land surface is controlled under artificial drainage conditions, and storm and sanitary sewerage treatment facilities have been constructed at thirty-eight locations in the basin which feed into the existing natural river drainage system.

The areal arrangement of the natural and artificial drainage features creates a functional organization similar in character to the water supply system, previously discussed. The principle difference lies in the fact that drainage facilities collect the water rather than dispersing it. (Figure 18.)

Three functional levels have been developed by communal action to provide the response to drainage and sewerage treatment requirements. The first level of organization is a collection system consisting of storm and sanitary sewer lines in urban areas where the heaviest concentration of water uses and waste disposal requirements is located. The second level includes the several multi-stage sewerage


SAGINAW BASIN
DATA SOURCE:
SOIL CONSERVATION DISTRICTS
AND U.S. DEPARTMENT OF HEALTH,
EDUCATION, AND WELFARE.
SAGINAW BAY
TITTABAWASSEE
SAGINAW
CASS
SHIAWASSEE
FLINT
RIVER BASINS
AREAL ARRANGEMENT OF NATURAL AND ARTIFICIAL DRAINAGE AREAS AND FACILITIES
ARTIFICIAL DRAINAGE FACILITIES NECESSARY IN MOST AREAS
PUBLIC STORM & SANITARY SEWERAGE TREATMENT FACILITIES
INSTITUTIONAL STORM & SANITARY SEWERAGE TREATMENT FACILITIES
C COMBINED STORM & SANITARY SYSTEM
S SEPARATE STORM & SANITARY SYSTEM
SC BOTH COMBINED & SEPARATE SEWERAGE SYSTEM
S.O.D.

treatment plant facilities found at thirty-eight important locations throughout the basin. At these treatment facilities, the sewerage wastes are removed from the water, neutralized, and placed in bulk storage fields for other purposes. The water is chlorinated and returned to the nearest natural drainage feature, normally a stream. The final, or third level of the drainage system, is the natural tributary system of the Saginaw River which ultimately delivers the water into Lake Huron at Saginaw Bay, thus completing the cycle which began with the water source in the water supply function.

One important deviation of functions in the first level of the drainage system is provided by the tile fields and drainage ditches in the agricultural areas of the two and one-half million acre lakebed plain. Farmers in this great agricultural area lay tile lines across their fields to accelerate the removal of water from the heavy clay soils. The tile lines normally feed the water to drainage ditches by natural gradient flow. The drainage ditches in turn move the water along to the nearest natural tributary outlet, ultimately leading to the Saginaw River. This accelerated removal of excess surface waters from agricultural areas has been contested at numerous locations and times, by court injunctions or threats of injunctions, by downstream interests who are fearful of aggrivated flood conditions.

Public concern for this problem was sufficient to motivate a request to the Detroit District, Corps of Engineers, in 1947, for an investigation of flood and drainage problems at the site of seven cities and villages and two highly fertile farm areas within the basin. The resulting report and plan presented a multi-million dollar flood control and watershed management program which would be a basis for all water resource development objectives within the basin for many years.[8] The adoption and implementation of the recommendations outlined would alleviate many of the legal and technical difficulties now prevalent in the rural sections of the study area.

Despite institutional handicaps the present areal arrangement of natural and artificial drainage and sewerage facilities provide a functional organization utilizing a given natural environment and recognizing cultural needs to resolve many of the drainage and sewerage requirements of the area.

Organization of Water Facilities Within the Saginaw River Basin and Relationship to Areas Outside the Basin

The importance of the areal arrangement of public water supply sources and distribution systems to water resource management is emphasized in contrast by Mr. Bernard M. Conboy, Director

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[8] Saginaw Valley Regional Planning Commission, Progress Report, October 1951, p. 3.

of the Michigan State Department of Economic Expansion who says "We're spoiled, California brings water to some communities from sources four hundred miles away, while there is no place in Michigan more than eighty-five miles from the Great Lakes and yet we can't manage."[9] With this statement Mr. Conboy was both acknowledging a fact and pointing to a trend that has developed in the arranagement of water supply sources and distribution systems.

Areal Arrangement of Public Water Supply Sources and Distribution Systems

In 1946 the citizens of Saginaw and Midland saw the successful conclusion of a forty-year old dream of tapping Lake Huron for their water supply. They marked the first instance where two Michigan cities developed a joint water supply from distant sources outside their normal watershed area.[10] The communities joined forces to construct an eighty-mile concrete pipeline beginning two miles offshore in Lake Huron near Whitestone Point and connecting both Saginaw and Midland. Costing twelve million dollars and with a pumping capacity of 70 mgd, the system, including reservoir and

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[9] Barbara Stanton, Water, Water--Everywhere (Detroit, Michigan: Detroit Free Press, March 8, 1964), C-1.

[10] "80 Mile Pipeline Taps Lake Huron," Engineering News-Record (April 29, 1948), p. 100.

filtration plants, insured an adequate water supply for both urban areas for at least fifty years.[11] (Figure 19.)

Whitestone Point, sixty-three miles northeast of Saginaw, was selected as the water intake point, primarily to establish a water source outside the effects of pollution from the Saginaw River that are prevalent in the Saginaw Bay. This pollution is caused chiefly by sugar beet processing wastes, chlorides and brine from chemical plants, and from the petro-chemical by-product of oil fields and refinning facilities to the west. For more than seventy-five years Saginaw had obtained its water supply from the Saginaw River, but gradual contamination from industrial and domestic wastes forced the seeking of another water source. Midland had taken its water from the Chippewa and Tittabawassee Rivers, both of which suffered destruction as potable water supplies due to domestic and industrial pollution. The results of the Saginaw and Midland cooperative effort produced the first major water supply system in the study area with a source outside the Saginaw River Basin. This system was only a beginning for the new areal arrangement of public water distribution systems in the basin.

In the Detroit metropolitan area problems of water supply and pollution, similar to those of Saginaw and Midland, have presented themselves. The City of Detroit has adopted a policy of extending

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[11] Ibid.

