COMMONWEALTH OF PENNSYLVANIA
Dick Thornburgh, *Governor*

DEPARTMENT OF ENVIRONMENTAL RESOURCES
Clifford L. Jones, *Secretary*
RESOURCES MANAGEMENT
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THE STATE WATER PLAN

SUBBASIN 15

LAKE ERIE

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Prepared by

OFFICE OF RESOURCES MANAGEMENT
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INTRODUCTION

The history of Pennsylvania can be traced through the development of its water and related land resources. From its founding as a settlement in the port of Philadelphia to its present position as a leading industrial, agricultural, and financial center, Pennsylvania's growth has depended on its varied and ample water resources. As the Commonwealth continues to mature and change, its dependency on these water resources will increase dramatically; consequently, the value of water itself will increase as more diversified uses compete for this renewable, but limited resource.

Such competition is leading to increasingly complex problems regarding the management of our vital water resources. The past decade has seen heavy emphasis placed on the environment, and water resources in particular, through the adoption of more sophisticated laws, policies and institutional arrangements at the State and Federal levels to protect, conserve, and manage water.

The Pennsylvania portion of the Lake Erie Drainage Basin, known as the Lake Erie subbasin, which is the subject of this report, encompasses many forms of man's effect on the environment and its effect upon him. The present and future importance of water and related land resources is realized throughout this area, as it is throughout the Commonwealth.

In recognition of the growing urgency for statewide management of water and related land resources, the General Assembly charged the former Department of Forests and Waters with the responsibility of developing water resources management policy. This authority was then transferred to the Department of Environmental Resources through Act No. 275 of 1970, which created the new Department.

The State Water Plan has been developed as a management tool to guide the conservation, development, and administration of the Commonwealth's water and related land resources on a comprehensive and coordinated basis. Only through the practice of such management will the Commonwealth be able to maintain its current prosperity, provide adequate flood control for its citizens and assure the supplies of good quality water necessary to meet its future needs.

This report is one of 23 reports being published as a result of the initial investigations and studies conducted in connection with the State Water Plan. The first report in the State Water Plan series, "Planning Principles SWP-1", was published in March 1975. That report, which expressed the goals, objectives, standards and criteria, and outlined the work program as well as described planning methodology, is referred to throughout this report. Three other reports; "Statewide Summary Report", "Water Laws and Institutional Arrangements", and "Water Resources Data System—WARDS", like "Planning Principles" deal with their respective subjects in a statewide manner. Nineteen subbasin summary reports deal with the water resources problems, and solutions to those problems, for each of the 20 subbasins[1] delineated in the Commonwealth for this study. This subbasin report provides background material, identifies problems, and presents alternative and recommended solutions to both the short- and long-term problems in Subbasin 15, the Lake Erie subbasin[2].

Development of the Plan in itself will achieve little. Successful implementation of the Plan, including continued development and use of the planning resource, is the key to Pennsylvania's future. Such implementation will be carried out under the laws and policies established by the General Assembly to manage our water resources in the interests of all the Commonwealth's citizens, including generations yet to come.

This report, along with the others comprising the State Water Plan, is intended to provide the General Assembly, State and local governments, business, industry, water suppliers, and all interested citizens with the information necessary to comprehend the scope of Pennsylvania's water problems and to enable administrators to wisely manage the Commonwealth's water and related land resources through the use of the developed planning resources including data bases, analytical methods and staff expertise.

[1]Because of its relatively small land area, Subbasin 14 is included in the Subbasin 16 report.

[2]The terms "subbasin" and "watershed" as used throughout this report are not used in their true hydrologic sense, but rather refer to water resources study areas which were arbitrarily defined, taking into account similar hydrologic and physical features of the Commonwealth's land mass.

I. SUMMARY AND RECOMMENDATIONS

The purpose of this report is to provide a general understanding of the water resources of the Lake Erie subbasin and sufficient insight into the relationships between man, economy and environment to rationally examine the problems associated with water resources and determine viable solutions which could support man's continued well-being while living in harmony with his surroundings. The report examines the physical features of the basin and the impacts from man's development of the area's natural resources. Both population and economy were forecast based on existing trends. Those forecasts were used as the future baseline upon which water resources problems could be examined. In the absence of actions to change existing trends, these forecasts are estimates of conditions which are likely to occur. The forecasts provided the basis for examining the range and costs of available alternatives for identified problems if current trends prevail.

While the problems and identified solutions are derived from trend conditions, it is important to note that State government and many regions throughout the Commonwealth are questioning the desirability of perpetuating existing trends. At the State level, recommendations of the Land Policy Program and policies adopted for the State's Environmental Master Plan propose policies which would result in changes to past trends and resource management practices. This subbasin report, while describing the impacts and consequences of existing trends, is also providing useful information for decision-makers to determine whether or not trend forecasts should be modified.

As State policies, regional plans, and community actions continuously define the desired character of future development, the ongoing State Water Plan program can readily identify potential impacts and propose subbasin alternatives consistent with State policy and compatible with community goals.

The scope of this study includes major aspects of water use and water management which can be affected by changing conditions in the future. Pennsylvania's intense water resources development dictated that problems be explored on a watershed, municipality and even company basis. For each problem which was identified, feasible solution alternatives have been examined and discussed, with consideration given to their physical, economic, environmental and social implications in order to determine and recommend solutions. In some instances, no single solution was recommended because more detailed studies are required.

In deriving its summary and recommendations this study has: (1) utilized the trend analyses as well as the many assumptions expressed in this text and "Planning Principles SWP-1", (2) solicited extensive public participation and reflected local desires and wishes to the maximum extent possible, and (3) considered both the natural physical features and socio-political jurisdictions and restrictions imposed by society.

The Lake Erie subbasin is one of two areas in Pennsylvania (the other is the Genesee Basin, Subbasin 14) which drains into the Great Lakes and the St. Lawrence River. The basin has two distinct physiographic characteristics. Along the 47-mile Lake Erie shoreline, inward for about four miles the land is basically level, as is the western third of the basin. The remainder of the area is made up of rolling hills. The drainage divide is formed by a ridge roughly 15 miles inland from the Lake Erie shoreline. Lake Erie is not only a major factor in the development of the area, but is also a major influence on the climate. Cold air moving across the lake produces unusual amounts of cloudiness and winter snowfall. Also, the large water mass has a tempering effect on cold weather, making it possible for better agricultural production than normal for its latitude.

Historically, the triangular Lake Erie tract did not become Pennsylvania's until 1792, when the Congress prevailed upon the States of New York, Massachusetts and Connecticut to relinquish their claims to it. The Port of Erie was used to distribute farm produce to Buffalo. However, the Erie-Pittsburgh Canal, in 1844, and the railroads about ten years later were the biggest factors leading to its development. By the end of the 19th century, the economy was begining to flourish and Germans, Poles, Russians, Italians and others immigrated here to work in the factories, mills, and fishing and shipping industries. Today, there is a stable economy in the Erie metropolitan area based on the manufacturing of electrical and paper products, in addition to the vineyards, orchards and dairy farms. A proposed steel plant to be located beside Lake Erie on the Pennsylvania-Ohio State line will further strengthen the economy of this region. Minerals of importance in the basin include sand and gravel, clay suitable for bricks and tiles, and natural gas.

Water resources of Subbasin 15 continue to be a vital factor in its overall economy. While shipping and commercial fishing have declined, Lake Erie is used heavily for recreational boating, and is the source of water supply for most of the population, the industry and the power plants. Water quality in Lake Erie had deteriorated during the twentieth century; however, through the International Joint Commission, a cooperative program between Canada and the United States has made substantial progress in reducing pollution to the Great Lakes and improving the water quality in Lake Erie. Sport fishing is very popular in Lake Erie and in certain streams, such as Crooked Creek, Elk Creek, Trout Run and Conneaut Creek, where chinook and coho salmon make spawning runs. Also, the State park on Presque Isle peninsula is the most intensely utilized of all parks in Pennsylvania. Inland flooding is a very minor problem but on-lot sewage disposal is a very serious, widespread problem because of very poor infiltration qualities of the soil. Various water resources needs must be addressed for the future, and the following sections summarize the more prominent problems in the subbasin and their recommended solutions.

A. WATER QUALITY

Lake Erie, being a downstream lake and one of the smallest of the Grest Lakes, has had an accelerated eutrophication rate. Pollution from cities as far away as Detroit accumulate in Lake Erie, causing decreases in dissolved oxygen and enrichment of aquatic plants. Through the Great Lakes Water Quality Agreement, the pollution loadings of Canada and the United States have been vastly reduced and Lake Erie is showing definite signs of recovery. Eutrophication continues to be the main problem of the lake but progress with such a large body of water is slow. The quality of the water in Presque Isle Bay is best along the north shore. Along the south shore combined sewer overflows and urban runoff are causing high coliform counts. Correcting the sewer overflow situation should solve most of this problem. Crooked Creek, Little Elk Creek, Twelvemile Creek and Twentymile Creek have excellent water quality. All of the other small streams which drain directly into Lake Erie have high coliform bacteria contamination, and ammonia, iron, phosphate and pH problems due to domestic discharges, septic tank effluents, combined sewer overflows, and urban and agricultural runoff. Normally, this type of pollution would evidence low dissolved oxygen and high BOD concentrations, but because of short stream reaches and small travel times, this process does not occur. The one exception is Walnut Creek which has a slightly longer travel time to the lake. As a result, low dissolved oxygen levels occur due to discharges from private treatment facilities and industrial discharges. Groundwater in the basin is generally poor. Excessive iron, manganese and hardness (usually 150 mg/l or greater) are general problems associated with all aquifers. In addition, deep wells are not possible because of salt water problems. Contamination of groundwater is widespread due to on-lot sewage systems which were in place prior to implementation of the Department of Environmental Resources' regulations. The soils are poorly suited for on-lot disposal, as evidenced by septic tank malfunctions in the suburban townships of Erie, Cranesville and McKean Borough. In addition, salt water brine, road salt and fertilizers are polluting the groundwater. The completion of planned and under-construction treatment plants and sewer facilities will greatly improve this overall condition. The agricultural land of the basin is intensely farmed and conservation measures should be employed.

B. WATER-RELATED OUTDOOR RECREATION

Some of the best water-related outdoor recreation in western Pennsylvania exists in Subbasin 15. At Presque Isle State Park, the current usage rate is over four million visitors per year. In addition, Walnut Creek, Sixteenmile Creek, Crooked Creek and Elk Creek are heavily fished, particularly when the salmon from Lake Erie make their spawning runs. Conneaut Creek, being one of the largest streams draining into Lake Erie, provides warm-water fishing as well as boating opportunities. The Pennsylvania Fish Commission, Corps of Engineers, Erie County and Pennsylvania Department of Environmental Resources are planning fishery enhancement projects on Elk Creek which will provide a high quality game fishery there. Because of Lake Erie and its attraction for water oriented recreationists, there is a pressing need for additional boating access areas, launching facilities and picnic tables.

There is no room for expansion of any of these types of facilities at Presque Isle, but the State is exploring the possibility of developing an additional boating access area as part of the Coastal Zone Management Program. It is recommended that the county and regional planning agencies develop these types of facilities.

C. WATER SUPPLY

Water supply is not generally a serious problem in Subbasin 15 because Lake Erie provides essentially unlimited amounts of water for any purpose. In 1970 the total water use in Subbasin 15 was 389 mgd[3], and this usage is projected to decrease to 295 mgd by 1990, mainly due to the retirement of Front Street Generating Station Units 2 & 3 in 1984. Approximately 98 percent of all water used comes from Lake Erie, with electric power generation, Erie city water supply and two major industries accounting for the majority of that usage. There are 18 public water suppliers in the basin. Of these, four had insufficient water developed to meet their demands in 1970, and by 1990 and 2020, there will be seven and nine suppliers having this problem unless they develop additional supplies and/or reduce demands.

It is strongly recommended that applicable conservation measures be applied by all suppliers whose residential gpcd[4] exceeds 50 or whose industrial usage appears excessive. This should be the initial means to alleviate existing or projected deficiencies. In addition, installation of meters for the Palmer Shores Water Company and reduction of losses in the water supply system of the Pennsylvania Water Company-Whitehall Village should be considered to alleviate their water supply problems. Specific problems and recommended solutions for each of the individual suppliers are given in Table 16 of Chapter V. The City of Erie, which uses 44.4 mgd, accounts for 93 percent of all the public water supply within the subbasin. Erie's treatment plant is more than adequate to meet existing and future demands. Also, their source of water from Lake Erie is more than adequate. However, there is no metering of customers within their system, which increases water treatment costs as well as wastewater treatment costs for all of their customers. It is recommended that metering of water in the Erie water system be implemented along with the future sewerage and wastewater treatment plans for the city.

Currently, a U.S. Steel Plant is proposed to be located along the southern shore of Lake Erie at the Pennsylvania-Ohio State line. Water use of the plant would be supplied from Lake Erie. If the proposed plant is constructed and operated, an additional 27,000 persons or 10 percent over the trend projected population for 1990 will reside in Erie County and the western half of Crawford County. This additional increase in population will certainly increase the water use in all categories; however, the most severe impact would be on 26 public water suppliers in Erie County and the western half of Crawford County. After analyses, it was concluded that (1) water is plentiful in Lake Erie for the uses of the proposed U.S. Steel Plant, (2) surface and groundwaters are sufficient in this subbasin to meet the additional water demand from the development of the proposed plant, (3) some of the water suppliers' systems will have to be expanded or improved to meet these additional water demands, and (4) impact of this project on water quality, fish and wildlife in Lake Erie should be studied prior to the implementation of the project.

D. WILD AND SCENIC RIVERS

Four stream reaches have been selected as candidates for the Pennsylvania Scenic Rivers System. These streams include Little Elk Creek, Elk Creek, Walnut Creek and Conneaut Creek. In all, 72 miles of stream have been designated for consideration. These streams, are mapped on Figure 15 of Chapter V.

The Commonwealth recognizes the irreplaceable qualities of many of its waterways. The management of these resources for aesthetic and utilitarian purposes is dependent upon the diligence of both the governmental and private sectors. Water resources projects whose necessity has been proven by thorough study of the alternatives must be planned so as to minimize disruption of the natural environment.

Because of their outstanding characteristics, all streams listed in Table 29 of Chapter V should be subject to careful environmental assessments with full consideration of all alternate solutions before any projects are proposed, which may affect their designated reaches. Streams listed, including second or third priority, although not receiving immediate in-depth investigation by the Scenic Rivers Program, should be preserved or improved to the extent possible by all levels of government, as well as private interests, until such time that they may be protected by legal adoption as components of the Pennsylvania Scenic Rivers System.

E. FLOOD DAMAGE REDUCTION

Flood damages in Subbasin 15 have been relatively small in comparison to other areas of Pennsylvania. The worst floods occurred in 1915, 1936, 1941, and 1947. In 1915, more than a million dollars in damages occurred to the City of Erie. In addition, there have been recent flood damages to the Presque Isle peninsula in the amount of a million dollars erosion per year. However, since the Presque Isle damage was a beach erosion problem rather than a flooding situation, it is not included here. It should be noted that the Corps of Engineers has proposed a beach erosion control project for five miles along Presque Isle. The Corps of Engineers has done stream clearance work in Conneaut Creek, which helped reduce damages in Conneautville. Also, the Department of Environmental Resources has completed a bank stabilization project at Wesleyville. It is recommended that nonstructural measures such as Federal flood protection insurance,

[3]mgd: million gallons per day.

[4]gpcd: gallons per capita per day.

flood zoning, relocation and flood proofing be utilized to prevent future flood damages from occurring and to reduce existing problems already mentioned.

F. NAVIGATION

Commercial use of the Erie Harbor has declined greatly over the last 30 years. Total tonnage of freight through Erie Harbor fell from nine million short tons in 1945 to less than one million short tons in 1966. Most current traffic has been in bulk construction materials and petroleum products because the harbor, until recently, was not adequately equipped to handle general cargo. General cargo requires sophisticated equipment to move it efficiently; lacking such equipment, Erie has not been competitive with other ports. Pennsylvania's Coastal Zone Management program will provide technical assistance for long range planning and financing for redevelopment of the port facility. The Port Authority's acquisition of a new 300-ton crane should substantially increase shipping in the harbor, particularly in the categories of steel products and machinery.

II. GOALS AND OBJECTIVES

The Commonwealth recognizes the importance of citizen participation in any program which has the potential for such direct impact upon the everyday lives of the public as does the State Water Plan. In order that an effective level of citizen participation might be achieved in this important program, the Department established through the Northwest Pennsylvania Regional Planning and Development Commission, a Water Resources Advisory Committee. Membership on this committee was open to the general public and participants included representatives from many public, industrial and governmental organizations.

Development of the materials contained in this report was coordinated with this committee through a series of meetings conducted in Titusville. As work on various sections of the report was completed, meetings were held to allow discussion of the information which had been developed to that point. Modifications and corrections were then incorporated.

One of the committee's coordinative functions was the development of a set of subbasin goals and objectives which, when merged with those for the overall State, would provide the basis upon which decisions could be made in the water resources planning process for this area. This section outlines the Subbasin Goals and Objectives which are the final product of that effort.

A. WATER SUPPLY

1. *Goal*

Water supplies of adequate quantity and quality to meet both short- and long-term needs.

2. *Objectives*

a. Inventory the available surface and groundwater resources.

b. Identify existing and potential water supply problems.

c. Identify feasible alternative solutions taking into account physical, social, political, economic, and environmental factors, to make possible the selection of practicable solutions.

d. Encourage the reuse of water, and the development and use of new water-saving technology.

e. Stress conservation measures to help ensure the future availability of water resources.

f. Encourage the installation of metered water systems in order to promote conservation.

g. Suggest those changes in water laws and institutional arrangements deemed necessary to ensure the adequacy of present and future water supplies and the equitable distribution thereof.

h. Protect public drinking water supplies from degradation of quality and reduction in yield.

i. Develop water resources to ensure adequate supplies during water shortages, droughts, and other possible emergencies.

B. FLOOD DAMAGE REDUCTION

1. *Goal*

The mitigation of existing flood problems with the resulting minimization of future flood damages and loss of life.

2. *Objectives*

a. Establish a list of urgent flood hazard reduction needs for the purpose of guiding flood control investments.

b. Identify feasible alternatives (i.e., structural measures and nonstructural measures) to the flood problem, taking into account physical, social, political, economic, and environmental factors.

c. Promote floodplain management and its integration with local land use management as the first priority method of minimizing future flood damage.