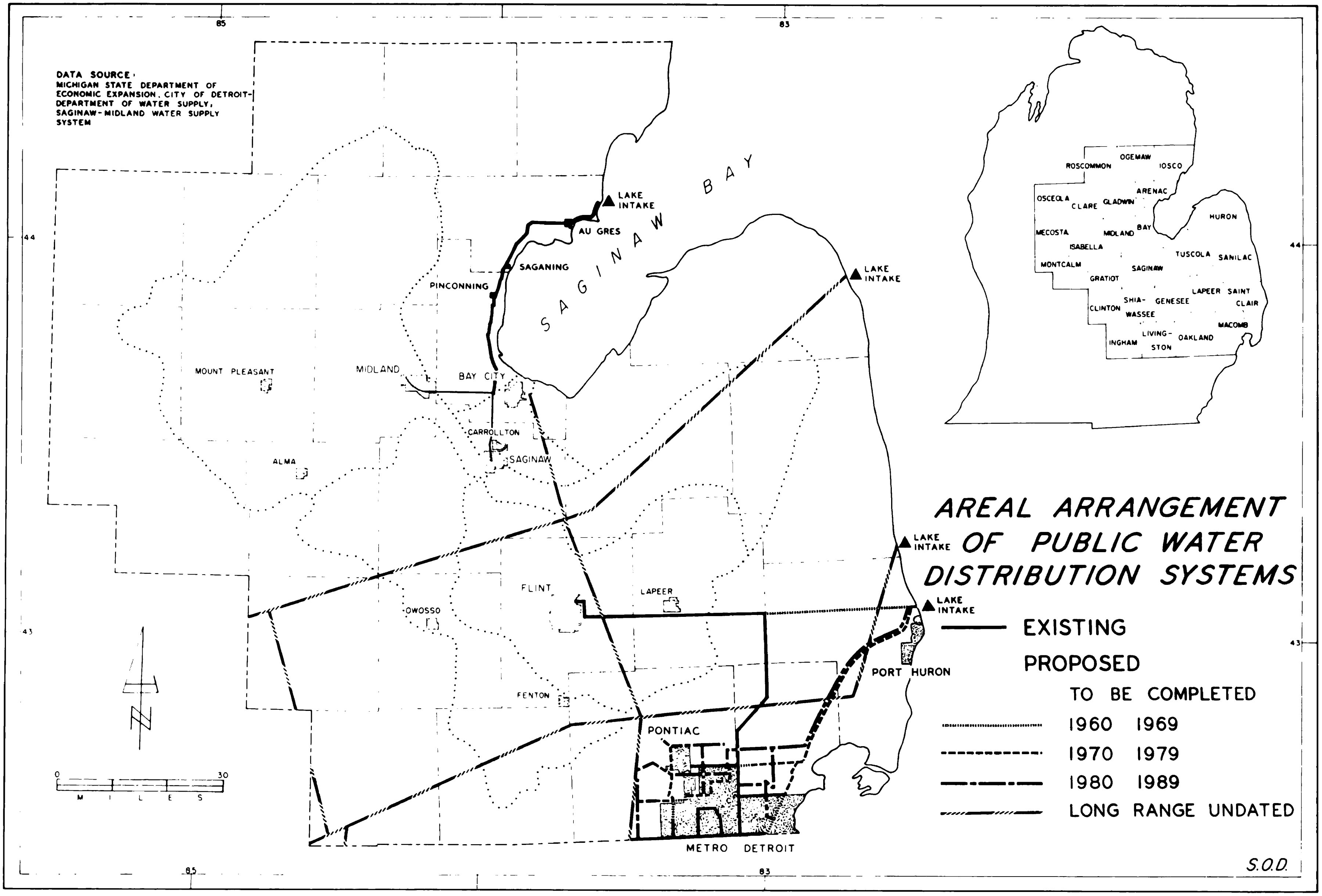
AREAL ARRANGEMENT OF PUBLIC WATER DISTRIBUTION SYSTEMS
EXISTING
PROPOSED
TO BE COMPLETED
1960 1969
1970 1979
1980 1989
LONG RANGE UNDATED
DATA SOURCE:
MICHIGAN STATE DEPARTMENT OF ECONOMIC EXPANSION, CITY OF DETROIT-DEPARTMENT OF WATER SUPPLY, SAGINAW-MIDLAND WATER SUPPLY SYSTEM
SAGINAW BAY
LAKE INTAKE
AU GRES
SAGANING
PINCONNING
MIDLAND
BAY CITY
CARROLLTON
SAGINAW
MOUNT PLEASANT
ALMA
OWOSSO
FLINT
LAPEER
FENTON
PONTIAC
METRO DETROIT
PORT HURON
ROSCOMMON
OGEMAW
IOSCO
OSCEOLA
CLARE
GLADWIN
ARENAC
HURON
MECOSTA
MIDLAND
BAY
ISABELLA
TUSCOLA
SANILAC
MONTCALM
GRATIOT
SAGINAW
LAPEER
SAINT CLAIR
CLINTON
SHIA-WASSEE
GENESEE
MACOMB
INGHAM
LIVING-STON
OAKLAND
MILES
0
30
85
83
44
43
S.O.D.

Fig. 19

water services on a utility basis to communities well beyond its political limits. The source of water supply for all affected communities in the Detroit area is the Great Lakes, with water intake points in Lake St. Clair.

In 1959 the Department of Water Supply, City of Detroit, prepared a comprehensive water development program for the Detroit Metropolitan Area which extended the system northward to Flint in the Flint River tributary of the Saginaw River Basin. (Figure 19.) In 1964 construction began on a fifty-seven mile trunk water main from the North Service Center of the Detroit System at Troy, to the Flint Metropolitan Area, with completion anticipated by 1966.

To adequately supply the Flint-metropolitan area will require the development of new water source intakes and treatment facilities at the point ten miles north of Port Huron of Michigan's east coast by 1968. These intake facilities will use water from Lake Huron through crib and piping five miles offshore, north of the Lake Huron Outflow into the St. Clair River. Water will be treated and pumped inland fifty-five miles to serve the Flint metropolitan area. Water delivered to the Flint area will serve the water demands and will then leave the Flint sewerage collection and treatment system and flow via the Flint and Saginaw Rivers into Saginaw Bay and Lake Huron, thus completing the organizational system using a combination of natural and man-made facilities.

Areal arrangements for public water distribution systems from outside the study area apparently are not complete. The Michigan Department of Economic Expansion projects the need for some eight hundred miles of adueducts to distribute Great Lakes water throughout southern Michigan. Such a system would assure communities a continuing pure water supply and provide one less quality reducing factor in maintaining the purity and water level of our lakes, streams, and natural underground reservoirs.[12]

Mr. Conboy has announced that engineers and economists at the University of Michigan now have such a new system of aqueducts under study.[13] The aqueduct system would cost an estimated one billion dollars in local, state, and federal funds.[14] The general system as conceived by the Department of Economic Expansion is shown as the undated grid of pipelines in Figure 19. Unlike Chicago's controversial plan to flush Lake Michigan water through Illinois to the Mississippi River, the Michigan aqueduct system would not involve the knotty legal problems of water loss and water rights, for nearly all the used water would be returned to the Great Lakes via the

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[12] Barbara Stanton, Water, Water--Everywhere (Detroit, Michigan: Detroit Free Press, March 8, 1964), C-1.

[13] Ibid., p. C-2.

[14] Ibid.

natural tributary systems of the Saginaw River Basin and other affected watersheds.[15]

The areal arrangement of public water supply sources and distribution systems will become, in the near future, one of the significant determinants of Saginaw Basin organization and growth. The functional order of water supply systems, drainage and sewerage systems, and natural streams and lakes will be tied into a basin-wide network of water-related facilities. The final need is a governmental organization equipped to supervise the best use of these natural and man-made facilities and to help the people solve the spatial aspects of water resource problems in the study area.

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[15] John E. Hostetler, The Metropolitan Sanitary District of Greater Chicago and Its Impact on Regional Development (East Lansing, Michigan: Michigan State University, Department of Resource Development, 1961, p. 11.

V

SUMMARY, CONCLUSIONS, AND THE FUTURE

This study has emphasized the areal arrangements of physical and cultural phenomena and the resulting water use patterns and problems in the Saginaw River Basin of Michigan. The interpretation of spatial distributions was thus related to and integrated with the water resource problems within the basin, encompassing both the physical landscape and the cultural patterns of human organization. The geographic method has provided a most effective means to approach a water resource study, to analyze the relationships between relevant elements of the study area in their areal and organizational context, and to identify areas where present and future conflict in water resource utilization can be anticipated.

The multiple roles which man has assigned to water in the process of settling and organizing the Saginaw River Basin are the basic source of problems confronting the proper management of the water resources today. In attempting to resolve conflicts thus created, the residents of the basin have used or developed methods of area organization designed to coordinate uses and areas of the basin environment.

Three separate and distinct forms of organization were recognized to exist in the basin. The first, a physical organization, is that which gradually evolved through the various physical processes. The second, is a governmental organization which was developed by society and superimposed on the physical fabric of the basin for ease in administering community functions. The third type of organization is functional, wherein the people used the tools of governmental organization and the resources of the physical environment to build facilities necessary to attempt solutions for water resource problems and requirements. Physical, governmental, and functional organizations exist and operate simultaneously within the study area.

The spatial aspects of water resource problems in the Saginaw River Basin emphasize the haphazzard nature of past water resource development programs. Multiple decisions at numerous separate locations throughout the basin provided exploitive organizational adjustments which may have appeared immediately beneficial both to individuals and society; however, the imbalances created in the physical, governmental, and organizational framework are now measured in the resource and aesthetic inequities. Such decisions, both individually and collectively, have created the pattern of institutional and organizational features which make up the spatial distribution of water-related facilities and functions within the basin.

Summary

The Saginaw River Basin is the largest of sixty-three watersheds which make up the surface drainage system of the state. The region consists of all or part of twenty-one counties which include the semicircular basin of 4,000,000 acres drained by the Saginaw River and its four tributaries.

Beginning with the first major settlements about 1840, the inhabitants of the Saginaw River Basin have made decisions involving water resources. The original environment of the drainage basin was dominated by swamps and marsh land interspersed with forests of hardwood and pine. The area had been described by the original surveyors as suitable only as a home for Indians and muskrats and hardly worth the cost of surveying. As the agricultural value of these lands became known, however, farmers began digging ditches and installing tile to drain the lower and fertile lands which had poor natural drainage. The area ultimately became one of the rich agricultural regions of the country. The natural association of land, forest and water further enhanced the development of the area, for the timber barons used the stream network for the flotation of logs during the lumber period.

As settlement moved northward in the basin, a system of roads and railroads was constructed which established the necessary transportation and communication lines centered on natural points of organizational convenience dictated by physical resource factors of the basin area. The focal points collectively established a functional heir-archy thriving on the exploitation of land and water and which today are the major urban centers of the study area.

From the beginning of settlement, water problems of flooding, drainage, and water supply were an inherent part of the basin development. The scope of the problem was not, in most cases, restricted to the landholdings of a single individual or governmental jurisdiction. This fact tended to direct water management decisions and developments into the governmental arena. However, local self-interest on the part of various units of government forestalled a comprehensive approach to water resource development.

Organizational Programs

In recent years attempts have been made to organize governmental and functional activities in water resource management with the hopeful end result of improving the physical environment for water resources of the Saginaw Basin. In December, 1946, the Saginaw Valley Regional Planning Commission was organized with the responsibility of working toward a solution of the flood problems in the watershed. Over a period of time, the interests of the Commission were graduallybroadenedto include a number of allied problems such as water supply, drainage, pollution, irrigation and recreation, all under the general concept of multiple use of land and water resources.[1]

In June, 1947, the Saginaw Valley Regional Planning Commission and local interests submitted a request to the Detroit District of U. S. Army Corps of Engineers to investigate flooding and drainage problems in the basin area. The District Engineer recommended that a detailed survey report and plan be prepared for the problem areas of the basin. The resulting report-plan was presented by the Planning Commission on March 15, 1951.[2] As a comprehensive watershed study, it involved local, state and federal units of government and included recommendations on the several aspects of water resource problems with the exception of pollution. Development proposals for facilities throughout the basin in general ignored the subregional divisions of the watershed as outlined in Chapter IV, and herein may lie the significant institutional handicaps which halted the implementation of the comprehensive basin-wide plan.

The basic plan proposed improved drainage and flood protection for basin cities by deepening and widening river channels, constructing dikes, and raising the lengthening bridges. In rural

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[1] W. E. Demison, "A Grass Roots Flood Control Plan" (Reprint), The County Officer (August, 1951), p. 5.

[2] Leslie M. Reid, Dis-Integrated Resource Development, A Case Study of the Saginaw Valley Watershed Development Plan (Ann Arbor, Michigan: University of Michigan, 1962), p. 10.

areas where drainage, water supply, and irrigation were important factors, the plan proposed more than forty miles of river channel improvements on the main tributary system of the study area. These channel improvements would allow construction of additional upstream drain facilities after existing drainage injunctions were removed.[3]

At the juncture of the four main tributaries of the Saginaw River, the critical "Shiawassee Flats," the watershed plan proposed additional channel improvements and one hundred and twenty-five miles of dikes which would divide the flood plain into four large storage basins. A further recommendation of the U. S. Fish and Wildlife Service would include an 11,000-acre combination wildlife refuge and storage basin of great value for recreation.

Despite ample federal financial support, final agreement did not materialize for implementing this complete inter-areal relationship for water resource development. Local interests focused upon local water problems by constructing their own facilities which continue to be reflected in the functional organization of water-related facilities.

Recognition of the geography of the basin by administrators, and more particularly, the characteristics of subregional divisions, may have averted the rejection of the watershed plan by the

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[3] Ibid., p. 11.

majority of local representatives. Subsequent developments in public water distribution systems, as well as artificial drainage systems and facilities, throughout the study area, including some areas outside the basin, would indicate that local interests do acknowledge the interconnection of natural, governmental, and functional organization patterns in the water realm.

Physical Limitations Which Motivate Cooperation

In the final analysis, the precipitation element of the climate has the greatest impact upon water resources. Mean annual precipitation in the study area totals thirty inches; however, evapotranspiration losses of plants, soils, and surface waters are estimated to total twenty inches annually. These losses reduce the potential water supply from thirty inches to a manageable supply of ten inches per year. This manageable supply of runoff respresents the water which can be manipulated by man in various ways within the basin.

Topographic conditions on the flat valley floor provide little opportunity to construct reservoirs to conserve part of the manageable supply of runoff. Since the drainage system of the basin developed from the headwaters to the mouth in reverse of normal erosion patterns, long stretches of the tributary system flow across the valley floor at gradients of less than three feet per mile. Slow gravity flow is not altogether consistent with the drainage needs of the lakebed plain.

In the subterranean realm of the basin, vast quantities of saline water are encroaching upon the underground aquifers which are important sources of water supply. As water demands increase and ground water withdrawal expands, the rate of salt water intrusion will accelerate. The net result is diminishing returns from what was formerly a renewable resource.

Further, the pollution-producing elements of cultural activities are expanding in variety, as well as quantity. These quality-diminishing factors imposed upon the surface waters of the basin are reducing the use capacity of the fixed supply of surface water resources as well as the possible alternatives for multiple use.

The areal and volumetric extent of these physical limitations defy solution on any basis short of considering the water resources of the entire basin. The collective problems of water supply, drainage, saltwater intrusion, and chemical and bacterial pollution loom at a scale requiring cooperative effort on a comprehensive basis throughout the entire basin. Only through cooperation can the water resources of the basin be developed for the benefit of the basin community.

Conclusions

Since the elements of the triumvirate of organization are at different stages of development in the study area, it cannot be clearly stated that the present pattern of organization will lead to ultimate resolution of the problem aspects of water resource management. The unity of the basin is the result of functional structure created during the several stages of sequent occupance of the land and utilization of water resources. Solving the inherent problems caused by that occupancy and use requires that water-related functional facilities be provided at many locations over time.

Solution of water problems is an excellent example of the need to look at all impinging physical and cultural factors. The spatial approach, emphasizing areal or regional differences--physical character and cultural organization, is workable in identifying problems and suggesting certain solutions to them.