  (1) Encourage appropriate State legislation to manage floodplains.

  (2) Regulate new structural development in flood prone areas.

  (3) Require that construction of essential development on flood prone areas be flood proofed and designed to minimize obstruction to flood flows.

  (4) Encourage the relocation of floodplain development to nonflood prone areas, where economically feasible.

d. Advocate and apply a basinwide system approach to flood damage reduction measures.

e. Stress the interrelationship between traditional State-Federal flood control measures and urban storm drainage.

f. Encourage municipalities to participate in the National Flood Insurance Program.

g. Educate the public, and especially members of local government, on the need for floodplain management.

C. OUTDOOR RECREATION

1. *Goal*

Adequate water and related land resources to meet present and future water-oriented and water-enhanced recreational needs.

2. *Objectives*

a. Protect natural and free-flowing streams to preserve their recreational potential.

b. Inventory all water-related and water-enhanced public recreation facilities.

c. Examine existing and potential recreational facilities and water projects to determine future potential for recreation development.

d. Determine water-related recreation needs to guide recreation investment in conjunction with water resources project development.

e. Give highest priority to those recreation projects that meet the greatest needs within minimum required travel time.

f. Provide adequate fishing and boating opportunities through the development of access areas on public water and by promoting access to additional private waters.

g. Coordinate the water-related outdoor recreation planning activities and responsibilities of Federal, State, local and private entities.

h. Coordinate water-related outdoor recreation planning with other related State planning efforts.

i. Encourage local government participation in the development of future recreation opportunity.

D. WATER QUALITY MANAGEMENT

1. *Goal*

Prevent further pollution of the waters of the Commonwealth, and restore to an unpolluted condition all presently polluted waters, so that present and future uses will be protected.

2. *Objectives*

a. Establish water quality standards designed to protect all probable uses of the Commonwealth's waters.

b. Provide for the development of water quality management programs which include both individual and regional waste collection and treatment systems designed to protect and conserve the Commonwealth's waters.

c. Identify and develop institutional arrangements for implementation of regional or basinwide water quality plans.

d. Control nonpoint source pollution and prevent pollution incidents by requiring adequate product and waste handling safeguards.

e. Develop and institute programs for control and abatement of acid mine drainage and pollution from oil and gas wells.

E. ENVIRONMENTAL QUALITY

1. *Goal*

Management of water and related land resources to abate and prevent pollution, protect and preserve environmental values, and enhance and maintain ecosystems.

2. *Objectives*

a. Protect wetlands, wild areas, natural areas and other resources which may be fragile, rare or endangered.

b. Develop criteria to maintain aquatic ecosystems and protect other instream environmental values.

c. Protect the character of streams having wild and scenic values, and prevent degradation of streams.

d. Encourage land and water resources management which is compatible with the protection of prime farmlands.

e. Promote floodplain management which maintains the floodplain ecosystems, protects natural resource values and provides community open space opportunities.

f. Develop a groundwater management program to prevent groundwater contamination, facilitate recharge and reduce runoff.

g. Manage water and related land resources to protect habitats for fisheries and wildlife resources.

h. Identify areas where frequent or severe low flows caused by man's activities may threaten environmental values.

i. Encourage environmentally sensitive land and water planning by all levels of government such that the natural hydrologic character of watersheds is respected.

III. PHYSICAL FEATURES & RESOURCES

The term *water resources management* typically brings to mind the concept of controlling rivers and streams to provide water for man's use. However, one should be reminded that what is really being managed is a resource that is all-pervasive. Groundwater saturates much of the Commonwealth's bedrock. Surface water in the form of streams and lakes occupies over one percent of the Commonwealth's land surface. Water vapor, or moisture in the air, while not readily available for man's use, is the source of water in its other usable forms. Physical features of the environment affect water in all forms by controlling flows, natural storage, evaporation and precipitation.

Physical features of the land also affect water resources management, not only because of their direct effects on water in quantity and quality, but also because of their indirect effects on its use, resulting from their influence on man's activities. This chapter discusses in general terms the physical features of Subbasin 15. For the reader who is unfamiliar with the area, it should provide a description sufficient to understand the physical characteristics of the subbasin; and for all readers it should provide insight into the general relationships between physical land features and water resources.

Much of the material presented in this chapter was either developed by other State or Federal agencies, or was developed from information provided by those agencies, including the Pennsylvania Fish and Game Commissions, the U.S. Weather Bureau, the Bureau of Topographic and Geologic Survey of DER, the U.S. Department of Agriculture's Soil Conservation Service and Forest Service, as well as the State Forestry and Soil Conservation Bureaus. In some cases the planning process involves the use of information of greater detail than that which is presented here. It is not intended that this report present a detailed description of physical features. More detailed information is available in reports and publications from the respective agencies with specific authority in given program areas. In addition, development of more localized physical features data will occur as the State Water Plan program examines in greater detail those water resources problems which have been identified as being of urgent concern to Pennsylvania's future.

A. BASIN ORIENTATION

Located in the extreme northwest corner of the state, the area abutting Lake Erie is referred to as Subbasin 15. The subbasin includes the northwest half of Erie County and the northwest corner of Crawford County. Overall, the land area of the Lake Erie Subbasin totals 511 square miles.

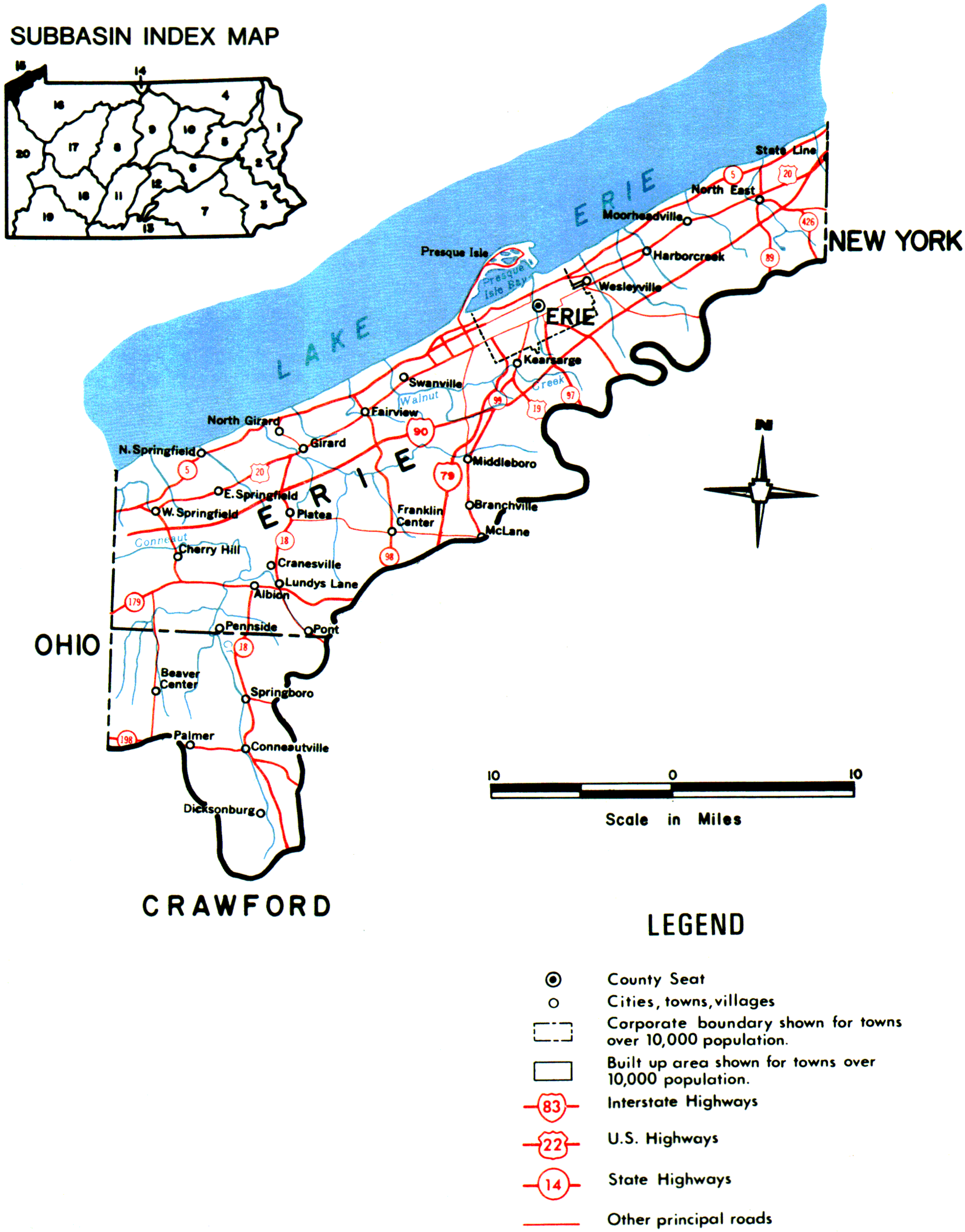
Subbasin 15 is roughly rectangular in shape as indicated on Figure 1. The east-west distance from State Line in Erie County to Beaver Center in Crawford County is 45 miles; the average north-south distance from the shore line of Lake Erie to Franklin Center in Erie County is eight miles. Surrounding the Lake Erie Subbasin to the south is the Upper Allegheny, Subbasin 16, and the Ohio, Subbasin 20. To the east and west, the Lake Erie Subbasin is bounded by the states of New York and Ohio, respectively. Subbasin 15 is bordered to the north by Lake Erie, the fourth largest of the Great Lakes.

Two principal topographic sections, the Lake Plain (a subdivision of the Eastern Lake Section of the Central Lowland Province) and the Upland Area (Glaciated Section of the Appalachian Plateaus Province), comprise the physiography of Subbasin 15. The Lake Plain lies parallel to Lake Erie in a northeast to southwest direction and extends inland five to six miles. The Upland Area is southeast of the Lake Plain. In general the Upland Area has gently sloping relief but in places there are valleys formed through stream erosion.

Population concentrations in the subbasin are centered in the City of Erie, located on the Lake Plain. Other scattered population centers on the Lake Plain include Girard, Fairview, Wesleyville and North East. A small population center on the Upland Area is found at Albion.

Major transportation routes in the subbasin include Interstates 90 and 79. Interstate 90 links Buffalo with Cleveland in a northeast to southwest direction through Erie County. Interstate 79 is a north-south route connecting the City of Erie with Pittsburgh. Another north-south route, U.S. 19, links the City of Erie with Meadville. Following the Lake Plain, U.S. 20 parallels Interstate 90 as it connects the City of Erie with Buffalo to the northeast and Cleveland to the southwest.

This subbasin is noted for its manufacturing industries. Major industries include electrical manufacturers, paper producers and producers of electrical components. Agriculture is another of the principal industries in Erie County. Nearly all the grapes produced



Source:
United States
Department of the Interior
Geological Survey

FIGURE 1. Basin Orientation

Table 1

MAJOR RIVERS AND WATERWAYS

Watershed	Drainage Area (Sq.Mi.)	Major Waterway	Minor Waterway
A	511	Lake Erie	Walnut Creek Elk Creek, Conneaut Creek

in the state are grown here. Grapes, other fruit crops and early maturing vegetables are grown on the temperate Lake Plain. Dairy and truck farming predominate in the Upland Area.

Table 1 lists the major and minor waterways in Subbasin 15. As indicated on the table, Lake Erie is the major waterway in this subbasin. Three minor waterways draining the subbasin flow into Lake Erie. Of these three waterways, Conneaut Creek is the largest.

B. CLIMATE

The study area is dominated by atmospheric flow patterns relevant to the Humid Continental type climate. Lake Erie's geographical location in northwestern Pennsylvania and the usual eastward movement of air masses originating in Canada governed by large scale westerly atmospheric flow patterns, provide the general climatic conditions for the study area. The topography adjacent to Lake Erie has a pronounced effect on the climate of the study area. The prevailing winds from the south and southwest transport warm moist air, which has been conditioned by the Gulf of Mexico and the surrounding tropical waters, into the area.

During the winter months, the succession of cold air outbreaks migrating from Canada are modified by the relatively warm waters of the Great Lakes, causing excessive cloudiness and frequent snowfalls from November through March.

The spring weather for the area is usually cloudy and cool. The adjacent lake waters frequently temper the killing frosts that are observed farther south.

Hurricanes or tropical disturbances, as they move northward in the middle latitudes, produce heavy rainfalls and strong surface winds in the study area. Frequently affecting water supplies and causing floods, these tropical storms are observed during the hurricane season, June through November. Tropical storms have little affect on the area weather except that heavy rains may fall in the study area as the storms move into the northwest portion of New York State.

The weather elements or activities of the atmosphere, such as precipitation, temperature, wind direction and speed, relative humidity, and sunshine, are measurable quantities which affect the study area.

Precipitation in both liquid and solid forms is the initial source of all water supplies. Precipitation is well distributed throughout the year, with the study area normally receiving about 40 inches annually. The normal monthly precipitation totals range from a minimum of 2.5 inches in February to a maximum of 3.8 inches in June. The annual snowfall in the winter months exceeds 54 inches, with heavy snow sometimes experienced late in April. The greatest hazard in the area is heavy snowfall. Snow is produced as the cold polar air masses travel southward over unfrozen lake waters. These masses absorb considerable amounts of moisture in these lower levels as they move over the Great Lakes. The warm moistened lower air-parcels, as they reach the land, rise through the cold air aloft, causing heavy snow squalls capable of depositing 12 to 24 inches of snow on the leeward side of the lake. Lake Erie is subject to this heavy snowfall, "Lake-effect", in November and December; however, as the lake surface gradually becomes frozen by mid-winter, these snowfalls become less frequent. The mean annual number of days with snow cover of one inch or more is about 90 days.

Air temperatures are important to the management of water resources and water quality. The average annual temperature for the study area is about 49°F. The mean annual freeze-free period is about 195 days. The Lake Erie study area is of relatively small size compared to other subbasins; however, it has a unique and agriculturally advantageous climate, typical of coastal areas surrounding much of the Great Lakes. Both in spring and autumn the lake waters exert a retarding influence on the temperature regime and the freeze-free season is extended about 45 days annually. The subbasin, compared with other areas in the state, is subject to more gradual changes in temperature due to its topographic features and the "Lake-effect". Temperatures as high as 96°F have been recorded at Erie during the month of August, and as low as -16°F in February. The summer mean temperature is about 70°F and the winter mean is about 27°F.

Winds are important hydrologic factors because of their evaporative effects and their association with major storm systems. The prevailing wind direction in the area is from the west averaging 11 mph, with extreme wind speeds up to 55 mph from the southeast reported in the Erie area during severe storm activity.

Relative humidity also affects evaporation processes. The mean monthly relative humidities for the months of

Table 2

STREAMFLOW STATISTICS FOR SELECTED GAGING STATIONS

Station	Period And Years of Record Used	Drainage Area (Sq. Mi.)	Average Annual Runoff (csm[a])	Mean Annual Flood (csm[a])	Ratio of 100-Year to Mean Annual Flood	7-Day 10-Year Low Flow (csm[a])
Conneaut Creek at Conneaut, Ohio	1922–35 1950–61 1961–72 35	175	1.4	38.6	2.5	–
Raccoon Creek near West Springfield	1961–72 11	2.5	1.7	84.2	11.7	–

[a]Cubic feet per second per square mile.

Source: United States Geological Survey.

January, April, July and October, are about 76 percent, 70 percent, 69 percent and 74 percent, respectively.

Sunshine, which varies with latitude and the time of the year, is a factor to be considered in the various aspects of waste treatment processes. The mean annual sunshine in hours per year for the study area is about 2,350 hours.

The evaporation process is controlled by temperature, wind, sunshine and humidity. The rate of evaporation during the warmer months has an important impact on water storage in reservoirs and on irrigation. High evaporation rates can cause humid regions to become vulnerable to droughts. The mean May to October evaporation for the study area accounts for about 80 percent of the total annual evaporation.

References

1. U.S. Weather Bureau, *Climates of the States - Pennsylvania, Climatography of United States No. 60-36*, (U.S. Department of Commerce, Washington, D.C., 1960–1971).
2. U.S. Weather Bureau, *Climatic Data - Section 87 - Western Pennsylvania*, (U.S. Department of Agriculture, Washington, D.C., 1930).
3. Department of Interior, Geological Survey, *The National Atlas of the United States*, (Washington, D.C., 1970).

C. HYDROLOGY

Management of water resources requires a knowledge of the quantity of water which is available for use and which must be managed in order to provide for the safety and welfare of the public. For studies of water use and quality, low flow conditions are of general concern; whereas, for flood management it is necessary to know the high flow characteristics of streams. Hydrologic factors discussed in this section include main stream systems, annual basin runoff, low flows, and flooding.

There is no major waterway flowing through Subbasin 15. Instead, all of the streams drain into Lake Erie. Three of the larger streams, draining approximately 56 percent of the subbasin, are Conneaut Creek, Elk Creek, and Walnut Creek.

Average annual runoff ranges from 20 inches in the southwest to 26 inches in the northeast and is primarily influenced by precipitation distribution. However, other factors such as land cover and use, geology, and physiography influence the variability of flows from individual watersheds. Table 2 contains average annual runoff values for selected gaging stations within the subbasin.[5]

Runoff has a distinct seasonal variation, with the period of highest runoff occurring in late winter or early spring, and the period of lowest runoff occurring in late summer and early fall. The seasonality of evapotranspiration accounts for most of this variation.

Low flow deficiencies develop after prolonged periods of little or no precipitation and persist until sufficient rainfall relieves the situation. Flow deficiencies of significant duration may cause new water supply problems and may magnify existing water quality problems.

The 7-day 10-year low flow, a common description of low flow characteristics, is frequently used as a basis for water management. For other stream gaging stations in the subbasin, the magnitude and frequency of low flows for this and other durations are contained in two bulletins (Bulletin No. 7[6] and Bulletin No. 12[7]) published by the Pennsylvania Department of Environmental Resources.