Basic conclusions regarding the spatial aspects of water resource problems and organizational developments in the Saginaw River Basin, can be summarized as follows:

A. The three forms of organization which exist in the basin as physical, governmental, and functional patterns, must be recognized as they relate to the sub-regional divisions of the watershed in any comprehensive resolution of the conflicts resulting from the multiple use of water resources.

B. The functional organization made possible by improved techniques of water processing and distribution has enabled the creation of facilities at four basic levels to supply the water needs of the basin. These include the source of supply, processing, distribution, and elimination of waste water.

C. The complex network of governmental units results in a jurisdictional morass burdened by invisible boundaries and stands as possibly the greatest single barrier to successful water management in the basin.

D. Cultural modifications of the landscape may increase the use capacity of available water resources assuming the multiple use concept is fully applied in management practices. The probability of a water deficit in the foreseeable future points up the need for a close look at the water resource management programs now operating in the basin area.

E. Drainage of the land was the key to the settlement of the basin initially, while storage of drainage water during periods of surplus may be an important key to the basin's continued development.

F. The use of water for irrigation purposes will increase and farm operators will become more interested in storage facilities for surplus water available during the spring season to insure adequate supplies.

Despite communal action to solve many water problems, there are indications that reorganization of the governmental framework may be necessary before full utilization of the water resources can be accomplished and identified areas of future conflict eliminated.

Future Outlook

Estimates of water resource needs for the study area in the future indicate that demands will exceed the supply available within the basin before 1980.[4] The probability of a water deficiency in the foreseeable future points up the need for exploring multiple use management of available resources. As has been shown, many problems can be alleviated through modification by man. Individual local community actions at numerous locations within the basin have adequately solved water problems on an isolated basis, but not the basin wide problems. The spatial aspects of basin water problems such as water supply,

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[4] D. R. Woodward, Availability of Water in the United States with Special Reference to Industrial Needs by 1980 (Washington, D. C.: Industrial College of the Armed Forces, 1957), p. 49; also note Table 2, p. 27.

drainage, saltwater intrusion, and chemical and bacterial pollution, demand a coordinated approach toward control and development to evolve satisfactory solutions. This circumstance would indicate that a higher order of coordination and agreement must be developed among the physical, governmental and functional organizational elements.

Recent action by the Michigan State Legislature may have provided the key to higher organization. On May 28, 1964, Governor George Romney signed into law the "local river management act" otherwise known as Act. No. 253 of the Public Acts of 1964, State of Michigan.[5] The local river management act was adopted to promote cooperation among local governments in planning and carrying out a coordinated water management program in the watershed they share.[6] The Michigan State Water Resources Commission is empowered to establish a watershed council upon receipt of a petition from three or more local governments lying wholly or partially within a defined watershed.[7] A formally established watershed council is composed of representatives of local governments appointed with respect to population or area contained within the watershed.[8]

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[5] 72nd Legislature, State of Michigan, Act No. 253, Public Acts of 1964, Approved May 28, 1964. M.S.A. 11.431-11.450.

[6] _Ibid._, Preamble, Sec. i.

[7] _Ibid._, Sec. 3 (1).

[8] _Ibid._, Sec. 6, a-i.

The council may study the water resources of the watershed as to uses, quality, reliability, and emerging water proglems, as a basis for formulating appropriate public policies and programs necessary to maintain adequate water resources for the watershed area.[9]

An organizational arrangement of this type is ideally suited for the problems of the Saginaw River Basin. Water problems extending beyond the jurisdictional boundaries of local governmental units could be assigned to a basin-wide watershed council for study and active implementation of resulting recommendations. The river management act further provides for the creation of a management district as an agency for acquisition, construction, operation and financing of water storage, sanitation, and river control facilities necessary for water resource management.[10] The management district could overcome the reluctance of many local units within the Saginaw River Basin concerning financial obligations incurred for water resource facilities that do not directly benefit their jurisdiction. Boundaries of individual management districts within the watershed could be drawn to acknowledge local water problems within the framework of comprehensive basin-wide resource planing.

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[9] Ibid., Sec. 6, a-i.

[10] Ibid., Sec. 7.

Before a management district is established, the Michigan Water Resources Commission must show that the following conditions exist:

> (1) That the proposal (district) is consistent with the public interest in the conservation, development and use of water resources, and the proposed district is geographically suitable to effectuation of the district purposes. (Italics mine.)
>
> (2) That the establishment and operation of the district will not unreasonably impair the interests of the public riparians in lands or waters or the beneficial public use thereof, and will not endanger public health or safety.[11]

As further assurance that the spatial aspects of water problems within a watershed are fully acknowledged, the plans of the river management district must be coordinated with the plans of adjacent river basins and with any comprehensive regional management programs.[12]

This legislative enactment by specific provision asknowledges the geographic method as valuable in studying water resource problems where areal relationships are extremely important in recognizing the distribution and organizational patterns as they relate to the resources of a watershed. Occupants of the Saginaw River Basin face, in the near future, a crisis in water resources which will demand their collective action and participation. Greater attention must be focused upon subregional divisions of the watershed within the areal

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[11] Ibid., Sec. 7, (1) & (2).

[12] Act No. 253, Public Acts of 1964, Sec. 7, Acticle (2) par. 3.

organization of the entire basin, as well as the areal organization of water-related features and facilities representing the accumulative water development decisions of over one hundred and thirty years.

APPENDIX A

Public Water Supplies in the Saginaw River Basin[1]

The following symbols are identified to assist in using this table.

M	- city or village	D	- district
T	- township	S	- state
P	- private	U.S.	- federal
C	- county		

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[1] Data for this Appendix is a combination of field data accumulated during traverses of the study area, plus data contributed by the Michigan Department of Health from Engineering Bulletin No. 4, Lansing 4, Michigan.

LOCATION	POPULATION	OWNERSHIP	SOURCE	TREATMENT: STD. FILTRATION	TREATMENT: LIME SOFTENING	TREATMENT: ZEOLITE SOFTENING	TREATMENT: IRON REMOVAL	TREATMENT: CHLORINATION	TREATMENT: FLOURIDATION	STORAGE CAPACITY IN THOUSANDS OF GALLONS: TREATED WATER AT PLANT	STORAGE CAPACITY IN THOUSANDS OF GALLONS: GROUND LEVEL ON SYSTEM	STORAGE CAPACITY IN THOUSANDS OF GALLONS: ELEVATED
ARENAC COUNTY												
Au Gres	584		Lk. Huron-Saginaw-Midland Pipeline, Diatomite Filtration									
Standish	1,214	M	Wells in rock 120' deep									100
Cedar St. & E.W. City Limits, (3 wells)												
Well 1												
Well 3												
Whitestone Point		M	Lk. Huron 60" intake 10,000' long 51' deep					X				
Saginaw-Midland Water Authority											5,000	
Municipalities served:											1,000	
Arenac County												
Au Gres												
Bay City												
Auburn												
Bangor Monitor Metro. Dist.												
Frankenlust Twp., Tri County College.												
Kawkawlin Metro. Dist.												
Linwood Metro. Dist.												
Monitor Twp. E. Midland Water Assoc. Gotez Waterline												
Midland County												
Midland												
Saginaw County												
Carrollton Township												
Saginaw												
Saginaw Township												
BAY COUNTY												
Auburn	1,497	M	Lk. Huron-Saginaw-Midland Pipeline									
Bangor Monitor Metro. Dist.	3,600	D	Lk. Huron-Saginaw-Midland Pipeline									
Bangor Township	1,600	T	Water from Bay City									
Bay City	53,604	M	Saginaw Bay 4,000' 48" intake 10' deep 18,000' 48" intake 17' deep		X					5,000		2,100
Essexville	4,590	M	Water from Bay City									
Frankenlust Twp., Tri Co. College		D	Lk. Huron-Saginaw-Midland Pipeline									200
Kawkawlin Metro. Dist.	700	D	Lk. Huron-Saginaw-Midland Pipeline									
Linwood Metro. Dist.	360	D	Lk. Huron-Saginaw-Midland Pipeline									
Monitor Township,												
East Midland Water Association	180	P	Lk. Huron-Saginaw-Midland Pipeline									
Goetz Waterline Association	380	P	Lk. Huron-Saginaw-Midland Pipeline									
Pinconning	1,329	M	Saginaw Bay 5,400' 10" intake 7 1/2' deep	X						55		75
CLARE COUNTY												
Clare	2,442	M	Wells in drift 60' to 125' deep									75
Maple & Third Streets												
Wheaton Street												
Third Street & Ann Arbor RR												
Farwell	737	M	Wells in drift 229' deep									56
Village Park (2 wells)												
Harrison	1,072	M	Wells in drift 225' deep									85
Lake & Beech Streets (2 wells)												

LOCATION	POPULATION	OWNERSHIP	SOURCE	TREATMENT: STD. FILTRATION	LIME SOFTENING	ZEOLITE SOFTENING	IRON REMOVAL	CHLORINATION	FLOURIDATION	STORAGE CAPACITY IN THOUSANDS OF GALLONS: TREATED WATER AT PLANT	GROUND LEVEL ON SYSTEM	ELEVATED
GENESEE COUNTY												
Burton Township	29,700	T	Well in rock 257' deep-drift 168'-169'									250
Carmen Street & Deming Road												
Carem Street & Camdem Street												
Friel Ave. & Morrison Street												
Schumacher & Saginaw Streets												
Clio	2,212	M	Wells in rock 145' to [illegible] deep, drift 141'									100
Mill Street												
New & Hughes Streets (Well No. 2)												
New & Hughes Streets (Well No.50)												
Cherry & Butler Streets												
Washington & Jefferson Streets												
Davison	3,761	M	Wells in rock 210' to [illegible] deep									60
Mill & State Streets												
Lexington & Davidson Streets												
Greenway Drive & Surfway Lane												
Aloha Street & M-21												
Fenton	6,142	M	Well in rock [illegible] deep, drift 60' to 70'					X				1,063
Waterworks Park (Well No. 2)												
North & Spunner Roads												
Caroline Street & Pontchartrain Blvd.												
Fenton Township	280	T	Wells in drift 73' deep									3.0 pn
Lake Fenton Orchards Subdivision												
S. Long Lake Rd. Appletree Lane												
Flint	196,000	M	Flint River/Detroit Water Authority		X					13,000	10,000	2,000
Flint Township												
Mandeville Park Subdivision	300	T	Well in rock 160' to 167' deep									7.5 pn
Renault & Riviera Dr.'s (2 wells)												
Flushing	3,761	M	Wells in drift 2[illegible]' to 61' deep									654
Sunny Side Drive												
Dalton Well												
Kelly Road & Elm Road												
Gaines Township												
Winchester Village, Mich. Consolidated Service Company	870	F	Wells in drift 60' to 65' deep				X	X				300
Vernon Twp. Shiawassee Co.(2 wells)												
Genesee Township & Mt. Morris Twp.												
Beecher Metropolitan District	17,000	D	Wells in rock 350' to 431' deep, drift 98', tp 124' deep					X				720
Louis Avenue & Saginaw Road												
Clark & Alfred Streets												
Harvard Avenue & Harvard Street												
DuPont Street & Princeton Street												
Penwood & Barch Road												
Grand Blanc	1,565	M	Wells in rock 287' to 306' deep									
Saginaw Street												
Bush Avenue												
Grand Blanc Township												
National Estates Subdivision	640	T	Wells in rock 267' to 300' deep									14.5 pn
Westdale & Northdak Drive												
Springdale Boulevard												
South Hampton Subdivision (South Hampton Water Board)	120	P	Wells 200' deep									pn
Nichols Street & Saginaw Road, (2 Wells)												

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Wildwood Subdivision--Revere &												
Rollins Streets	320	F	Well in rock 230' deep									1.0 pn
Linden	1,146	M	Well in rock 96' deep									50
Mill & Bridge Street												
Montrose	1,1[illegible]	M	Wells in drift 67' to 77' deep									50
Washington & Ash Street												
Saginaw Street & Coke Drive						X	X					50
Mt. Morris	3,484	M	Wells in drift 60' to 82' deep									
Saginaw & Hughes Streets (2 wells)												
Wilson & Benson Avenues												
Otisville	701	M	Well in rock 415' deep									50
East Street												
GLADWIN COUNTY												
Beaverton	926	M	Wells in drift 93' deep									50
Brown Street & Elevated Tank												
Gladwin	2,226	M	Wells in rock 470' to 575' deep								82	75
Cedar St. Pumping Station (2 wells)												
GRATIOT COUNTY												
Alma	8,978	M	Wells in drift 82' to 164' deep. Standby well in rock 550' deep								1,000	200
Lincoln South of Mechanic												
Center & Pine												
Superior Street Pumping Station												
Hasting & Court												
Elizabeth & Park												
N. of Pine River at W. City Limits												
Ashley	448	M	Wells in rock 325' to 330' deep			X		X				75
Oak Street & Ann Arbor RR												
Village Park												
Breckenridge	1,131	M	Wells in rock 393' to 402' deep			X	X					60
Saginaw & Second												
Summit & Pine												
Ithaca	2,611	M	Wells in drift 126' to 175' deep									290
Woodland Park												
McNabb Well												
Woodland Park-North												
Perrinton	424	M	Wells in drift 90' deep									9.8 pn
Arnold & South Streets (2 wells)												
St. Louis	3,808	M	Wells in drift 213' to 223' deep									
Mill Street Light Plant (3 wells)												
East Well												
West Well												
South Well												
City Garage												
City Park												
HURON COUNTY												
Bad Axe	2,998	M	Wells in rock 258' to 270' deep									85 STP.
City Park (2 wells)												
Caseville	659	M	Wells in rock 226' to 231' deep									60 pn
County Park												
Clay & Ash Street												
Elkton	1,014	M	Wells in rock 175' to 200' deep									pn
Mullin Street												
S. Main Street												
E. Mill Street												
Harbor Beach	2,282	M	Lk.Huron 2,900' of 20" intake 16' deep	X						460		100