Although floods occur in all seasons, studies of the relationships among storm intensity, duration, affected area, and seasonality suggest a tendency for flooding on

[5]U.S. Geological Survey, *Water Resources Data for Pennsylvania, Part 1: Surface Water Records*, (1972).

small streams to occur mostly in summer. Large area floods are caused by storms of low rainfall intensity and long duration covering the entire area of principal watersheds. Small area floods, on the other hand, are caused by storms of high rainfall intensity and relatively short duration. An exception to this is tropical storms, which normally occur during the summer months and cause extensive flooding over large areas.

Magnitudes of mean annual floods for selected gaging sites in Subbasin 15 are given in Table 2. This data was obtained from a U.S. Geological Survey computer analysis of annual peak discharge records for a statewide study of flood magnitude and frequency relations.

D. TOPOGRAPHY

The topography, or physical land features, of the study area determines the drainage patterns and surface flow characteristics. Steeper slopes cause increased runoff and erosion and discourage infiltration to the water table. Unconfined (nonartesian) groundwater flow direction is controlled in part by the topography.

The Lake Erie Subbasin lies within the Glaciated Section of the Appalachian Plateaus and the Eastern Lake Section of the Central Lowland Physiographic Provinces as shown on Figure 2. Each physiographic province and its respective section is separated from the other by an erosional scarp running from southwest to northeast approximately three to four miles inland from Lake Erie.

The dominant topographic feature of the subbasin is the forty-seven miles of shoreline on Lake Erie and the Peninsula, approximately seven miles in length and one mile wide, forming the bay and harbor for the City of Erie. Topographic characteristics include a lake plain with gradual parallel ridges continuing three to four miles inland and rising to an elevation of approximately 500 feet above lake level. From this point to a ridge 15 miles inland, the elevation increase is rapid. The ridge, 1,300 to 1,500 feet above sea level, is predominant in the northeast and extends in a southwest direction to a point two-thirds the length of the subbasin where it disappears into rolling hills.

The land area in the subbasin is split by a series of ravines or gorges, and streams as they empty into the lake. The terrain south of the ridge is a series of rolling hills interspersed with small waterways and their tributaries which flow south. Except for the relatively level west one-third of the subbasin and a three-to four-mile lake shore plain, the majority of the subbasin is characterized by rolling hills.

E. GEOLOGY AND GROUNDWATER

Except in this subbasin where most of the groundwater is contained in glacial deposits, bedrock geology has ultimate control on the storage, transmission, and utilization of groundwater. Geologic factors such as rock type, intergranular spacing, rock strata inclination, faults, joints, folds, bedding planes, and solution channels affect groundwater movement and availability. Natural groundwater quality is a result of the interaction between the groundwater and the bedrock with which it is in contact. The more soluble bedrock types will allow more compounds to become dissolved in the groundwater. For example, groundwater in highly soluble limestone aquifers will commonly have high hardness values. Groundwater quality will eventually affect surface water quality as it percolates into surface streams as base flow.

The areal distribution of the rocks exposed at the surface of the subbasin is shown on the Geologic Map (Figure 3 in cover pocket). These rock units or formations form aquifers with distinct hydrologic characteristics. Typical well characteristics for the principal aquifers of the subbasin are shown in Table 3.

The shore cliffs along most of the southern shore of Lake Erie are composed of blue shale, and the escarpment region consists of shales which are more resistant than the rocks along the lake shore. The sedimentary rock layers underlying the county are from 6,000 to 7,500 feet thick. All the bedrock formations are part of a large basin-shaped structure, and as a result the beds dip gently to the south and southwest. The slope of the bedrock rarely exceeds twenty feet per mile.

Extensive ice sheets moved down the Erie Basin into northwest Pennsylvania and easternmost Ohio as a tongue of the major Erie Lobe of ice referred to as the Grand River Lobe. Sandy till and loam till blankets were deposited with each ice sheet's advance. Water activity during the melting of the ice sheets formed extensive outwash deposits.

Later ice advances failed to enter the subbasin; however, they approached the area close enough to back up waters in the Erie Basin to form a succession of high level lakes. The higher waters reworked the previously laid till and deposited a sand and gravel blanket with beach ridges along a wide plain south of the present Lake Erie shore. During all of the time that the subbasin was free of ice, the previously deposited materials were subjected to erosion and weathering and were locally worked and redeposited as stream alluvium or as lake and swamp deposits.

Historically speaking, the Lake Erie waters worked upon the preexisting sediments, most of which were tills, and upon the bedrock where it was exposed. This produced the sand, silt and clay deposits along the present lake plain and a series of beach ridges at different

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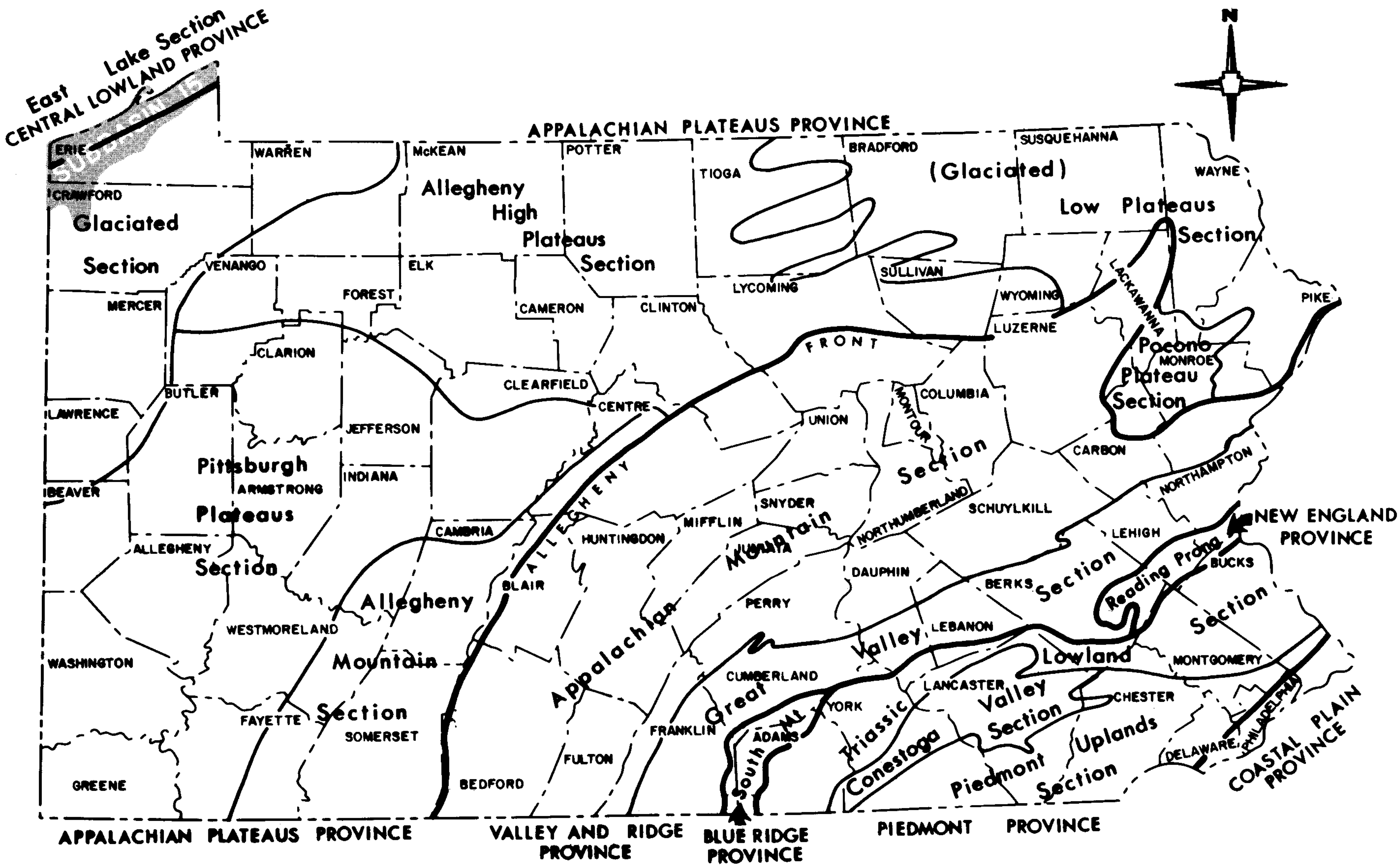
[6]Office of Engineering and Construction, *Water Resources Bulletin No. 7, Long Duration Low Flow of Pennsylvania Streams*, (Pennsylvania Department of Environmental Resources, 1972).

[7]L. V. Page and L. C. Shaw, *Water Resources Bulletin No. 12, Low Flow Characteristics of Pennsylvania Streams*, (Pennsylvania Department of Environmental Resources, 1977).



Source:
Commonwealth of Pennsylvania
Topographic and Geologic Survey

FIGURE 2. Physiographic Provinces

Table 3

CHARACTERISTICS OF WELLS IN PRINCIPAL GEOLOGIC UNITS[a]

Map Symbol	Rock Units		Well Depth (Feet)	Number of Wells Sampled	Casing Length (Feet)	Number of Wells Sampled	Static Water Level (Feet)	Number of Wells Sampled	Drawdown (Feet)	Number of Wells Sampled	Well (Gal./Min.)	Number of Wells Sampled	Remarks
	Outwash, valley train deposits	m[b] R[c]	60 20–97	39	53 20–72	21	9 4–22	16	12 2–34	12	500 60–1500	22	Yields range from 60 to 1500 gpm. These deposits found beneath major alleys. Occasional occurrences of high iron and salt water. Screen needed in well construction.
	Stratified drift, ice contact deposits	m R	26 12–73	24	24 12–68	17	21 4–50	7	6 1–17	6	100 14–800	19	Range of yield is 14–800 gpm. Occasional salt water and iron. Will not contain water if located above the water table. Deposits have limited areal extent. Not suitable for intensive pumping.
Mp	Pocono Gp.	m R	68 47–150	28	50 18–60	23	5 0–34	17	5 –	3	20 2–70	14	Suitable for domestic supplies and small developments. Yields range from 2–70. Wells over 200 feet deep are likely to encounter salt water.
Dr	Riceville Fm.	m R	80 40–95	3	29 21–56	3	5 3–35	3	62 –	1	3 3–15	3	Few wells. Barely adequate for domestic wells.
Dcr	Cattarugus Fm.	m R	56 38–200	67	31 12–162	64	12 2–95	67	38 3–60	41	7 <1–90	67	Wells greater than 100 feet deep often encounter salt water. High iron content is sometimes a problem. Yields range from 0.2 to 90 gpm. Unit not suited for public supplies.
Dct Dcn	Conneaut Gp. Canadaway Fm.	m R	52 3–130	67	22 10–101	63	14 1–80	67	37 4–74	57	3 <1–50	67	Yields range from 0.3 to 50 gpm. Wells greater than 100 feet in depth usually encounter salt water. Adequate for most domestic supplies. Salt water and pockets of natural gas are common.

[a]Data are primarily from public and industrial water supply wells. In instances where there is an insufficient number of public and industrial wells domestic wells are used to supplement data. Median well characteristics, in most cases, correspond to typical values obtained from randomly located wells. Considerably larger well yields may be obtained by using scientific well location and development techniques.

[b]Median

[c]Range

elevations. The thickness of the deposits over most of the lake plain varies between 10 and 75 feet. The clay deposits produce a negative effect on drainage or infiltration. The high runoff factor, in turn, has caused gorges, gulleys, and loss of the somewhat limited top soil.

F. MINERAL RESOURCES

Mineral resources and mining areas that are near the water table can have a large influence on groundwater quality. Quarries commonly alter the groundwater flow pattern by developing new flow channels. Where the water table must be lowered to continue quarrying activity, large cones of depression will develop that may adversely affect local groundwater availability and stream baseflows.

Quarrying produces large areas of disturbed land that is highly erodible, and if techniques for sediment control are not used, large quantities of sediment are contributed to surface streams. In addition, the processing of many quarried materials produces large quantities of silt which can be damaging to surface streams. Where possible, settling ponds or lagoons should be used to allow suspended solids to settle out so clear water can be recycled. Closed water circuits are often used for economic reasons for the prevention of stream pollution.

Major mineral resources of the subbasin include sand, gravel, sandstone, clay and natural gas as shown on Figure 4.

1. *Sand and Gravel*

Sand and gravel are used by the construction and paving industries. In this subbasin, sand and gravel deposits are contained in kames, kame terraces, beach ridges, and outwash valley fills, where they are sometimes mixed with silt and clay in irregular masses. For most construction and paving uses screening, washing and crushing are required to obtain sized materials.

2. *Sandstone*

None of the quarries in the subbasin are operated for building stone; however, quarries may be temporarily opened for crushed stone for construction purposes. In the past, large operations have quarried sandstones of the Cattaraugus Formations for crushed stone. Reserves of good quality sandstone are plentiful throughout the subbasin.

3. *Clay*

Certain areas in the subbasin may contain valuable clays. The tills are composed primarily of the minerals, illite, and chlorite in the clay fraction. The clays are quite plastic, with moderate to high shrinkage, and fire at low temperatures. The Hiram Till deposit contains a large proportion of clay and may be found useful for the manufacture of common brick or tile. Investigation of the lake deposits associated with the Hiram Till may reveal clay beds. Likely areas for such deposits are in and around Conneautville and west and southwest of Albion.

4. *Natural Gas*

One of the subbasin's largest mineral resources is natural gas, which shows steadily increasing production. Total gas production in 1970 was approximately 2.4 billion cubic feet. Further development of new and deeper onshore gas fields is likely. Offshore gas exploration and development may occur in Lake Erie when authorization is granted. About 30 wells produced limited quantities (138 barrels) of crude oil during 1970. Total crude oil production decreased approximately 75 percent from the previous year and no new well completions were reported during 1970.

Salt water brine occurs in certain sandstones and is extracted as a result of gas well operations. Some interest has been shown in the possibility of commercial utilization of the brines for the salt content.

G. SOILS

Soil characteristics influence precipitation after it comes in contact with the earth's surface. Coarse-textured soils enhance infiltration to the water table, while fine-textured soils have slow infiltration rates and produce higher surface runoff. Water in contact with soil may leach out soil ions, thereby changing the chemical composition of both the infiltrating water and the soil. The general properties of soils help to determine their suitability for on-lot disposal and land disposal through their wastewater renovating potential. Poor soil suitability means disposal systems will eventually pollute the groundwater or surface waters, or both. The suitability of subbasin soils for waste disposal is mapped and discussed in more detail in the Comprehensive Water Quality Management Plan (COWAMP) study area reports.

The soils of Subbasin 15 can be divided into two broad groups based on association with a specific parent material. These groups are: 1) soils formed in glacial till, and 2) soils formed in unconsolidated water sorted materials. The groups are listed in Table 4 along with soil substrata and association, and displayed on a general soil map, Figure 5. In addition, soils can be further categorized by hydrologic groups, which are also listed on Figure 5. The hydrologic groups are determined by a soil's infiltration rate, which is dependent on the soil's physical and chemical composition, dominant slope, and depth of soil profile as discussed in Appendix A-1.

Along the shoreline of Lake Erie lies the Eastern Lake Section of the Central Lowland Province. The soils within this section are soils formed in unconsolidated water sorted materials. These soils have substrata of sands, silts and gravel and are characterized by slow and very slow infiltration rates; so, they fall in between the C and D hydrologic classes. The deeper substrata of this region, as with the remainder of the subbasin, are composed of sandstones, siltstones and shales. The topography of this region is generally flat or rolling with soil depths that exceed 72 inches. In addition, the region is