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Huron Township												
Lighthouse Park (Huron Co. Rd. Commission)	120	C	Lk. Huron 300' of 4" intake 7' deep	X						10		3 pn
Owendale	298	M	Wells in rock 200' to 225' deep									50
Seventh & Mill Street												
Main at Third Street												
Pigeon	1,191	M	Wells in rock 178' to 187' deep									60
E. Michigan Avenue												
S. Main & Park Well												
School												
Pointe Aux Barques Township												
Pointe Aux Barques Land Co.	200	P	Lake Huron 1,000' of 6" intake 8' deep					X				8
Port Austin	706	M	Well in rock 150' deep									
State & Line Street												
Port Hope	349	M	Lk. Huron 1,365' of 12" intake 10' deep	X						62		1.5 pn
Sebewaing	2,026	M	Wells in rock 301' [illegible]									75
East Main Street												
Sharpsteen Street												
Ubly	819	M	Wells in rock [illegible]0' to 175' deep									75
Main & Queen Streets												
Main Street Park												
ISABELLA COUNTY												
Mt. Pleasant	14,875	M	Wells in drift 75' to 165' deep						X			500
Broadway Street & Mill Race												
Douglas & Gaylord Street												
Brondstetter												
O'Conner												
Leaton & Fessenden												
Mt. Pleasant State Home & Training School	1,500	S	Water from City of Mt. Pleasant									250
Shepherd	1,293	M	Well in drift 151' deep									35
N. Third Street												
LAPEER COUNTY												
Almont	1,035	M	Wells in drift & rock 40' to 183' [illegible]									50
Clair Street & Branch St. (Well No. 1)												
Clair Street & Branch St. (Well No. 3)												
Church Street & North Street												
Clifford	330	M	Well in rock 400' deep									50
Columbiavilla	789	M	Wells in rock 280' to 300' deep									75
4718 First Street												
4842 Pine Street												
Dryden	476	M	Wells in drift 96' deep									pn
Almont Metamora Rd. (East)												
Imlay City	1,654	M	Wells in drift 44' deep									38
Fourth Street & Black Corners Rd.												
Lapeer	9,020	M	Wells in rock 200' deep									850
Monroe Street												
Lapeer Home & Training School		S	Wells in rock									
North Branch	832	M	Wells in rock 250' deep									40
Jefferson & Banker												
LIVINGSTON COUNTY												
Brighton	2,282	M	Wells in drift 94' to 97' deep					X				100
Pierce Street (2 Wells)												

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Brighton Township												
Brighton County Club Annex Subdivision	450	T	Wells in drift 105' deep									2.0 pn
Ethel & Clara Jean Blvds. (2 Wells)												
Fowlerville	1,674	M	Wells in rock 225' deep									100
Ann & Powers Streets (2 Wells)												
Green Oak Township												
Boys Vocational School	[illegible]	S	Wells in drift 81' to 90' deep				X	X				100
Saxony & Willmor Subdivision	1,000	T	Wells in drift 116' to 126' deep									4.3 pn
Stephens Dr. & Beth Ave. (2 Wells)												
Stephens Dr. & Shirley Ct.												
Howell	4,861	M	Wells in drift 92' to 94' deep, rock 425'			X	X	X	X			450
Michigan Ave. & PM RR (3 Wells)												
Norton Road												
Marion Township												
Howell State Sanitorium	550	S	Well in rock 172' to 352' deep									50
Well No. 1												
Well No. 2												
Well No. 3												
MECOSTA COUNTY												
Big Rapids	8,686	M	Muskegon River 900' of 18" intake	X					X		190	400
MIDLAND COUNTY												
Coleman												
Jackson & 6th Streets (Well No. 1)												
Jackson & 6th Streets (Well No. 2)												
Midland	[illegible],779	M	Lake Huron: 10,000' of 66" intake, 51' deep at Whitestone Point in Arenac Co.	X					X	7,600		128
MONTCALM COUNTY												
Carson City	1,291	M					X	X				100
Olive St. & Division St. (2 Wells)												
Edmore	1,234	M	Wells in drift 90' to 160' deep									200
Gilson Street												
Pine Street												
First Street												
Greenville	7,440	M	Wells in drift 40' to 100' deep									500
Clay & Charles												
N. of Fairplains, W. of Elm Well # 5, 6, 7, 8, 9, & 10.												
Howard City	1,004	M	Wells in drift 54' to 97'					X				100
White & Rathburn (Stand by)												
621 Cedar Street (2 Wells)												
Lakeview	[illegible]	M	Wells in drift 89' and 109' deep					X				75
Lincoln Ave. (2 Wells)												
Sheridan	606	M	Wells in drift 120' to 150' deep					X	X			50
Main & Pleasant Street												
Jasper Ave. & General Sheridan Rd.												
Stanton	1,139	M	Well in drift 131' deep									2 pn
Mill Street & Lake Street												
OAKLAND COUNTY												
Avon Township												
Avon Twp. Water District No. 1	725	T	Wells in drift 167' deep									100

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Wabash St., Hickory Lawn(2 Wells)												
Bloomer Park Subdivision	240	P	Wells in drift 154' deep									1.2 pn
Sunnydale Gardens Subdivision	375	P	Wells in drift 164' deep									3 pn
University Hills Subdivision	1,250	T	Wells in drift 129' to 131' deep									4.3 pn
Berkly	23,275	M	Water from Detroit through SOCWA									
Beverly Hills	8,633	M	" " " "									500
Birmingham	25,525	M	" " " "									500
Bloomfield Hills												300
Cranbrook Institute		P	Wells in drift				X					
Cranbrook Manor Development		P	Wells in drift 175' deep									2 pn
Bloomfield Township												
Balmora Orchards Subdivision	800	T	Wells in drift 239' to 247' deep									4.3 pn
Birmingham Farms Subdivision	600	T	Wells in drift 130' deep									125
Bloomfield Twp. Water Dist. No.1	4,500	T	Wells in drift 197' to 221' deep					X			1,000	100
Chappel Hill Estates Subdivision	700	T	Wells in drift 233' deep									4.3 pn
Charing Cross Estates Subdivision	450	T	Wells in drift 133' to 145' deep									4.3 pn
Colberry Park Subdivision	760	T	Wells in drift 175' to 210' deep									4.3 pn
Eastover Estates Subdivision	90	T	Wells in drift 57' to 163' deep									4.3 pn
Foxcroft Subdivision	900	P										
Franklin Woods Manor Subdivision	350	P	Wells in drift 160' deep									4.3 pn
Hickory Heights Subdivision	1,390	T	Wells in drift 77' to 119' deep					X				8.6 pn
Hugo Hills Subdivision	380	T	Wells in drift 60' deep									4 pn
Knob Hills Subdivision	1,200	T	Wells in drift 217' deep									43
Morningside Heights Subdivision	200	P	Wells in drift 191' deep									4.3 pn
Oakland Hills Country Club Subdivision	100	P	Wells in drift									pn
Riverside Meadows Subdivision		P	Wells in drift 105' deep									3.5 pn
South Bloomfield Highland Subdivision	1,040	P	Wells in drift 185' to 227' deep									8.5 pn
Wing Lake Estates Subdivision	600	P	Wells in drift									3.9
Clawson	14,795	M	Water from Detroit through SOCWA									
Commerce Township												
Golf Manor Subdivision	1,060	C	Wells in drift 119' to 128' deep									4.3 pn
Hill'n Dale Welch Park Sub.	950	C	Wells in drift 140' deep									2.5 pn
Mt. Royal Subdivision	1,100	C	Wells in drift 112' to 125' deep									5
Farmington	6,880	M	Water from Detroit									240
Farmington Township												
Briar Hill Subdivision	650	C	Wells in drift 230' deep									4.3 pn
Farmington Township (Section 36)	2,900	T	Water from Detroit									
Franklin Hills County Club Subdivision	100	P	Wells in drift									
Franklin Knolls Subdivision	640	P	Wells in drift 102' to 160' deep									4.3 pn
Grand River Homes Subdivision	300	P	Wells in drift 70' deep									
Guy E. Pooley Subdivision	350	C	Wells in drift 186' deep									4.3 pn
Kendallwood Subdivision	3,300	C	Wells in drift 134' to 262' deep									150
Kimberly Subdivision	425	C	Wells in drift 93' deep									4.3 pn
Old Farm Coloney Subdivision	325	P	Wells in drift 146' deep									7.5 pn
Old Homestead Subdivision	865	C	Wells in drift 295' deep									5 pn
Villa-Capri Subdivision	1,275	C	Wells in drift 92' to 100 deep									105
West Brooke Manor Subdivision		C	Connected to Kendallwood Subdivision									
Woodbine Subdivision	580	P	Well in drift 108' deep								3	
Woodbrook Subdivision	450	C	Well in drift 199' to 211' deep									4.3 pn
Ferndale	31,347	M	Water from Detroit								3,000	
Hazel Park	25,631	M	Water from Detroit									
Holly	4,220	M					X					100
Broad Street Pumping Station			Well in drift 105' deep									