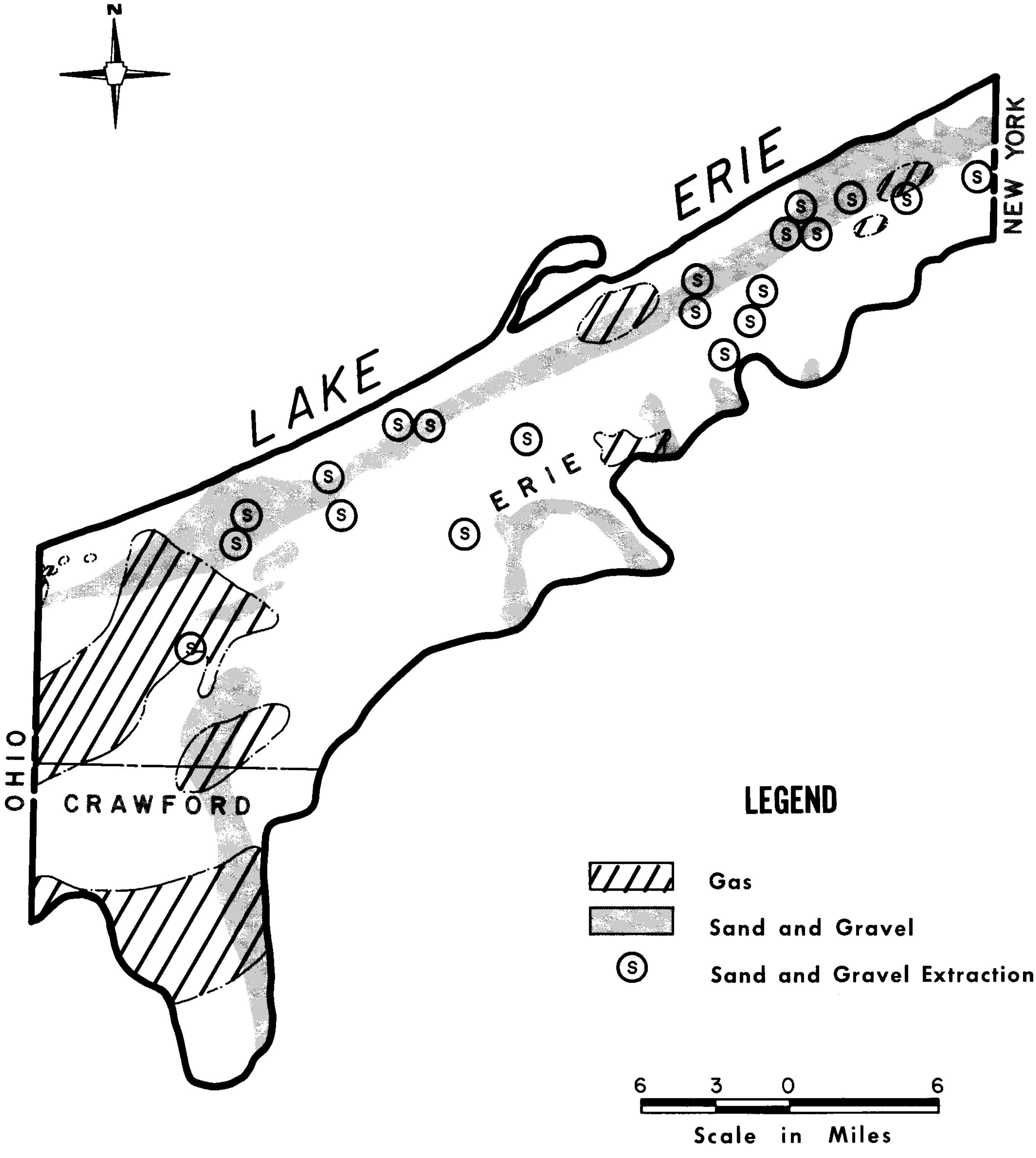
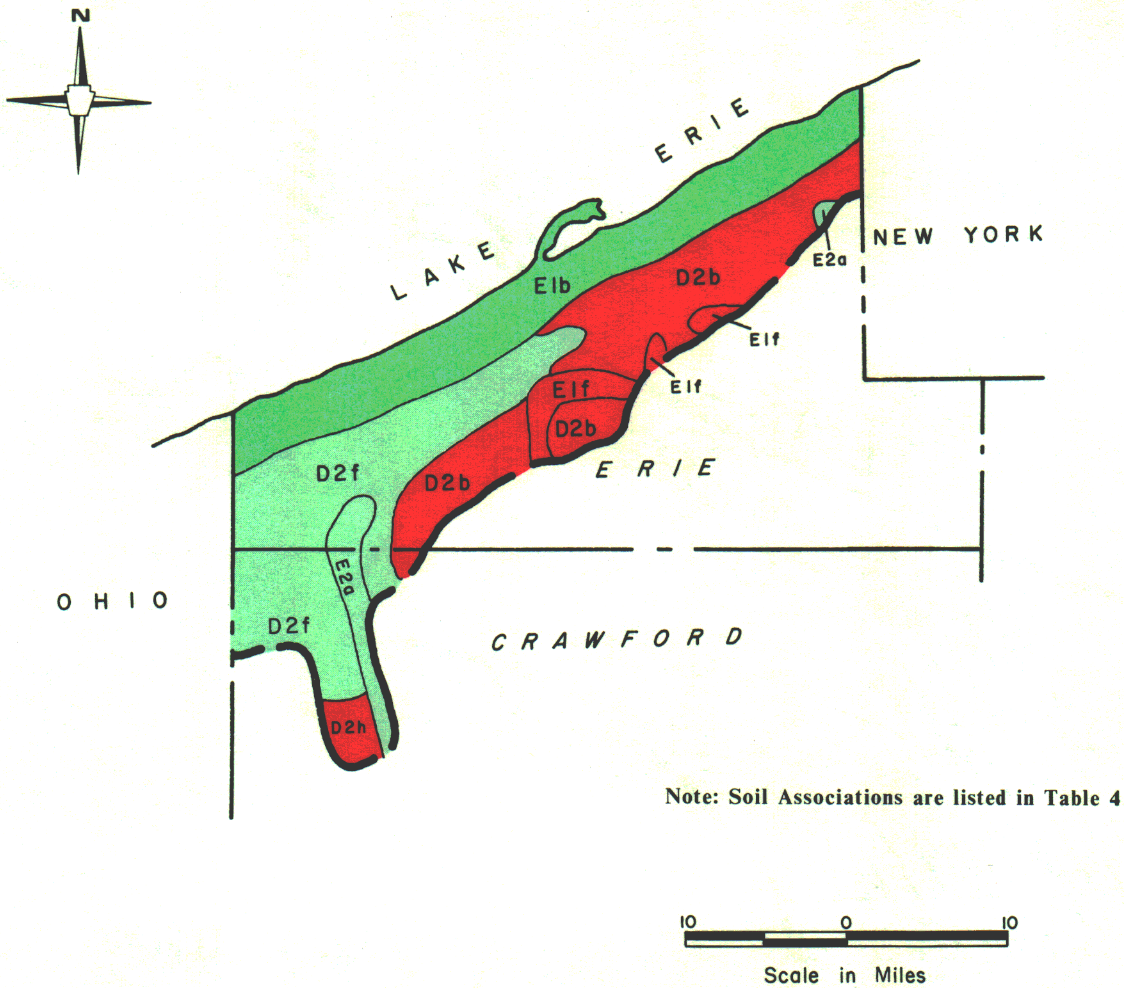


FIGURE 4. Mineral Resources



Hydrologic Group	LEGEND
A	(Low runoff potential.) Soils having high infiltration rates even when thoroughly wetted. These consist chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission in that water readily passes through them.
A—B	Combined properties of soil groups A and B.
B	Soils having moderate infiltration rates when thoroughly wetted. These consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
B—C	Combined properties of soil groups B and C.
C	Soils having slow infiltration rates when thoroughly wetted. These consist chiefly of soils with a layer that impedes downward movement of water or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.
C—D	Combined properties of soil groups C and D.
D	(High runoff potential.) Soils having very slow infiltration rates when thoroughly wetted. These consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

FIGURE 5. General Soils and Hydrologic Characteristics

SOURCE:
GENERAL SOIL MAP OF PA.
USDA. SCS 1972

Table 4

SOIL ASSOCIATIONS

D. Soils formed in glacial till

- D2. Substrata grayish
  - D2b. Erie-Langford Association
  - D2f. Sheffield-Platea Association
  - D2h. Venango-Cambridge Association

E. Soils formed in unconsolidated water sorted materials

- E1. Substrata of stratified fluvial sand, silt, and gravel
  - E1b. Conotton-Birdsall Association
  - E1f. Wayland-Chenango-Braceville Association
- E2. Substrata of lacustrine clay or silt
  - E2a. Canadice-Caneadea Association

moderately drained by a succession of streams that empty into the lake.

The southwestern portion of the subbasin is largely of soils formed in glacial till. The only exception to this is a group of soils along Conneaut Creek that were formed in unconsolidated water sorted materials. Almost all of the soils within this portion of the subbasin have very slow infiltration rates, and are, therefore, of the D hydrologic group. Furthermore, the gently rolling area is poorly drained. The soil depths average 60 or more inches but increase in depth near Conneaut Creek. Here, soil depths exceed 72 inches.

Lastly, the soils of the central and northeastern portions of the subbasin are of the C hydrologic class. The majority of these soils were formed in glacial till, although three small areas of soils formed in unconsolidated water sorted materials also exist. All of these soils are deep and may exceed 72 inches in many areas. In addition, the land is somewhat poorly drained and has a rolling topography.

H. FOREST RESOURCES

Forests affect water resources in both a protective and a depletive manner. They offer protection from floods and erosion, while at the same time contributing to the depletion of streamflows. The latter occurs primarily during the growing season.

Forest soils are covered with litter (leaves and twigs), which acts as a protective layer to the soil and reduces the possibility of sheet erosion caused by raindrop splash and impact on soil. In addition, litter decays and becomes humus, which helps to form a highly permeable layer of soil, in which infiltration rates usually exceed rainfall intensities[8]. This retards runoff from heavy rainfall, thus reducing downstream flood peaks.

However, where the forest floor becomes disturbed, the potential for erosion increases. Soil loss then becomes a function of soil erodibility as well as the length and steepness of slopes.

The amount of soil reaching a stream is affected by the care used in locating and draining the logging road system and maintaining it after logging. For example, one study found that the maximum turbidity from a cutover watershed with no road plan and no provision for drainage was 56,000 parts per million.[9] However, on a similar cutover watershed, with careful planning and drainage, the maximum turbidity was only 25 ppm.[10] For an uncut watershed, the maximum was 15 ppm.

A more recent study in central Pennsylvania reported similar results[11]. Maximum storm turbidity during logging was 550 ppm and could be traced to scarified log loading areas. This decreased immediately after completion of logging and averaged only 11 ppm the following year. On an adjacent uncut watershed, storm turbidity never exceeded 25 ppm during the logging period and averaged less than 5 ppm after logging. These studies emphasize the fact that with careful planning of timber harvesting operations, water quality can be preserved through the reduction of erosion and sedimentation.

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[8]H. W. Lull and K. G. Reinhart, *Research Paper NE-226, Forests and Floods in the Eastern United States*, (USDA Forest Service, Upper Darby, Pennsylvania, 1972).

[9]K. G. Reinhart, A. R. Eschner and G. R. Trimble Jr., *Research Paper NE-1, Effect on Streamflow of Four Forest Practices in the Mountains of West Virginia*, (USDA Forest Service, Upper Darby, Pennsylvania, 1963).

[10]ppm: parts per million.

[11]J. A. Lynch, W. E. Sopper, E. S. Corbett and D. W. Aurand, *Technical Report NE-13, Effects of Management Practices on Water Quality and Quantity: The Penn State Experimental Watersheds*, (USDA Forest Service, Upper Darby, Pennsylvania, 1973).

Table 5

FOREST LAND DISTRIBUTION

County	Total Acres Within Subbasin (1,000's)	Forested Acres (1,000's)	Percent Forested
Crawford	62	25	40
Erie	265	94	35
Total	327	119	36

Source: U.S.D.A. Forest Service, 1974

Table 6

FOREST LAND BY FOREST COVER TYPE

Forest Cover Type	Acres	Percent
Oak-Hickory	32,510	27.3
Aspen-Birch	28,105	23.6
Red Maple	27,033	22.7
Maple-Beech-Birch	22,150	18.6
White-Pine	5,478	4.6
Other Oaks	2,858	2.4
Virginia-Pitch Pine	953	0.8
Total	119,087	100.0

Source: U.S.D.A. Forest Service, 1975

Forests reduce water yield because they consume large amounts of water through transpiration. It has been estimated that, in the northeast, 40 to 60 percent of all precipitation is returned to the atmosphere through the combined processes of evaporation and transpiration and never reaches the groundwater or streams[12].

In view of this, the potential for increasing water yield through properly managed forest cutting practices exists. Several studies, carried out by the U.S. Forest Service, The Pennsylvania State University, and others have documented this potential. Maximum annual increases in water yield by harvest cutting under an even-aged management program, with provision for a protective ground cover, have been found to be about 10 inches or 270,000 gallons per acre cut[13]. In contrast, for an equal volume of timber removed, a selection cutting will provide no more than one-fourth of the increase resulting from the clearcut[12].

Experiments have shown that streamflow increases are largest the first year after timber harvesting. In subsequent years, as regrowth continues, the transpiring surface area increases and the streamflow increase diminishes[14]. Therefore, if maintaining the maximum yield is the primary objective of the watershed management program, forest regrowth will have to be controlled. This will eventually result in a closed cover of herbaceous and low shrubby growth which will prevent site deterioration and adverse water quality effects. Because of variability in factors such as climate, slope, direction of slope, soils, and geology, a considerable variation in the amount and timing of the water yield increase may exist between different watersheds.

Presently, 36 percent or 119,087 acres of Subbasin 15 is forested. However, by 2020 this is expected to increase to 54 percent or 175,997 acres. Most of this increase will be due to abandoned crop and pasture land reverting to forest cover. Table 5 indicates the forested acreage within the subbasin portion of each county in Subbasin 15.

Major forest cover types occurring in the subbasin include oak-hickory, aspen-birch, and red maple. Other cover types include maple-beech-birch, white pine, other oaks, and Virginia-pitch pine. Table 6 contains the acreage distribution of each of these categories.

I. FISH, WATERFOWL, AND FURBEARER RESOURCES

1. *Fish*

The rich and varied fishery resource base of the Lake Erie watershed is dominated by Lake Erie itself and Presque Isle Bay, which is biologically managed as a warm-water inland body of water.

High gradient, short run tributaries flow to the lake east of Erie while longer streams of somewhat more moderate gradient flow to the lake west of Presque Isle Bay. All streams flow down or through the shale Portage Escarpment and consequently they are shallow flows of bedrock or gravel-rubble substrates, often developing deep gorges throughout their courses. Pool development is poor and, except for portions of Conneaut Creek and Elk Creek, sedimentation, siltation and composite-mud bottom substrates are uncommon. These factors more

[12]H. W. Lull and K. G. Reinhart, *Paper NE-66, Increasing Water Yield in the Northeast by Management of Forested Watersheds,* (USDA Forest Service, Upper Darby, Pennsylvania, 1967).

[13]H. W. Lull, *Effects of Trees and Forests on Water Relations,* (University of Massachusetts, Symposium on Trees and Forests in an Urbanizing Environment, 1972).

[14]James E. Douglas and W. T. Swank, *Research Paper SE-94, Streamflow Modification through Management of Eastern Forests,* (USDA Forest Service, 1972).

Table 7

TOTAL NUMBERS OF FISH STOCKED

County	Cold-Water 1970[a]	Cold-Water 1975[a]	Warm-Water 1970[a]	Warm-Water 1975[a]	Total 1970[a]	Total 1975[a]
Crawford	59,430	71,710	7,494,890	35,380	7,554,320	107,090
Erie	283,300	1,190,480	4,280	10,050	287,580	1,200,530

[a]Fiscal year (1970 would be June 1, 1970 to June 30, 1971).

Source: Pennsylvania Fish Commission

often than agricultural and industrial pollution limit the forms of fish life. Municipal sewage, to some extent, may still affect the fishery resource.

Lake Erie lists at least 17 species of fish involved in the sport fishery and 14 or 15 species in the commercial harvest. Only salmonids are stocked in the lake or its tributaries; other species are self-sustaining. Tallying the entire salmonid stocking effort by all state and provincial agencies, 3.6 million salmon and trout were released in Lake Erie in 1977. In recent years, this type of management augmented the traditional warm-water fishery of yellow perch, walleye, smelt, smallmouth bass, suckers, pike, panfishes and other species.

The future development of industrial parks and electric power generation facilities, dredging, stream mouth alteration, watershed channelization, shoreline erosion, nutrient eutrophication and contaminant accumulation in fishes all pose potential threats to the Lake Erie resource base.

Trout ascend several tributaries in late winter through late May and provide large fish along with legal sized stocked trout. In some areas of these tributaries, natural recruitment of trout has been noted. Twentymile Creek, Sixteenmile Creek, Walnut Creek, Elk Creek and Crooked Creek are in this category. Actually, all but the smallest tributaries sustain spawning runs of coho, chinook salmon, steelhead and rainbow trout which support fishing but not necessarily successful spawning.

Seasonally, smallmouth bass, white suckers, smelt and emerald shiners also use the mouths of the larger streams as nursery areas or spawning grounds. Elk Creek, Walnut Creek, Sixmile Creek, Raccoon and Crooked Creeks, Sixteenmile and Twentymile Creeks include such streams. Figure 6 shows the streams which presently support cold- and warm-water fisheries.

Impoundments are few except for some small ponds and reservoirs. Because of the lake and the ready access to Presque Isle Bay with its wide variety and abundance of fishes, the angler public has not demanded reservoir fishing and boating.

The total numbers of fish stocked in the subbasin during 1970 and 1975 are listed in Table 7. Stocking has included northern pike, muskellunge, channel catfish in recent years as well as seven species of salmonids to support the fishery of these species. The development of nursery spawning grounds may show some promise for northern pike management in Presque Isle Bay.

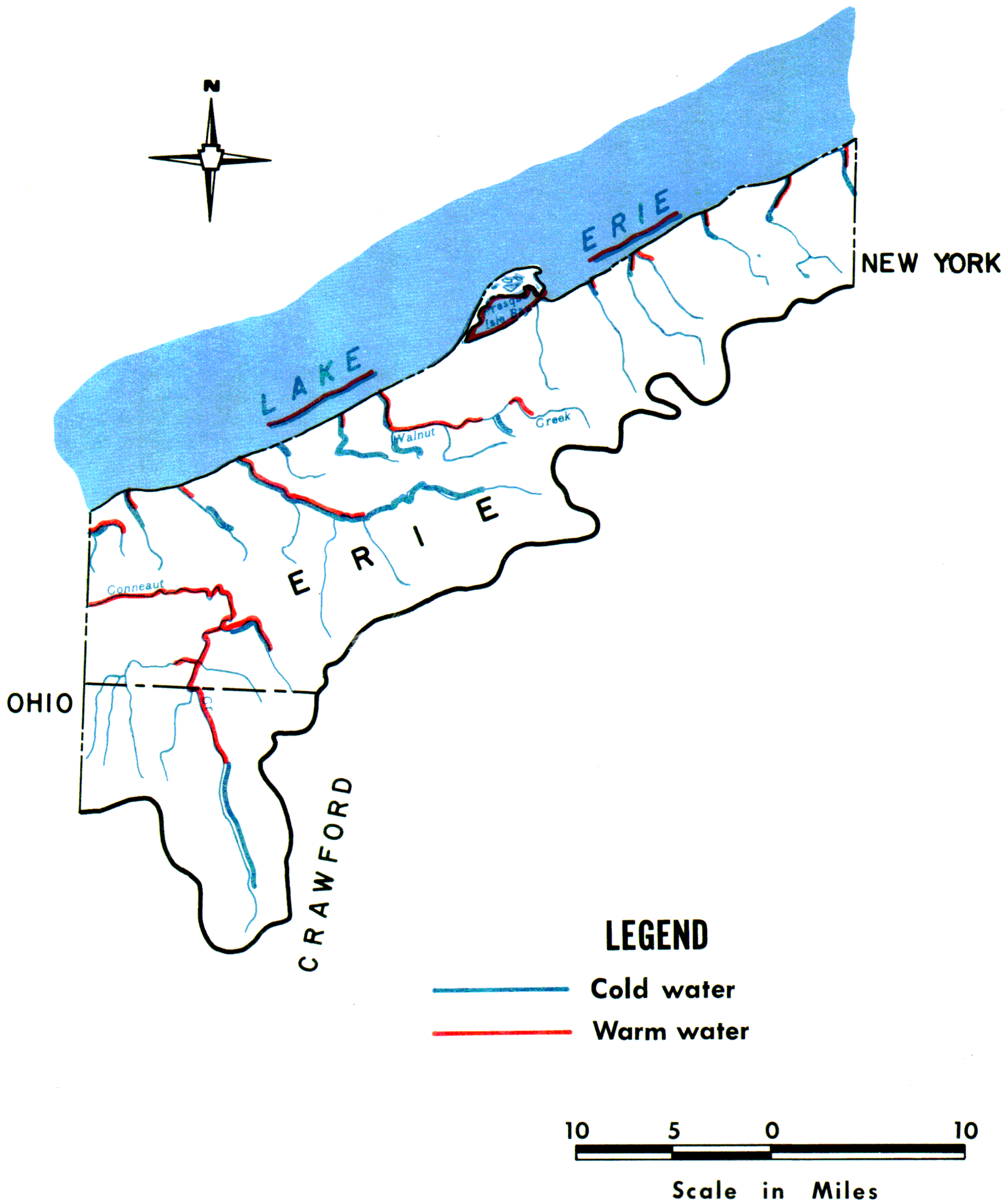
The future management of the fishery revolves about obtaining access to the lake and bay for the increasing numbers of boaters and anglers. The development of small boat launching facilities in the bay and the construction of small boat harbors, launching areas and mooring facilities along the Lake Erie shore are seen as necessary, future projects to bring the user to the available resource.

2. *Waterfowl and Furbearers*

This subbasin is located on a major waterfowl migration route which is part of the Atlantic flyway. Besides being used by whistling swams and Canada geese, it is also the general route taken by pintails, baldpate, teal, wood, and black ducks enroute to and from their breeding grounds.

On a regional basis there are no significant wetlands providing waterfowl habitat within the subbasin, although the inlets and bays of Lake Erie serve as resting areas for migrating waterfowl. There may be some wetlands, however, which are locally significant as waterfowl habitat and produce waterfowl on a sustained basis. Usually, the resident species include black, mallard and wood ducks. Locally important wetlands are not always dependable waterfowl producers because their existence is often threatened by changing land use patterns and natural disturbances such as floods.

Furbearers needing water as a habitat include beaver and muskrat. In addition, mink prefer watercourses as part of their habitat. All of these species, including a high population of beaver, are found within the subbasin.



Source:
Pennsylvania Fish Commission

FIGURE 6. Warm- and Cold-Water Fisheries

IV. SOCIO-ECONOMIC FEATURES

Water resources cannot be managed based on physical characteristics alone. Socio-economic factors play just as much a part in water management as do physical and environmental factors. This chapter, after an initial discussion of the historical development of the area, describes the basic social and economic characteristics which were used in developing this study's conclusions and recommendations. As was true of Chapter III, the information presented in this chapter was developed by or from information provided by other agencies. The Office of State Planning and Development was responsible for much of the information presented in this chapter, along with the U.S. Department of Agriculture's Economic Research Service.

Again the discussions in this chapter are not rigorous. More detailed data for the subjects presented is available from the responsible agencies. In the particular case of land use, significantly more detailed data is now available from several sources including the LUDA system of the United States Geological Survey. Although this more recent land use data was not available for use in the development of this planning report, future water resources planning in conjunction with the State Water Plan will certainly make use of the most up-to-date information available.

It should also be emphasized that statewide plans involving economic development and land use management as well as transportation planning are currently in progress within the responsible State agencies, and coordination with those planning efforts has been a key element in the development of the State Water Plan.

A. HISTORICAL SETTING

Subbasin 15 is a small area that comprises the Erie plain, a portion of the Erie triangle, and the entire shoreline of Lake Erie that lies along the Pennsylvania boundary. Also included is the City of Erie, Pennsylvania's northern-most city and the state's only port on the Great Lakes. This harbor is the best on Lake Erie because it is landlocked by a curved peninsula seven miles long.

The area's first inhabitants were Indians of the Erie nation, from which the lake and, later, the city received their names. They were conquered by the Senecas about 1654, and, thereafter, the region remained under the control of the Iroquois Confederacy. In 1753, a French force originating in Montreal, recognizing the strategic possibilities afforded by the sheltering arm of the peninsula, established a fort at Presque Isle. By 1760, however, French claims to the Ohio Valley had been shattered and Fort Presque Isle was abandoned to the conquering English who soon garrisoned the port.

In 1784, Pennsylvania acquired by treaty with the Six Indian Nations all land in the northwestern part of the state except the triangular tract fronting on Lake Erie, as Connecticut, New York, and Massachusetts had claims to this area. Congress, taking up Pennsylvania's plea for adequate frontage on the lake, requested New York, Massachusetts, and Connecticut to relinquish their claims to the territory. It was, therefore, deeded to the U.S. Government, and in 1792, was sold to Pennsylvania. However, the Indians resisted colonization and permanent settlement was not established until 1795.

The area grew slowly, but by 1805, the town of Erie was incorporated as a borough. The settlements established in the subbasin consisted of small bands of New Yorkers, New Englanders, Scotch-Irish, and German pioneers from southern Pennsylvania. As settlement increased, sawmills, gristmills, brick yards, foundries and other enterprises developed.

The subbasin is ideally suited for farming. Lake Erie was once larger, and the total plain is the bed of the once huge lake, thus the soil is very fertile. Lake Erie also tempers the climate, prolonging the normal growing season while providing a constant cooling breeze. These factors combined make the area suitable for farms, orchards and vineyards, while the port serves as the distribution center for agricultural products.

Prior to the War of 1812, there were about a dozen merchant ships operating on Lake Erie, with salt and furs the principal commodities. By 1826, however, three steamboats and several schooners cleared from the port every week, and by 1846, daily steamboat service had been established between Erie and Buffalo. With the opening of the Erie and Pittsburgh Canal in 1844, and the advent of the railroads in the 1850's, the area grew considerably.

In addition to the transportation facilities, the lake provided water for Erie and its industries, and the port became a magnet for industrial and commercial development. Thus, the lake indirectly contributed to the population composition, for Germans, Poles, Russians, Italians, and other nationalities were drawn to the area in the late nineteenth century, not only by the mills and factories, but also by the fishing and shipping. Ships delivered pulpwood, iron ore, limestone, and grain to the area and carried out coal, oil, and manufactured products.

The subbasin has experienced steady growth and a stable economy through the years. Commercial fishing on Lake Erie, once among the nation's most prolific fishing, has suffered a serious decline from pollution, although some steps are being taken to revitalize the lake. There has been some unemployment in the City of Erie, but civic leadership and State aid are creating new employment opportunities for the area.

Table 8

HISTORICAL AND PROJECTED EMPLOYMENT BY INDUSTRY

Industry	Erie Labor Market Area 1970	Erie Labor Market Area 1990
Agriculture	1,900	666
Mining[a]	12	7
Contract Construction	4,853	6,674
Manufacturing	44,980	54,264
Transportation, Communication and Public Utilities	5,739	7,026
Wholesale and Retail Trade	21,430	27,515
Finance, Insurance and Real Estate	3,626	6,162
Services	17,740	27,988
Government	11,100	19,070
Totals	111,380	149,371

[a]Employment in mining category may be affected by recent National energy policies.

Source: Pennsylvania Office of State Planning and Development, *Pennsylvania Projection Series*, 1973.

B. ECONOMY AND EMPLOYMENT

Economic development is closely related to the availability, development, and use of water resources. Past economic conditions have dictated the extent to which water resources have been utilized. Therefore, a forecast of economic conditions will help to determine when and to what extent future water resources development is likely to occur. The most fundamental concept which can be used to define Pennsylvania's future economy is employment[15]. By observing which types of employment exist in the subbasin and the trends of each type, general observations concerning the possible trends in water resources development and use can be made.

Subbasin 15 falls within two labor market areas whose boundaries do not coincide with the subbasin. The Erie Labor Market Area includes all of Erie County, although only the western half of the county is actually located within the subbasin. The northwest corner of the Meadville Labor Market Area includes all of Crawford County, which is located partially within the subbasin, but it is included in the study of economy and employment in the Subbasin 16 report.

Employment by industry for 1970 and projections for 1990 for each of the nine categories are listed in Table 8.[16] Seven of the nine categories in the Erie Labor Market Area are expected to increase in employment during the twenty-year period. Those categories expected to decline in employment are *Agriculture* and *Mining*.

Employment trends in the *Agriculture, Mining, Contract Construction* and *Manufacturing* categories are more closely related to water use than are the remaining five categories in Table 8. Although employment in the *Agriculture* category is projected to decline, two key factors, the value of farm produce and total acres harvested, have both increased during the past five years.[17] In addition, the amount of vegetable and fruit acres on which irrigation may be used, have also increased. Therefore, even though employment in *Agriculture* is projected to decline, it would appear that the need for water, especially for irrigation, is going to continue to expand.

Similarly, although the number of employees in mineral industries is expected to decline, DER information indicates that water use by mineral industries will continue to grow gradually for the next 20 years. An increase in employment is projected in the *Contract Construction* industry Some of this construction represents new development, including urbanization. Water use will increase with this apparent build-up. The most important category as far as water use is concerned is *Manufacturing*, which also shows an increase in employment. This implies increased production which could require more water use. In this subbasin, primary water users include paper, apparel and plastic industries.

Another measure of the subbasin's economy is found in the ranking of individual counties with regard to two factors: 1) Economic Growth and 2) Level of Economic Development. Economic Growth is based on a composite of equally weighted factors which generally describe each county's growth in terms of changes in population, market value of real estate, aggregate personal income and value added by manufacture. The level of Economic Development is also based on a composite of equally weighted factors which generally describe each county's status in terms of standards of living, industrial sophistication, economic diversification, urbanization, and infrastructure development. Growth was not a factor used in determining a county's development status. By utilizing a breakdown of counties into five categories: (1) high, (2) moderately high, (3) moderate, (4) moderately low, and (5) low, rankings of economic growth and economic development have been established by the Office of State Planning and Development[18]. In this subbasin, Erie County enjoys the first or high level of economic growth as well as the high level of economic development.

[15]Office of State Planning and Development, *Pennsylvania's Economy, Interim Report Technical Working Memorandum No. 1, Pennsylvania Economic Program for Balanced Growth*, (Harrisburg, 1974), p.1.

[16]Office of State Planning and Development *Employment, Pennsylvania Projection Series*, (Harrisburg, 1973).

[17]Bureau of Statistics, *Pennsylvania Statistical Abstract 1971 and 1973*, (Department of Commerce, Harrisburg).

[18]Fritz J. Fichtner Jr. and Fong L. Ou, *Comparative Study of Economic Development in Pennsylvania*, (Office of State Planning and Development, Harrisburg, 1973).

Table 9

WATERSHED AND COUNTY POPULATIONS

Watershed	1970	1980	1990	Percent Increase
A	232,487	236,833	253,096	8.9

Source: DER allocations of O.S.P.D. county projections, 1973.

County	1970	1980	1990	Percent Increase
Erie	263,654	270,809	290,416	10.2
Crawford	81,498	83,353	86,639	6.3

Source: Office of State Planning and Development, 1973.

C. POPULATION

Population projections for each of Pennsylvania's counties have been developed by the Office of State Planning and Development. Their projections of population are conceptually tied to the projections of economic trends, as discussed in the Economy and Employment section. To allocate the projected county populations to the watershed areas, population allocation models developed by State Water Plan staff were employed.

Projected populations were used directly to evaluate future water supply and waste treatment requirements. In addition, population distributions and concentrations are important factors in the analysis of the flood damage reduction needs, including urban storm runoff management, and industrial water supply and power generation cooling requirements.

Population figures and projections for Subbasin 15 from 1970 to 1990 are listed by subbasin and county in Table 9. Subbasin 15 as well as Erie and Crawford Counties show a small but steady increase in total population during the 20-year period. The projections do not include the increase in population in those two counties, which may result from a proposed U.S. Steel Plant. Currently, this plant is proposed to be located along the southern shore of Lake Erie at the Pennsylvania-Ohio state line. The largest population is found in the City of Erie and the surrounding suburbs in Erie County. Located northeast of the Erie urbanized area in the same county, the community of North East is the center of a second population concentration.

D. TRANSPORTATION

Transportation is a key factor in the establishment of a sound economic base in any area. Good transportation facilities are mandatory if an area is to experience any substantial economic growth. Transportation also has a major influence on land development which in turn affects water resources.

The most important method of transportation available today in terms of moving people and goods and influencing land development is the highway system. As is true in most counties of Pennsylvania, the existing highway network in Erie County represents a complex pattern. Tracts of land were originally laid out in grids with boundaries at true north-south and east-west directions so that the initial road systems tended to follow a gridiron pattern. In the developing stages of land parcelization there evolved more streets in a north-south direction than in an east-west direction; however, the predominant travel pattern, particularly along the lake plain, is in an east-west direction.

There is a total of 2,192 miles of roads in Erie County which includes private as well as public roads. Of this total, 65.6 miles are in the Interstate system (I-79 and I-90), 21 miles are principal arterials, 189 miles are minor arterials, and 340 miles are major collectors. The balance of highways in Erie County, approximately 1,576 miles, would be considered local streets.

In Erie County, a more than an adequate system of rail lines traverses the subbasin. At the present time there are four railroad companies serving the county. Conrail (formerly Penn Central), and Norfolk and Western maintain service to points east and west of the subbasin while only Conrail extends service to southeastern points. The Bessemer and Lake Erie Railroad is concentrated in the western sector of the subbasin. The fourth railroad is the East Erie Commercial, a switch road, in the port area. In general east-west rail service within the Erie subbasin is far superior to north-south service.

Area passenger service is under control of Amtrak using the east-west Conrail line. The Lake Shore Limited provides passenger service from New York to Chicago stopping in Erie. No train service is available directly south to New Castle, Youngstown or the Pittsburgh area.

The quantity of freight movements within the subbasin is determined to a large extent by the local economy and movements in or out of the port of Erie. The Conrail System has extensive freight yards locally and major control of the waterfront maintaining connections to the south central part of the state, Harrisburg and Philadelphia.

Subbasin 15 is served by the Erie International Airport located just west of the City of Erie in Millcreek Township. Allegheny, Mohawk, and Keystone Commuter Service presently utilize the airport for commercial flights providing jet prop service through interconnecting airports to the total air system of the United States.

The prime system of mass transit in the subbasin is the bus system operated by the Erie Metropolitan Transit Authority. The Erie Metropolitan Transit Authority (EMTA) operates an integrated mass transit system covering 57 route miles within the City of Erie and the adjacent urbanized area of Lawrence Park and Wesleyville to the east and Millcreek Township to the south and west.

The Port of Erie is one of the few natural harbors on the Great Lakes. The traffic in coal, iron ore and grain, which for many years accounted for most of Erie's port traffic, has disappeared and the growth of general cargo has been less than originally hoped for. Competing ports have been expanded and improved facilities of those ports have contributed to the decline in Erie's port traffic. The St. Lawrence Seaway, although it contributed to the diversion of Erie's grain traffic to other ports, still provides a potential for the port. New industry is being attracted to the community and promotional efforts are expected to produce more traffic for the port. The Port of Erie consists of two major areas; the harbor with its inlet entrance channel, and the waterfront which includes commercial port facilities such as docks and piers for handling various types of cargo.

E. LAND USE

1. *Water Resources Implications*

The wise utilization of our land and water resources has emerged as an important concern during this decade. Because of the close environmental interrelationship existing between land use and water management, land and water resources cannot be viewed as separate entities. Land use patterns and decisions can exert a tremendous impact on the quantity, quality, and utilization of surface and groundwater. Also, hydrologic processes and water resources management decisions profoundly influence existing and future land use patterns in the subbasin.

Land uses have been broken into four categories for this report: *Urban or Built-Up, Agriculture* (including open, cropland and pasture), *Forest*, and *Other* (including Federal noncropland, water areas, disturbed land, and miscellaneous uses). Each of the land use categories can have a significant impact on water resources.

Urban or Built-Up areas consist of residential, commercial and industrial development. If the location, intensity and type of urban development is not properly planned and compatible with the surrounding natural environment, urbanization can adversely effect an area's water resources and overall environmental quality. For example, increases in impervious ground cover and the alteration of natural drainage patterns associated with urban development lead to increased surface runoff. Increased surface runoff causes greater flood magnitudes to occur more frequently, and increases the potential for increased erosion of the land and sedimentation of the streams. Impervious surfaces also decrease the amount of water infiltrating into the soil, thereby reducing recharge of groundwater supplies and lowering streamflows during droughts.

In addition, urbanization can also adversely influence surface water and groundwater quality. Water pollutants emanating from urban environments include discharges from sewage treatment facilities and industrial plants, as well as contaminants picked up by stormwater runoff. Finally, urban development of the floodplain increases flood damages and destroys the valuable resources and amenities of the floodplain environment.

Agricultural lands are important environmental resources because of their capability to produce food and fiber, to serve as valuable wildlife habitat and open space, and to provide attractive landscapes. Agricultural lands can serve as important groundwater recharge areas. Geological formations associated with prime agricultural soils often yield high quantities of groundwater.

Mismanagement of agricultural lands can create water pollution problems. Groundwater near agricultural areas becomes contaminated with nitrates and bacteria unless proper precautions are taken. Soil erosion increases the amount of sediment entering streams. Excessive applications of fertilizers and pesticides also degrade the water quality of surrounding streams.

Forests and woodlands provide valuable timber resources, wildlife habitat, recreational opportunities, and are important components of basin hydrology and water resources management. Vegetative cover decreases storm runoff, thereby reducing flood potential and soil erosion. Vegetative cover also increases the infiltration of water into the ground, which enhances groundwater recharge and supplies. Streams located in forested areas often serve as public water supplies, and properly managed forests will assure the protection of these supplies. However, the misuse of forest resources can degrade forest resource values and aggravate water resources problems.

The impacts of *Other* lands on water resources will depend upon the type of land use. Federal noncropland, water areas, and miscellaneous lands preserve land and water areas which can be used for water storage and supply. Disturbed lands or areas utilized for mineral extraction, on the other hand, could adversely affect water resources. Mineral extraction can have a significant impact upon environmental quality and water resources management. The potential for blighted landscapes,

Table 10

EXISTING AND PROJECTED SUBBASIN LAND USE

Land Use	1974 Acres	1974 Percent of Total Area	2020 Acres	2020 Percent of Total Area	Change Acres	Change Percent
Urban or Built-Up	35,050	11	60,046	18	24,996	71
Agriculture or Open	113,506	35	71,806	22	–41,700	–37
Forest	119,087	36	175,997	54	56,910	48
Other	59,689	18	19,484	6	–40,205	–67

Source: U.S. Department of Agriculture, Economic Research Service

interference with groundwater recharge, and water pollution are some of the problems which may be related to mining.