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Marion Drive			Well in rock 210' deep									
Huntington Woods	8,746	M	Water from Detroit through SOCWA									
Independence Township												
Clarkston Gardens Subdivision	1,420	T	Wells in drift 72' to 162' deep									4.3 pn
Goodrich Farms Subdivision	410	T	Wells in drift 204' deep									4.3 pn
Pelton Heights Subdivision	680	T	Wells in drift 295' deep									5 pn
Lake Orion	2,698	M	Wells in drift 95' to 143' deep									60
Lathrop Village	3,556	M	Water from Detroit through SOCWA									
Madison Heights	33,343	M	Water from Detroit									
Sarasonn Subdivision	75	P	Wells in drift 168' deep									
Michigan State University-Oakland		C	Wells in drift 115' deep									4.3 pn
Milford	4,323	M	Wells in drift 118' deep									350 STP
Novi Township												
Orchard Hills Subdivision	430	T	Wells in drift 70' to 95' deep									
Willowbrook Estates Subdivision	1,460	P	Wells in drift 36' to 55' deep									12.9 pn
OAKLAND COUNTY												
Oakland County Dept. of Public Works												
Oakland County Infirmary												
Oakland County T.B. Sanitorium												
Oak Park	36,632	M	Water from Detroit								4,000	25
Orion Township												
Judah Lake Estates Subdivision	770	T	Wells in drift 110' to 113' deep									4.3 pn
Oxford	2,357	M	Wells in drift 68' to 73' deep									60
Pleasant Ridge	3,807	M	Water from Detroit through SOCWA									
Pontiac	82,233	M	23 Wells in drift 102' to 281'					X			2,000	1,000
Pontiac State Hospital		S	Well in drift 135' deep					X				
Pontiac Township												
Auburn Development Co. Sub.	105	P	Well in drift 219' deep									3 pn
Bloomfield Orchards Subdivision	1,500	T	Wells in drift 174' to 292' deep									10 pn
Chandler Estate Subdivision	400	T	Wells in drift 185' to 138' deep									4.3 pn
Walton Heights Manor Subdivision	330	P	Wells in drift 138' to 166' deep									8.6 pn
Rochester	5,630	M	Wells in drift 65' to 120' deep									
Royal Oak	80,612	M	Water from Detroit through SOCWA									
Royal Oak Township	8,000	T	Water from Detroit								10,000	1,000
SE Oakland County Water Authority	175,000	M	Water from Detroit								7,500	1,000
Berkley											2,500	1,000
Beverly Hills												1,500
Birmingham												
Clawson												
Huntington Woods												
Lathrup Village												
Pleasant Village												
Pleasant Ridge												
Royal Oak												
Southfield												
Southfield	21,700	M	Water from Detroit through SOCWA									
Edgewood Hills Subdivision	150	P	Well in drift 85 deep									1 pn
Oakwood Hills Subdivision	185	M	Wells in drift 94' deep									2.1 pn
Rivercrest Subdivision	175	M	Wells in drift 164' deep									1.9 pn
The Ravines Subdivision	500	M	Wells in drift 96' deep									3.75 pn
San Marino Villas	500	P	Wells in drift 63' deep									4.3 pn
South Lyon	1,753	M	Wells in drift 104' to 118' deep									50
Sylvan Lake	2,004	M	Wells in drift -24' to 240' deep									

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Troy	19,058	M	Wells in drift 112' to 135' deep									50
Meadow Lane Subdivision	90	P	Well in drift 69' deep									4.5 pn
Pine Hill Subdivision	355	P	Wells in drift 63' deep									2.9 pn
Walled Lake												
Carole Acres Subdivision	280	M	Wells in drift 206' deep									4 pn
Tri- A Subdivision	400	M	Wells in drift 160' to 181' deep									4 pn
Waterford Township												
Garfield Home Subdivision	160	T	Wells in drift 169' deep									4.3 pn
Highland Estates Subdivision	1,200	T	Wells in drift 54' to 63' deep									6.7 pn
Holiday Farms Subdivision	665	T	Wells in drift 40' deep									5.0 pn
Jayno Heights Subdivision	725	T	Wells in drift 78' deep									4.3 pn
Lake Angelus Golfview Estates Subdivision	370	T	Wells in drift 86' to 93' deep									4.3 pn
Lake Oakland Heights Subdivision	1,200		Wells in drift 52' to 60' deep									5.0 pn
Lotus Lake Subdivision	1,175	T	Wells in drift 162' to 167' deep									4.3 pn
Pleasant Lake Woods Subdivision	340	T	Wells in drift 56' to 64' deep									4.3 pn
Silver Lake Estates Subdivision	760	T	Wells in drift 177' to 179' deep									4.3 pn
Waterford Twp. Water Dist. No. 1	6,000	T	Wells in drift									50
Watkins Hills Subdivision	604	T	Wells in drift									3.5 pn
West Bloomfield Township												
Bloomfield Farms Subdivision	540	P	Wells in drift 129' to 148' deep									4.3 pn
Bloomfield Knolls Subdivision	360	T	Wells in drift 118' to 130' deep									4.3 pn
Brookfield Highlands Subdivision	570	T	Wells in drift 140' deep									4.3 pn
Cass Lakeside Subdivision	540	P	Wells in drift 80' deep									4.3 pn
Franklin Knolls Subdivision No. 3	770	P	Wells in drift 105' to 175' deep									4.3 pn
Franklin Valley Subdivision	825	T	Wells in drift 220' deep									4.3 pn
Hammond Lake Estates Subdivision	350	C	Wells in drift 108' to 118' deep									4.3 pn
Knollwood Heights Subdivision	355	T	Wells in drift 72' deep									4.3 pn
New England Estates Subdivision	300	T	Wells in drift 205' deep									4.3 pn
Pine Center Subdivision	135	C	Wells in drift 116' to 202' deep									1.8 pn
Pine Lake Subdivision	200	C	Wells in drift 195' deep									5.0 pn
Shorewood Hills Subdivision	365	T	Wells in drift 134' deep									4.3 pn
Westacres Subdivision	500	C	Wells in drift 84' to 130' deep									75
West Bloomfield Hill Subdivision	570	T	Wells in drift 70' to 74' deep									4.3 pn
Wixom												
Palmer Lake Estates Subdivision	350	C	Wells in drift 64' deep									6 pn
Wolverine Lake												
Wolverine Lake Heights Sub.	290	M	Wells in drift 254' to 257' deep									2.5 pn
OGEMAW COUNTY												
West Branch	2,025	M	Wells in drift 219' deep									100
Fourth St. at Creek (2 Wells)												
OSCEOLA COUNTY												
Evart	1,775	M	Wells in drift 51' to 60' deep									10 pn
Fifth St. Well Field (5 Wells)												
Marion	898	M	Wells in drift 93' to 156' deep									40
Fifth St. at RR												
Morton St. at RR												
Reed City												
Slosson St. at RR												
Franklin and Higbee Streets												
Franklin and State Streets												
Church and Savidge Street												
ROSCOMMON COUNTY												
Roscommon	867	M	Wells in drift 42' to 103' deep								48	30