Conversely, water resources also play an important role in determining land use patterns. The Historical Setting section in this chapter describes how water resources influenced past settlement and economic development patterns in the subbasin. Water resources and decisions affecting their use will continue to exert a significant impact on emerging land use patterns.

For example, the construction of reservoirs may lead to the inundation of agricultural, forested and urban land, as well as increasing secondary development in surrounding areas by enhancing water supply and recreational opportunities. The extension of public sewer and water supply systems into rural areas can accelerate the conversion of agricultural and forested lands to urban uses. Floodplain management by local governments can decrease the amount of urban development occurring on the floodplain. Water supply deficiencies and consumptive water makeup requirements could also impact upon the expansion of urban development and agricultural water use in many watersheds throughout the State.

Many existing water resources problems have been precipitated and augmented by past land use practices. The historical development of Pennsylvania's floodplains has magnified the devastation and hardship created by recent floods. The impact of historic mining abuses continues to blight Pennsylvania's landscape and pollute water resources. Because of these precedents, current and future decisions affecting the management and development of land and water resources should not overlook the inherent and complex interrelationships between these resources.

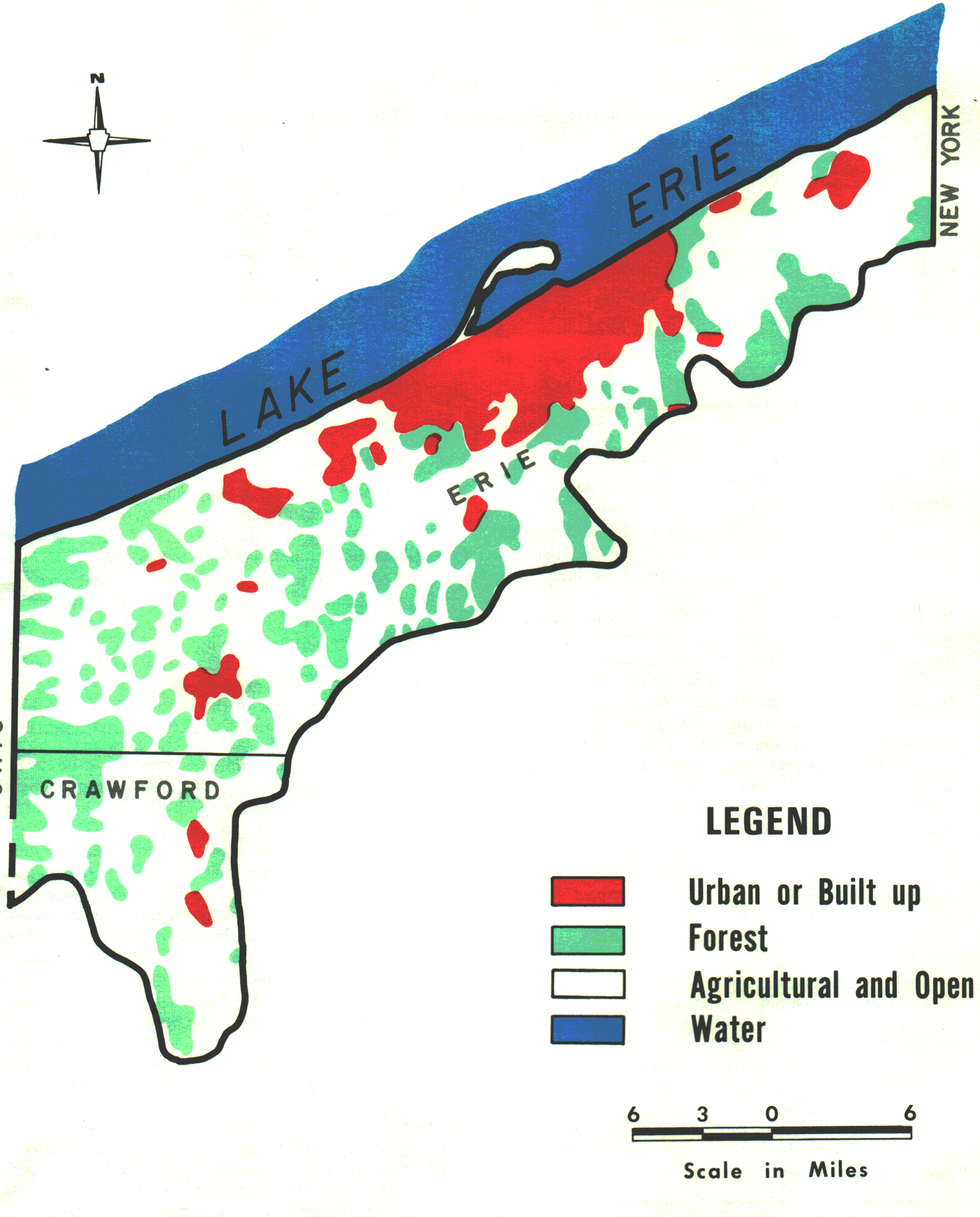
The careful consideration of environmental factors in land and water resources planning and decision-making processes will help minimize environmental quality and resource management problems. Although environmental concerns comprise only one aspect of water resources management plans and decisions, their consideration in the planning process can establish a sound basis upon which social and economic land use objectives can be guided.

2. *Existing Land Use*

The number of acres and the percent of each land use category in the subbasin are shown in the left side of Table 10 and illustrated on Figure 7. At the present time, *Forest* is the dominant land use comprising 119,087 acres, which accounts for 36 percent of the total area. Only slightly smaller, *Agriculture* land use encompasses 113,506 acres, which amounts to 35 percent of the subbasin's area. *Other* land use occupies 59,689 acres, or 18 percent of the total area. The smallest land use category, *Urban,* encompasses only 35,050 acres, which amounts to 11 percent of the subbasin's area. Table 11 lists existing land uses in Erie and Crawford Counties.

Some changes in land use patterns can be detected when comparing two land use maps compiled by the Office of State Planning and Development at the beginning and end of a thirty-year interval. The amount of land classified as *Urban* on the 1967 map, Figure 7, compared to the *Urban* land area on a 1937 map (not shown), has increased markedly in several areas[19]. The increase in *Urban* land use is particularly noticeable along the lake, west and east of the City of Erie. *Urban* growth has taken place at the expense of land designated as superior and above average farmland according to the 1937 land use map. As new urban areas continue to expand into above average and superior farm land, the diminution of prime agricultural land in the subbasin will be assured. The extent of possible loss in prime agricultural land is indicated by Table 12, which shows how much agricultural land is currently available and could potentially be lost to urban expansion in the absence of any zoning controls. In contrast to Erie County, the loss of prime agricultural land to urban growth could be less pronounced in Crawford County. Nevertheless, the loss of prime agricultural land to urban use stimulates the cultivation of lands of lesser quality. The result is lower

[19]Pennsylvania State Planning Board, *Susquehanna, Potomac, Genesee River and Chesapeake Bay, Part III, Drainage Basin Study of Pennsylvania*, (Harrisburg, 1937), Map, p.4.



Source:
Office of State Planning
and Development, Commonwealth
of Pennsylvania

Note:
Generalized from Aerial Photography and Data, 1958 to 1967.

FIGURE 7. Land Use

Table 11

EXISTING COUNTY LAND USE

County	Urban Acres	Urban %	Agriculture Acres	Agriculture %	Forest Acres	Forest %	Other Acres	Other %	Total Acres	Total %
Erie	56,670	10.2	179,501	34.5	189,409	36.4	98,100	18.9	519,972	100
Crawford	26,100	4.2	280,400	43.1	299,037	46.0	44,703	6.9	650,240	100

Source: U.S.D.A., Economic Research Service, 1974.

Table 12

EXISTING PRIME AGRICULTURAL SOILS

County	Class I Soils[a] Acres	Class I Soils[a] % in County	Class II Soils[a] Acres	Class II Soils[a] % in County	Classes I and II Acres	Classes I and II % in County
Crawford	10,750	1.7	83,505	12.9	94,255	14.6
Erie	7,095	1.4	98,456	18.9	105,551	20.3

[a]Class I and II soils are often considered prime agricultural land or land with high potential productivity.

Source: U.S.D.A. Economic Research Service, 1974.

crop yield, higher cost, and more important, increased erosion and sedimentation, which, in turn, adversely affects water quality and supply. Some mechanisms to preserve agricultural land subject to intense urban development pressure are listed in "A Land Policy Program for Pennsylvania,"[20] prepared by the Office of State Planning and Development.

3. *Future Changes*

A comparison of the subbasin's present land use with its projected 2020 land use is shown in Table 10. Also shown in the last columns is the projected acreage and percent of change within each land use category. From 1974 to 2020, the projected ranking of the four land use categories will vary slightly. *Forest* will remain the dominant land use followed by *Agriculture*. However, *Other* land use, while being replaced by *Urban* as the third leading land use in 2020, will fall from third to fourth in the land use ranking. By 2020, it is projected that 54 percent of the land area in the subbasin will be classified as *Forest*. This is an increase of 56,910 acres or 48 percent over the 1974 *Forest* land use total. It appears that forestland will increase at the expense of marginal agricultural land, which will revert back to its original forest cover. At the end of the 46-year period, *Urban* land use is projected to continue to occupy 18 percent of the subbasin, an increase of 24,996 acres or 71 percent over the 1974 *Urban* land use total. This expansion in urban land could take place at the expense of prime agricultural land which has the best characteristics for development. *Other* land use is projected to comprise only six percent of the subbasin by 2020. This is a decrease of 40,205 acres or a decline of 67 percent from the 1974 *Other* land use total. *Other* land use will probably continue to lose acreage to *Forest* and *Urban* land uses. The largest acreage loss in the subbasin is found in the *Agriculture* land use category. By 2020, *Agriculture* land use is expected to occupy 22 percent of the subbasin, a decrease of 41,700 acres or 37 percent below its 1974 land use total. In the future *Agriculture* land use will continue to lose acreage as *Urban* land use expands.

As previously stated, present land use categories are based on the intensity of development as reflected in population concentrations. The projection of future land use categories by watershed can also be determined by intensity of development based on projected increases in population and urbanization. Urbanization of land is defined as clustered construction of residential, commercial, and industrial establishments, the extension of a sewage collection infrastructure, the extension and widening of roads, etc. This process includes suburbanization, which may be seen as an early stage in the urbanization process.

The projected percentage increases in population and urbanization from 1970 to 1990 for Subbasin 15 are listed in Table 13. As indicated in the table, Subbasin 15 will continue to show a percentage increase in both population and urbanization. As a result, *Agriculture* will continue to be challenged by *Urban* land use.

[20]Office of State Planning and Development, *Land Policy Program for Pennsylvania, an Interim Policy Report*, (Harrisburg, April 1976), p.40.

Table 13

PROJECTED CHANGE IN WATERSHED POPULATION AND URBANIZED LAND

	Population			Percentage of Urbanized Land in Watershed		
Watershed	1970	1990	% Change	1970[a]	1990	Change
A	232,487	253,096	8.9	16.1	17.4	1.3

[a]Source: *Generalized Existing Land Use* map, Office of State Planning and Development, 1967.

V. WATER RESOURCES PROBLEMS AND SOLUTION ALTERNATIVES

Based on analyses of existing and projected conditions, future water supply, flood control, water-related outdoor recreation, water quality, and wild and scenic rivers problems have been identified. Possible alternative solutions to water supply, flood control and water-related outdoor recreation problems have been identified and examined.

Through a preliminary reconnaissance level assessment of physical, economic, environmental and social factors, supplemented by regional Water Resources Advisory Committee comments and input, the alternative solutions have been narrowed. The "recommended projects or actions" listed in this chapter are those which merit further detailed consideration as indicated by initial analyses. It should be emphasized that full environmental, social or economic analyses have not been conducted for each alternative. The purpose of this assessment is to screen those potential projects, programs and actions which, as concepts, deserve further study, refinement and possible implementation. If detailed studies of an alternative have been conducted, including where necessary an assessment of social, environmental and economic effects, the State Water Plan may recommend implementation by the appropriate agencies or parties.

The State Water Plan is a plan for resource management; it has been prepared as a tool for decision-making at the State, regional and local levels. The Plan is also a prime input by the Commonwealth to the development of water management policy and actions at the national and interstate levels. The Plan's selection of recommended alternatives was based on an assessment of basinwide and State concerns. These recommended alternatives may not be the most expedient or easiest solutions to each local problem. Because water is a shared resource, whose use and conservation affects the citizens, economy and environment of entire watersheds and the Commonwealth, the State Water Plan has attempted to identify those alternatives which best address the problems and interests of the whole basin and region.

It should be further emphasized that a prime purpose of the Plan is to provide vital information regarding water resources availabilities and problems, for use by decision-makers in both the public and private sectors. The problems discussed in this chapter are based on projections of current trends. However, such trends may not be optimal, or even desirable. Based on information provided in this Plan, as well as other relevant factors, State, regional and local agencies and private citizens may adjust land use planning, regulatory policies and investment decisions in a manner which avoids or moderates projected problems. This Plan's data and analyses regarding water resources should be a major consideration in decisions regarding future population distributions, the location of major development, and selection of technologies and processes which involve water use. Future work on the State Water Plan, as part of the continuing planning process, will include periodic revision of projections based on updated information. It is also intended that an "alternative future" analysis be conducted in the continuing planning process, in order to provide more detailed information to public and private decision-makers regarding the implications of possible options in land use development patterns and the use of alternate technologies.

A. WATER USES

Water is used for a variety of purposes, generally classified in one of two categories, either *instream* uses or *withdrawal* uses. Instream uses, which utilize water in place in lakes and water courses, include navigation, swimming, boating, fish and wildlife habitat, water quality maintenance, hydropower, and general environmental and aesthetic values. Withdrawal water uses are those which require the prior removal of water from its source and include both consumptive and nonconsumptive uses, consumptive uses being those which preclude the return of some or all of the water to the source. This section deals primarily with withdrawal uses.

Parts 1 and 2 focus on uses which divert or withdraw surface and ground waters. Part 1 includes a broad examination of withdrawal uses on both the watershed and subbasin levels; while Part 2 concentrates on existing and projected uses and problems of public water suppliers based on detailed analyses, and further discusses alternative and recommended solution concepts.

Part 3 examines consumptive and interbasin transfer withdrawal uses which may affect the availability of water for instream uses, particularly during periods of low streamflow. Alternative solutions for consumptive water use makeup are also discussed; however, no recommendations are made because more detailed studies are needed.

1. WATERSHED WATER USES AND REUSE

a. *Watershed Total Water Uses*

Withdrawal water uses have been divided into six categories for study purposes:

(1) Public water supply – Water which is sold to the public by water supply companies, water authorities or municipalities.

(2) Self-supplied industrial – Water withdrawn by either manufacturing or mineral industries from their privately owned sources or intakes.

(3) Self-supplied electric power generation – Water withdrawn for cooling purposes by electric generating facilities from their privately owned sources or intakes.

(4) Self-supplied agricultural – Water withdrawn by agricultural enterprises from privately owned sources or intakes and used for either irrigation or livestock operations (does not include domestic uses on farms).

(5) Self-supplied institutional – Water withdrawn from privately owned sources or intakes for use by institutions including schools, hospitals, correctional institutions and golf courses.

(6) Self-supplied domestic – Water withdrawn from privately owned sources (usually wells) for domestic use in private residences.

The total water use projections for all six categories of water use in the subbasin are listed in Table 14. The tables list the total and consumptive water uses in 1970 and projected uses for the years 1980 and 1990. The consumptive water use is the summation of consumptive losses and interbasin transfer losses. It can be seen from the table that interbasin transfer losses mainly result from public water supply uses. This is because of the spatial distribution of their sources and discharge points. Interbasin transfers may occur if a water supplier's sources are located in a different watershed than the discharge point of the sewage treatment facilities. The table list the net effect of interbasin transfers, taking into account both the export and import of water. Under the interbasin transfer column in the table, a positive figure indicates a loss of water from the subbasin, whereas a negative figure indicates a gain of water to the subbasin.

As shown in Table 14, the 1970 total water use was 389 mgd of which 300 mgd was used by Front Street Power Generating Station, 48 mgd was used for public water supply, 36 mgd was used by self-supplied manufacturing industries, and about 5 mgd was used by the remaining categories of water use.

The total water use is projected to decrease to 382 mgd in 1980. This will be caused by increased recirculation of processing water in two of the large self-supplied manufacturing industries. By 1990 total water use is projected to decrease to 295 mgd due to the retirement of Front Street Generating Station Units 2 & 3 in 1984. The total consumptive water use including interbasin transfer in 1970 was 9.7 mgd. Consumptive water use is projected to increase to 12.9 mgd in 1980 then to 23.3 mgd in 1990. This large increase will be due to cooling water requirements of the proposed Coho Electric Generating Station. It should be noted that Units 1, 4 and 5 of the Front Street Power Generating Station are planned for retirement in 1990, but the corresponding reduction in their water use and consumptive use are not reflected in Table 14.

b. *Use Intensity*

Figure 8 shows a comparison of total supply and total use upstream from the shore line of Lake Erie in Subbasin 15. The supply is represented by a daily duration curve, which indicates the total subbasin streamflow which is equalled or exceeded for any given percentage of time. This curve indicate not only the total flows available, but by its slope also indicates the reliability of the flows. A flat duration curve would indicate a stream with very steady flows; whereas a steep duration curve applies to a flashy stream on which flows are exceptionally high during periods of rainfall but recede quickly as the weather clears. The ultimate example of a flashy stream would be an erosion gully in a field, which is dry most of the time and sustains flows only during a rain. Exceptionally steady streamflows occur in limestone areas where rainfall infiltrates to the groundwater rather than contributing heavily to runoff and where underground storage contributes heavily to streamflows during dry conditions, thus maintaining higher low flows. Streams draining larger areas also tend to have flatter duration curves because the effects of localized heavy rain or drought conditions are minimized by flows originating in other areas of the drainage basin.

By overlaying the line representing total water use above the shoreline of Lake Erie upon the graph of the duration curve for that location, it is possible to compare the supply and its reliability against the total use. Although this comparison is of limited hydrologic value, it does provide a visual indication of the intensity of water use upstream of a selected location or the probability for water reuse to occur.

Reuse occurs when water returned to the stream by upstream users is used again by downstream users. The probability of this occurring is indicated by the percentage of time that total water use exceeds flow, as shown on the duration curve. An important consideration regarding reuse is potential degradation of water quality. Although many other factors affect water quality more directly, intensive use usually results in some degree of water quality degradation. Because the potential for degradation increases with reuse, effective water quality management

(Continued on page 33)

Table 14

SUBBASIN WATER USE TOTALS

(Subbasin 15) Type Use	1970 Water Use (mgd[a])						1980 Water Use (mgd[a])			1990 Water Use (mgd[a])		
	Groundwater Withdrawal	Surface Water Withdrawal	Total Withdrawal	Total Water Use	Consumptive Losses	Interbasin Transfer Losses	Total Water Use	Consumptive Losses	Interbasin Transfer Losses	Total Water Use	Consumptive Losses	Interbasin Transfer Losses
1) Public Water Supply:	1.519	44.438	45.957	47.653	4.765	−1.384	48.476	4.848	−1.354	51.743	5.174	−1.455
2) Self-Supplied Industry												
a) Mineral:	0.010	0.010	0.020	0.020	0.001	0.000	0.025	0.001	0.000	0.031	0.002	0.000
b) Manufacturing:	1.199	34.936	36.135	36.135	2.762	0.000	24.484	2.439	0.000	19.364	2.457	0.000
3) Self-Supplied Power[b]:	0.000	127.031	299.930	299.930	0.155	0.000	299.930	0.155	0.000	213.530	9.502	0.000
4) Self-Supplied Agriculture[c]												
a) Livestock:	0.380	0.042	0.422	0.422	0.316	0.000	0.328	0.246	0.000	0.363	0.272	0.000
b) Irrigation:	1.410	0.110	1.520	1.520	1.520	0.000	4.894	4.894	0.000	5.518	5.518	0.000
5) Other Self-Supplied												
a) Golf Course:	0.619	0.706	1.325	1.325	1.325	0.000	1.458	1.458	0.000	1.590	1.590	0.000
b) Institution:	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6) Self-Supplied Domestic:	1.968	0.000	1.968	1.968	0.197	0.000	2.302	0.230	0.000	2.782	0.278	0.000
Totals:	7.105	207.273	387.277	388.973	11.041	−1.384	381.897	14.271	−1.354	294.921	24.793	−1.455

[a]mgd: million gallons per day

[b]Power projections are for thermoelectric power generation only and do not include hydroelectric water use. Thermoelectric power generation water withdrawals and total usages reflect plant requirements when operating at design capacity.

[c]Agricultural irrigation and livestock projections are preliminary estimates, not to be used for allocation or other regulation of water use.

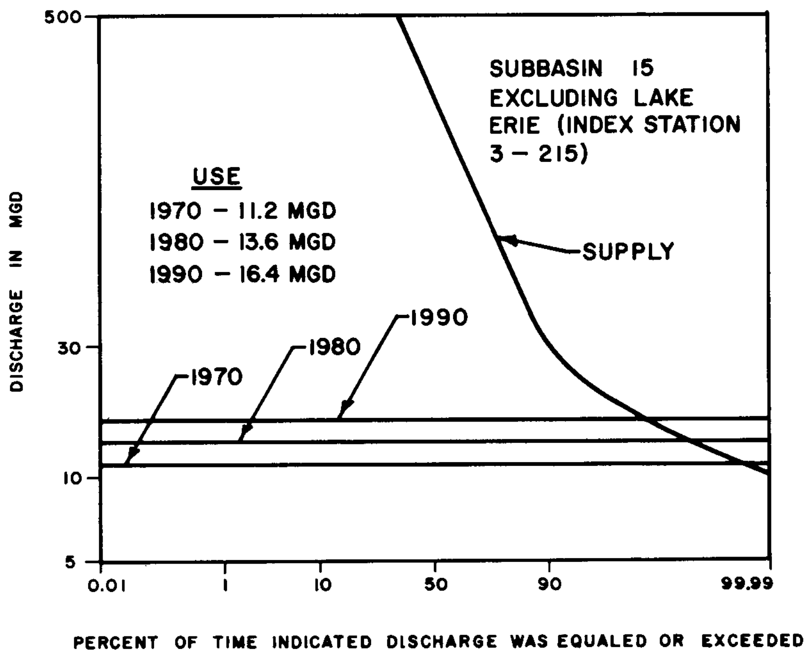


FIGURE 8. Comparisons of Supply and Use for Selected Drainage Area

becomes increasingly important with reuse to protect not only the stream itself, including instream uses, but also the downstream users. As shown on Figure 8, the use intensity in this subbasin is quite low. Further water resources development is possible in the subbasin. In addition, this subbasin also possess a huge water supply potential from Lake Erie. However, the usage of Lake Erie water should be carefully controlled to avoid creating water quality problems for the Lake in the future.

c. *Proposed U.S. Steel Plant in Erie*

Currently, a U.S. steel plant is proposed to be located along the southern shore of Lake Erie at the Pennsylvania-Ohio state line. The area of the proposed plant will be about four miles by two and one-half miles. The construction labor force is estimated to be about 18,000 persons and the operational labor force after plant construction will be 8,500 persons. Water use will be supplied from Lake Erie. If the proposed U.S. steel plant is constructed and operated, an additional 27,000 persons or 10 percent over the trend projected population for 1990 may reside within a one-hour driving distance from the proposed plant site. This area includes all of Erie County (Subbasin 15 and a portion of Watersheds 16-A and 16-D) and approximately the western half of Crawford County (portions of Subbasin 15, and Watersheds A and D in Subbasin 16). This additional increase in population will certainly increase the water use in all categories; however, the most severe impact would be on public water supply. It is estimated that 28 water suppliers in Erie and Crawford Counties will be affected by the proposed U.S. Steel Plant. The corresponding water use exceeding the 1990 projection is about 2.7 mgd. This is equivalent to about five percent of the trend projected public water use in this area in 1990. Most likely, the above excess water use may concentrate around those towns (Lake City, Girard, Cransville, Albion, Springboro, Conneautville, etc.) which are closest to the plant. As shown in Table 14, since the difference between the total yield of these water suppliers (4.57 mgd) and their total water use in 1990 (0.95) is greater than 2.7 mgd, the yield problem should be minor.

After analyses of water use and water availability in this subbasin, conclusions were made as follows:

(1) Water quantity is plentiful in Lake Erie for the use of the proposed U.S. steel plant.

(2) Surface water and groundwater are sufficient in this subbasin to meet the additional water demand in connection with the development of the proposed U.S. steel plant.

(3) In order to satisfy the public water supply needs in connection with the proposed plant, some of the public water supply systems will have to be expanded or improved.

(4) Impacts of this project on water quality, fish and wildlife in Lake Erie and the nearby area should be studied before implementation takes place.

2. PUBLIC WATER SUPPLY

a. *Problems*

Because public water supply is more complex than other water use categories, involving larger service areas and populations, public water supplier problems have been studied individually. Dependable yields have been estimated for all existing sources, including stream withdrawals, reservoirs, wells, and springs located in or nearby the subbasin. These estimates are based on information contained in the reports B-12 "Low Flow Characteristics of Pennsylvania Streams",[21] B-7 "Long Duration Low Flow",[22] and "Planning Criteria for Determination of the Adequacy of Water Supply Sources"[23]. Projected uses for individual water suppliers were determined using projections of population and daily per capita uses. These projection methods are described in "Planning Principles". Finally, each water supplier which has its own sources was analyzed to identify existing or possible future yield, storage and, where applicable, allocation or filtration plant deficiencies.

A yield deficiency was identified when the required daily withdrawal (determined considering peak and average daily water use as well as total raw and treated water storage) exceeds the safe yield of all combined surface and groundwater sources of a particular supplier. Because safe yield is based upon long term drought conditions, a yield deficiency indicates a supplier's inability to provide for normal uses during the occurrence of a major drought.

A storage deficiency was identified when the average daily water use exceeds the total available treated storage. Treated water storage equal to one day's normal use is a minimum public safeguard in case of electrical or mechanical failures or in case of temporary pollution of the source.

A deficiency in filtration capacity was identified when the required daily withdrawal (determined from peak and average daily water use in addition to treated water storage) exceeds total filtration capacity. This indicates that the supplier cannot treat water at a rate equal to which it is being used. A deficiency in filtration plant capacity will, therefore, affect water use on a continuous, daily basis.

All public water suppliers using stream withdrawals as supply sources are required to obtain a water allocation permit from DER, which specifies a maximum allowable daily withdrawal from that surface source. An allocation deficiency was identified when the peak daily water use exceeds the allocation permit and indicates that the supplier cannot legally withdraw water at a rate equal to which it would be used on a peak use day.

(Continued on page 36)

[21] L. V. Page and L. C. Shaw, *Water Resources Bulletin No. 12, Low Flow Characteristics of Pennsylvania Streams*, (Pennsylvania Department of Environmental Resources, 1977).

[22] Department of Environmental Resources, *Water Resources Bulletin No. 7, Long-Duration Low Flow of Pennsylvania Streams*, (December 1972).

[23] Department of Environmental Resources, *Planning Principles, SWP-1*, (March 1975), Appendix A-2.

Table 15

PUBLIC WATER SUPPLY STATISTICS

Legend (See Figure 9)	Water Supplier	Estimated Population Served (1970)	Total System GPCD[a] (1970)	Residential GPCD (1970)	Average Daily Water Use (mgd[b]) 1970	1990	2020	Existing Sources	Yield (mgd)
1	Lake City Borough	1,905	139	46	.264	.212	.358	3 wells	1.66
2	Borough of Girard	2,613	67	40	.174	.285	.438	3 wells	1.50
3	Palmer Shores Water Company	130	45	44	.006	.016	.033	1 well	.020
4	Fairview Borough Water Authority	1,716	57	43	.097	.181	.378	3 wells	.756
5	Pennsylvania Water Company – White Hall Village Subdivision	495	71	57	.034	.091	.156	3 wells	.065
6	Pennsylvania Water Company – White Swan Subdivision	315	40	35	.012	.073	.114	2 wells	.036
7	Pennsylvania Water Company – Walnut Heights Subdivision	248	62	50	.015	.027	.035	2 wells	.033
8	Pennsylvania Water Company – Greenbriar Subdivision	135	101	89	.013	.038	.070	1 well	.050
9	Pennsylvania Water Company – Westminster-Asbury Subdivision	5,858	92	45	.540	.804	1.172	9 wells Purchase – City of Erie (emergency)	.763
10	Lakeshore Maintenance Association	743	77	69	.057	.089	.149	2 wells	.360
11	Ridgeville Water Company	325	66	39	.021	.026	.032	3 wells	.345
12	City of Erie, Bureau of Water	169,444	262	105	44.44	51.29	55.50	Lake Erie	10[d]
13	North East Township Water Department	893	78	69	.069	.138	.296	Purchase – North East Borough Water Dept.	
14	North East Borough Water Department	3,846	432	56	1.730	2.086	2.513	Bull Reservoir on West Branch French Creek, Smith Reservoir on West Branch Sixteenmile Creek, Grahamville Reservoir on East Branch Sixteenmile Creek, 1 spring	7.09
15	Albion Borough	1,971	63	37	.153	.261	.500	3 wells,3 springs	.260
16	Cranesville Borough	663	45	37	.029	.050	.086	Purchase – Albion Borough	
17	Springboro Water Department	629	41	31	.025	.053	.065	2 wells	.432
18	Conneautville Borough Water Department	1,032	68	59	.070	.085	.134	2 wells	.720

[a]GPCD: Gallons per capita per day
[b]mgd: Million gallons per day
N/A: Not applicable
[d]Yield from Lake Erie is approximately 10^5 mgd.

Yield Deficiency (mgd) 1970	Yield Deficiency (mgd) 1990	Yield Deficiency (mgd) 2020	Total Water Allocation (mgd)	Allocation Deficiency (mgd) 1970	Allocation Deficiency (mgd) 1990	Allocation Deficiency (mgd) 2020	Treated/Total Water Storage (mg)	Treated Storage Deficiency (mg) 1970	Treated Storage Deficiency (mg) 1990	Treated Storage Deficiency (mg) 2020	Filtration Plant Capacity (mgd)	Filtration Plant Capacity Deficiency (mgd) 1970	Filtration Plant Capacity Deficiency (mgd) 1990	Filtration Plant Capacity Deficiency (mgd) 2020
0	0	0	N/A	N/A	N/A	N/A	.100/.100	.164	.112	.258	N/A	N/A	N/A	N/A
0	0	0	N/A	N/A	N/A	N/A	.176/.176	0	.109	.262	N/A	N/A	N/A	N/A
0	.031	.105	N/A	N/A	N/A	N/A	.041/.041	0	0	0	N/A	N/A	N/A	N/A
0	0	.174	N/A	N/A	N/A	N/A	.100/.100	0	.081	.278	N/A	N/A	N/A	N/A
.003	.116	.245	N/A	N/A	N/A	N/A	.035/.035	0	.056	.121	.194	0	0	.116
.014	.291	.475	N/A	N/A	N/A	N/A	.018/.018	0	.055	.096	N/A	N/A	N/A	N/A
.002	.032	.051	N/A	N/A	N/A	N/A	.005/.020	.010	.022	.030	.260	0	0	0
0	.095	.217	N/A	N/A	N/A	N/A	.035/.035	0	.003	.035	N/A	N/A	N/A	N/A
.101	.564	1.206	N/A	N/A	N/A	N/A	1.10/1.10	0	0	.072	N/A	N/A	N/A	N/A
0	0	.151	N/A	N/A	N/A	N/A	.070/.070	0	.019	.079	N/A	N/A	N/A	N/A
0	0	0	N/A	N/A	N/A	N/A	.006/.006	.015	.020	.026	N/A	N/A	N/A	N/A
0	0	0	45.0	13.7	22.7	28.3	59.6/59.6	0	0	0	88.0	0	0	0
0	0	0	N/A	N/A	N/A	N/A	4.00/829.0	0	0	0	3.90	0	.209	1.201
0	.001	.615	N/A	N/A	N/A	N/A	2.00/2.00	0	0	0	N/A	N/A	N/A	N/A
0	0	0	N/A	N/A	N/A	N/A	.050/.050	0	.003	.015	N/A	N/A	N/A	N/A
0	0	0	N/A	N/A	N/A	N/A	.280/.280	0	0	0	N/A	N/A	N/A	N/A

It is important to recognize that a water supplier may face many other types of problems. Water quality problems may affect sources and have led to the failure of some suppliers in the past. Many water suppliers, particularly smaller suppliers (generally less than 1,000 connections) with limited revenues, are plagued with deteriorating systems, resulting in wasteful leakage and frequent service interruptions. Institutional problems of public water suppliers are discussed in the State Water Plan document "Water Laws and Institutional Arrangements".

Eighteen public water suppliers are associated with Subbasin 15 as listed in Table 15 and shown on Figure 9. All suppliers have their service areas and discharge points within the subbasin. One supplier, North East Borough, has one surface source in Subbasin 16 in addition to two surface sources and one ground source in Subbasin 15. The remaining 17 suppliers have their sources located within the subbasin.

Table 15 shows existing sources and existing and future needs for the 16 water suppliers which have their own sources of supply. Suppliers which purchase 100 percent of their water from another supplier are not analyzed. Their existing and projected uses are considered as part of that other supplier's uses. Only one water supplier, the Conneautville Borough Water Department, show no deficiencies to the year 2020 in dependable yield, water allocation, storage, and filtration plant capacity. The other water suppliers show a deficiency at the present or in the future in one or more of the items examined. Four water suppliers have an immediate yield problem affecting 6,900 people in their service areas, as shown in Table 15 and Figure 10. Seven suppliers are projected to have yield deficiencies affecting 13,300 people by 1990, and by 2020 nine suppliers serving a total of 23,100 people will fall into this category.

Currently, the City of Erie, Bureau of Water has an allocation deficiency of 13.7 mgd. According to current projections, this water supplier will have allocation deficiencies of 22.7 mgd by 1990 and 28.3 mgd by 2020.

Three water suppliers have immediate storage deficiencies totaling 0.19 mg. Ten water suppliers will have combined deficiencies of 0.48 mg by 1990, and by 2020 storage deficiencies of eleven suppliers will total 1.27 mg.

Only one supplier, the North East Borough Water Department, will have filtration deficiencies of 0.21 mgd in 1990. By 2020, two water suppliers, the Pennsylvania Water Company-White Hall Village Subdivision in addition to the North East Borough Water Department will have combined filtration deficiencies of 1.32 mgd.

b. *Solution Alternatives*

Public water supply deficiencies may be overcome or relieved by either improved management of existing resources or, when necessary, new development. Pennsylvania's past enjoyment of abundant and dependable supplies of water has instilled in the public's mind an epicurean-like philosophy of convenience through wasteful water use without due regard to either environmental or in some cases social or economic effects. As increasing societal pressures on water supplies approach the limits of this finite resource, many Commonwealth water users will begin to realize the importance of water conservation practices. The costs to society, both monetary and environmental, of continued unnecessary or questionable development of water resources are becoming more difficult to bear as time passes. Until recently, many water conservation practices have been viewed as measures to be used only in emergency situations – during a drought, or while mechanical failures or floods or other natural events may temporarily shut down water supply systems either wholly or partially. Concerns other than convenience are now beginning to alter society's attitudes toward wanton abuse of the environment; as a result, resource conservation must be considered as the primary means of solving existing problems and avoiding future ones. Only when conservation has been utilized to the maximum extent practicable should further development of the resource be considered justified.

Although conservation has become a "household term" in the past few years, it is something whose practice cannot be limited to the household. In fact, many forms of significant water conservation do not apply to the household, but rather to industrial or power generation uses or even to the public water supply systems themselves. The costs of maintaining newly-mandated stream water quality standards are forcing industry to adopt recycling/reuse production techniques which demand less total water. Advances in industrial cooling technology have led to lower total water requirements, although this is offset somewhat by the resultant problem of increased evaporative loss, which is discussed in Part 3 of this section.

The major thrust of conservation as it relates to public water supply must be directed toward both the individual consumer and the supplier. Conservation education must be directed toward the consumer to enlighten him to both the importance of conservation and also the methods by which he can practice conservation. Measures which must be applied by the supplier to either conserve water directly or promote conservation by the consumer include:

(1) reduction of leakage and loss in the system

(2) adoption of conservation-promoting pricing policies

(3) rationing (primarily an emergency measure)

(4) the promotion of building codes which require the use of water-saving devices in new construction

(5) promotion of the use of water-saving devices by existing residential, commercial and industrial customers

(6) metering

(7) initiation of effective timber harvesting practices in water supply watersheds

Appendix B-1 provides a more detailed discussion of conservation techniques, particularly as they apply to the individual consumer.