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Main Street Reservoir												
George Street												
SAGINAW COUNTY												
Bridgeport Township	4,000	T	Wells in rock 116' to 140' deep, drift 63' to 71 deep									350
Fort Road Well Field (8 Wells)												
Well No. 1												
Well No. 7												
Curtis Road Well Field (5 Wells)							X	X				
Doerr & Sheidan Well No. 14												
Buena Vista Township	11,610	T	Water from City of Saginaw									
Carrollton Township	6,718	T	Lake Huron Saginaw-Midland Pipeline									150
Chesaning	2,770	M	Wells in rock 400' deep									75
Front Street												
Neitling & Willie Street												
Frankenmuth	1,728	M	Cass River 50' 10" intake 8' deep		X				X	270		50
Richland Township												
Hemlock	900	T	Wells in drift 171' deep									40
W. Saginaw Street												
W. Sproll Street												
Saginaw	98,265	M	Lk. Huron 10,000' of 66" intake 51' deep at Whitestone Point in Arenac County		X					9,200		
Saginaw Township	15,619	T	Lake Huron, Saginaw-Midland Pipeline							3,000		325
St. Charles	1,959	M	Infiltration lines & wells in rock 235' deep									70
City Park												
Brant Road W. M-47												
M-47 at Brant Road												
Spaulding-Bridgeport Metropolitan District	900	D	Water from City of Saginaw									
Tittabawassee Township												
Freeland	850	P	Wells in drift 115' to 139' deep									14 pn
E. Washington Ave. (3 Wells)												
Thomas Township	4,631	T	Wells in drift 145' deep									300
Frost Road												
N. Graham Rd. at Dice Rd.												
Zilwaukee Township	1,874	T	Wells in rock 105' to 171' deep									50
Tittabawassee Rd. Well 1												
Cornell Street												
Veney Rd. Well No. 3												
Schust Road												
Tittabawassee Rd. Well No. 5												
Veney Road Well No. 6												
SANILAC COUNTY												
Brown City	933	M	Wells in rock 330' deep									50
Vine & Merrill Streets (2 Wells)												
Carsonville	502	M	Wells in rock 150' deep								60	30 pn
Chandler & High Streets (2 Wells)												
Croswell	1,817	M	Wells in drift 82' to 96' deep				X					100
L. Sandborn Plant (2 Wells)												
Deckerville	798	M	Wells in drift 21' deep					X				40
Downington Road (2 Wells)												
Lexington	722	M	Wells in drift 31' deep; rock 139' deep									50
Simons Street Elevated Tank (2 Wells)												

LOCATION	POPULATION	OWNERSHIP	SOURCE	TREATMENT: STD. FILTRATION	TREATMENT: LIME SOFTENING	TREATMENT: ZEOLITE SOFTENING	TREATMENT: IRON REMOVAL	TREATMENT: CHLORINATION	TREATMENT: FLOURIDATION	STORAGE CAPACITY IN THOUSANDS OF GALLONS: TREATED WATER AT PLANT	STORAGE CAPACITY IN THOUSANDS OF GALLONS: GROUND LEVEL ON SYSTEM	STORAGE CAPACITY IN THOUSANDS OF GALLONS: ELEVATED
Well No. [illegible]												
Well No. [illegible]												
Marlette	1,[illegible]	M	Wells in rock 17[illegible]' and 300' deep								135	
[illegible] & Prospect St. (2 Wells)												
South Well												
North Well												
Minden City	[illegible]	M	Wells in rock 1[illegible]' deep									15
[illegible] & [illegible] Street (. Wells)												
Peck	[illegible]	M	Wells in r[illegible] 170' to [illegible]' deep									20
[illegible] Street [illegible] River [illegible]												
[illegible] & [illegible] Street												
Port Sanilac	302	M	Wells in drift 68' to 7[illegible]' deep									5 pn
[illegible] & Ri[illegible] Streets (2 Wells)												
Sandusky	[illegible]	M	Wells in rock 14[illegible]' to [illegible]' deep									50
Argyle Street (3 Wells)												
Well No. 1												
Well No. 2												
Well No. 3												
Courthouse												
SHIAWASSEE COUNTY												
Bancroft	[illegible]	M	Wells in drift 67' deep; rock 167' to [illegible]' deep									33
Elevated Tank (2 Wells)												
Grand River												
Byron	[illegible]	M	Well in rock 17[illegible]' deep									80
Warren Street												
Corunna	2,764	M										66
Hospital												
Cherry & [illegible] Streets												
Durand	[illegible]	M	Wells in drift 55' deep									128
Iron Removal Plant (. Wells)												
New Lothrop	[illegible]	P	Wells in rock 85' to 160' deep									10 pn
[illegible] Street at [illegible] Creek (3 Wells)												
Owosso	17,[illegible]	M	Wells in rock 220' to 260' drift 82' to [illegible]'				X	X		3,500		1.250 STP
Iron Removal Plant Site ([illegible] Wells)												
Perry	1,37[illegible]	M	Wells in drift 70' deep									60
[illegible] & Perry R[illegible] (. Wells)												
TUSCOLA COUNTY												
Akron	5[illegible]	M	Wells in rock 283' to 293' deep									
Irwin St. & Hill St. Extension												
[illegible] Street												
Caro	[illegible]	M	Wells in drift 120' to 166' rock 226' to 2[illegible]'									275
[illegible] Oakland St. Well No.1												
[illegible] Oakland St. Well No.2												
[illegible]												
[illegible] Fl. & [illegible]												
Cass City	1,945	M	Wells in rock			X						60
City Park (Wells)												
[illegible]	375	M	Wells in rock 85' to 185' deep									
[illegible] & First Streets (3 Wells)												
In [illegible] Fields Township												

LOCATION	POPULATION	OWNERSHIP	SOURCE	TREATMENT: STD. FILTRATION	TREATMENT: LIME SOFTENING	TREATMENT: ZEOLITE SOFTENING	TREATMENT: IRON REMOVAL	TREATMENT: CHLORINATION	TREATMENT: FLOURIDATION	STORAGE CAPACTTY IN THOUSANDS OF GALLONS: TREATED WATER AT PLANT	STORAGE CAPACTTY IN THOUSANDS OF GALLONS: GROUND LEVEL ON SYSTEM	STORAGE CAPACTTY IN THOUSANDS OF GALLONS: ELEVATED
Caro State Hospital												
Well No. 1 Building No. 71												
Well No. 2												
Well No. 3 Building No. 72												
Kingston	456	M	Wells in rock 215' to 331' deep									20
Ross & State Streets (2 Wells)												
Mayville	896	M	Wells in rock 272' to 327' deep									27 pn
Fox Street												
Trend Street												
Village Park Fulton Street												
Millington	1,159	M	Wells in rock 370' to 390' deep									50
State & Bishop Streets (2 Wells)												
Bishop Street & MCRR (2 Wells)												
Unionville	629	M	Wells in rock 200' deep									
Cass Street (2 Wells)												
Vassar	2,680	P	Wells in rock 260' to 270' deep									105
Cass & Grant Streets												
Grant & NYC RR Well No. 5												
Grant & NYC RR Well No. 6												
West & Athletic Avenues												

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