(Continued on page 39)

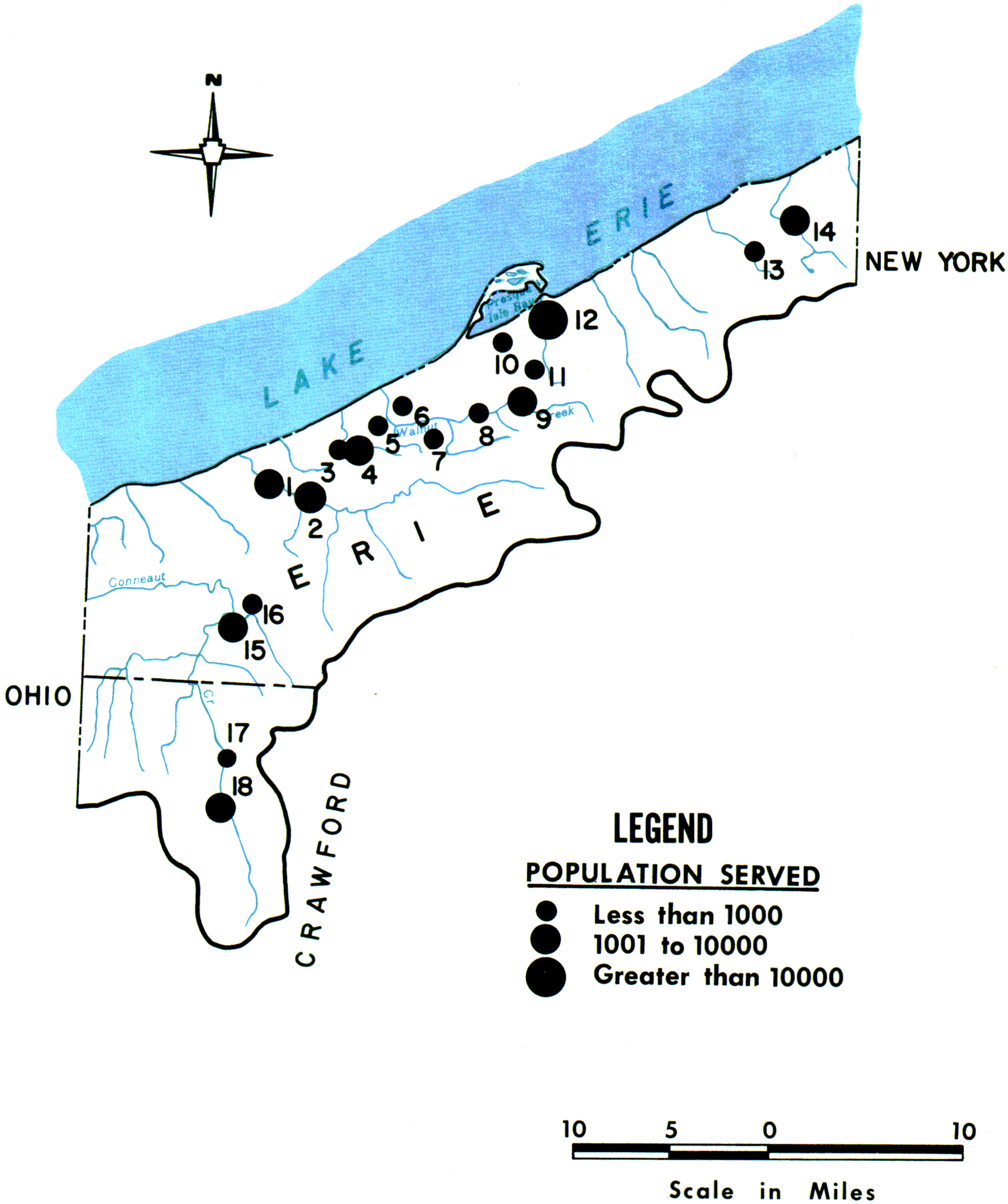


FIGURE 9. Location and Size of Public Water Suppliers

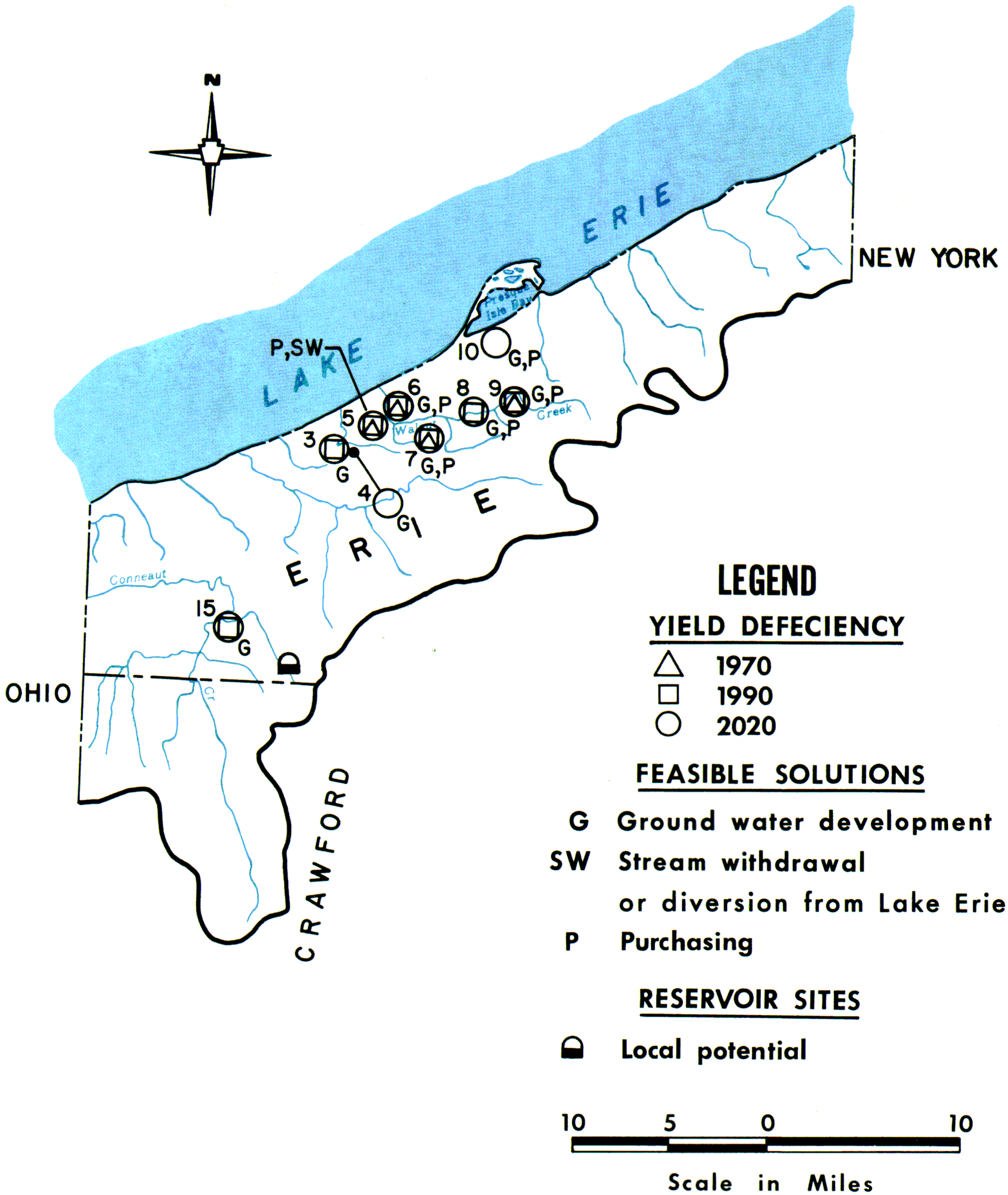


FIGURE 10. Water Supply Yield Deficiencies and Solution Alternatives

The following alternatives have been considered as conceptual solutions to public water supply problems:

(1) Yield deficit

 (a) Management of Existing Resources

 (b) New Development

  i. Stream withdrawal – taking water directly from a stream

  ii. Surface raw water storage – reservoir

  iii. Groundwater development – wells & springs

(2) Storage Deficit

 (a) Management of Existing Resources

 (b) Increase treated water storage (new development)

(3) Water Allocation Deficit

 (a) Management of Existing Resources

 (b) Increased Allocation

(4) Filtration Capacity Deficit

 (a) Management of Existing Resources

 (b) Increase Filtration Plant Capacity (expansion of existing facility and/or new development)

Management of existing resources includes the following measures:

(1) Reduction of demand through consumer conservation

(2) Metering (if not already being used)

(3) Purchasing from other suppliers which have excess supply (does not apply to storage deficit)

(4) Reduction of leakage and loss within the system

(5) Regionalization of water suppliers

Table 16 lists the present sources, projected short-term (1990) and long-term (2020) deficiencies, solution alternatives, and associated costs for those water suppliers which have been identified as having problems. The specific solution alternatives presented are the result of an examination of the conceptual solutions listed above, with regard to their feasibility for solving the identified problems. Conservation measures were examined in detail for suppliers whose residential gpcd exceeds 50 or whose industrial usage is significant. Metering was considered where it was not already being used. Structural measures were outlined and examined for obvious, overwhelmingly negative characteristics, either economic, social or environmental; only feasible solutions were then listed in Table 16. In all cases, if regional, county or utility plans were available, they were screened to obtain locally developed solution concepts or recommendations. Costs for new project development were estimated on an annual basis, at 1976 price levels using a 5–1/4 percent interest rate amortized over the assumed life period of the structure. These costs are preliminary planning estimates only, developed for use in reviewing alternatives, and should not be used for project budgeting or design.

Any reservoir solution alternatives listed in Table 16 are also located on Figure 10. Environmental and social parameters for major potential structural solution alternatives are listed and evaluated in Table 17. A discussion of the impacts associated with the major recommended structural solutions is presented in Chapter VI.

c. *Recommendations*

The feasible solution alternatives were examined in greater detail in order to determine which alternative or combination of alternatives appeared most capable of solving a given problem, not only from the standpoint of that problem, but also with respect to the overall water resources scenario of the subbasin. Some alternatives were rejected in favor of others after consideration was given to physical resource and environmental restrictions, such as Scenic Rivers candidates or already-taxed groundwater aquifers or in some cases known social-political considerations. For some problems two or more alternatives may appear equally satisfactory.

The alternatives which appear to most warrant further study for implementation are indicated by bold type in Table 16. In some cases, more than one total solution to a problem may be recommended if available information was not sufficient to determine the preference of one over the other. The recommendations include:

(1) It is strongly recommended that applicable conservation measures be applied by all suppliers whose residential gpcd exceeds 50 or whose industrial usage appears excessive. This should be the initial means to alleviate existing or projected deficiencies. In addition, installation of meters for Palmer Shores Water Company and reduction of losses in the water supply system of Pennsylvania Water Company-Whitehall Village should be considered to alleviate their water supply problem.

(2) Groundwater development will meet short-term (1990) and long-term (2020) yield deficiencies of 6 and 8 public water suppliers, respectively.

(3) Purchasing water from the Bureau of Water, City of Erie, should also be considered by four subdivisions; White Swan, Walnut Heights, Greenbrier and Westminster-Asbury, of the Pennsylvania Water Company and Lake Shore Maintenance Association as a viable alternative other than groundwater development to meet their yield deficiencies in 1990 and/or 2020.

(4) Withdrawal from Lake Erie or purchasing water from the Bureau of Water, City of Erie, will meet the yield deficiency of the Pennsylvania Water Company-Whitehall Village Subdivision in 1990 and 2020.

(5) A reservoir on Temple Creek combined with additional well development as planned by Albion Borough is a viable alternative other than groundwater development to meet its yield deficiencies in 1990 and 2020.

(Continued on page 48)

Table 16

PUBLIC WATER SUPPLY SOLUTION ALTERNATIVES

Public Water Supplier Map Legend – (DER Code)	Existing Source and Projected Deficiencies[a]	Solution Alternatives[b]
Lake City Borough 1 – (25925101)	3 wells	**1) Industrial conservation should be used to partially reduce the storage deficiency**
	1990 SD = 0.112 2020 SD = 0.258	**2) Increase treated storage**
Borough of Girard 2 – (25804101)	3 wells 1990 SD = 0.109 2020 SD = 0.262	**1) Increase treated storage**
Palmer Shores Water Company 3 – (25919105)	1 well 1990 YD = 0.031 2020 YD = 0.105	**1) Metering** 2) Surface withdrawal from Lake Erie with filtration **3) Well development in Conneaut Group**
Fairview Borough Water Authority 4 – (25918101)	3 wells 2020 YD = 0.174	1) Stream withdrawal from Walnut Creek with filtration **2) Well development in Conneaut Group**
	1990 SD = 0.081 2020 SD = 0.278	**3) Increase treated storage**
Pa. Water Company Whitehall Village Subdivision 5 – (25919104)	3 wells	**1) Residential conservation should be used to partially reduce the following deficiencies** **2) Reduction of leakage and losses**
	1990 YD = 0.116 2020 YD = 0.245	**3) Purchase water from the City of Erie** **4) Surface withdrawal from Lake Erie** 5) Well development in Canadaway Formation
	1990 SD = 0.056 2020 SD = 0.121	**6) Increase treated storage**
	2020 FPD = 0.116	**7) Expansion of existing filtration plant**
Pa. Water Company White Swan Subdivision 6 – (25919110)	2 wells 1990 YD = 0.291 2020 YD = 0.475	**1) Purchase water from the City of Erie** 2) Surface withdrawal from Lake Erie with filtration **3) Well development in Conneaut Group**
	1990 SD = 0.055 2020 SD = 0.096	**4) Increase treated storage**

[a]Includes the following quantitative deficiencies only: YD - Yield deficiency (million gallons per day); SD - Storage deficiency (million gallons); FPD - Filtration plant deficiency (million gallons per day); AD - Allocation deficiency (million gallons per day).

[b]Storage alternatives apply to storage deficiencies only and are supplement to yield, allocation and filtration solution alternatives. **Boldface** indicates recommended or preferred.

1990 Increased Capacity Requirement	1990 Annual Cost ($1,000)[c]	2020 Increased Capacity Requirement	2020 Annual Cost ($1,000)[c]	Remarks
.112	4.6	.258	7.6	
.109	4.6	.262	7.6	
16%	.70	12%	1.1	1) Would reduce the 1990 & 2020 yield deficiencies by 16% and 12% respectively
.031	26.3	.105	27.6	2) 1990 cost includes a 0.1 mgd capacity filtration plant
.036	1.72	.105	5.0	3) The company is contemplating additional well development
		.174	44.5	1) Stream withdrawal creates a CUM need of .02 mgd in 2020
		.174	8.3	
.081	3.80	.278	7.90	
.116	22.4	.245	44.3	2) Estimated 20% of the total water uses are leakage & losses 3) According to the company, the Whitehall system could possibly be tied into the White Swam system and be supplied from the City of Erie through Westminster & Asbury Water System
.116	6.1	.245	7.6	
.116	5.5	.245	11.7	
.056	3.1	.121	4.9	4) Stream withdrawal creates a CUM need of .01 mgd in 1990 in 1990 and .025 mgd in 2020
		.116	5.32	
.095	18.6	.217	39.7	1) According to the company, the White Swan System could possibly be tied to the Greenbrier water system and be supplied from the City of Erie through Westminster & Asbury Water System
.291	54.93	.475	73.70	
.291	13.9	.475	22.7	
.055	3.1	.096	4.2	

[c]Annual costs (1976 price level) are planning guidelines only, not to be used for project budgeting or design.

Note: The 2020 design capacity includes the 1990 design capacity, and long-term annual costs include the short-term annual costs unless otherwise noted in the remarks.

Table 16 (Cont.)

PUBLIC WATER SUPPLY SOLUTION ALTERNATIVES

Public Water Supplier Map Legend – (DER Code)	Existing Source and Projected Deficiencies[a]	Solution Alternatives[b]
Pa. Water Company Walnut Heights Subdivision 7 – (25919108)	2 wells 1990 YD = 0.032 2020 YD = 0.051	1) Stream withdrawal from Walnut Creek **2) Well development in Conneaut Group** **3) Purchase water from the City of Erie**
	1990 SD = 0.022 2020 SD = 0.03	**4) Increase treated storage**
Pa. Water Company Greenbrier Subdivision 8 – (25919103)	1 well	**1) Residential conservation should be used to partially reduce the yield and storage deficiencies**
	1990 YD = 0.095 2020 YD = 0.217	**2) Purchase water from the City of Erie** 3) Stream withdrawal from Walnut Creek with filtration **4) Well development in Conneaut Group**
	1990 SD = 0.003 2020 SD = 0.035	**5) Increase treated storage**
Pa. Water Company Westminster-Asbury Subdivision 9 – (25002101)	9 wells 1990 YD = 0.564 2020 YD = 1.206	**1) Purchase water from the City of Erie** **2) Well development in Conneaut Group**
	2020 SD = 0.072	**3) Increase treated storage**
Lake Shore Maintenance Association 10 – (25919101)	2 wells	**1) Residential conservation should be used to partially reduce the yield and storage deficiencies**
	2020 YD = 0.151	2) Surface withdrawal from Lake Erie with filtration **3) Well development in the Conneaut Group** **4) Purchase water from the City of Erie**
	1990 SD = 0.019 2020 SD = 0.079	**5) Increase treated storage**
Ridgeville Water Company 11 – (25002103)	3 wells 1990 SD = 0.020 2020 SD = 0.026	**1) Increase treated storage**

[a]Includes the following quantitative deficiencies only: YD - Yield deficiency (million gallons per day); SD - Storage deficiency (million gallons); FPD - Filtration plant deficiency (million gallons per day); AD - Allocation deficiency (million gallons per day).

[b]Storage alternatives apply to storage deficiencies only and are supplement to yield, allocation and filtration solution alternatives. **Boldface** indicates recommended or preferred.

1990 Increased Capacity Requirement	1990 Annual Cost ($1,000)[c]	2020 Increased Capacity Requirement	2020 Annual Cost ($1,000)[c]	Remarks
.032	4.2	.051	4.4	1) Stream withdrawal creates a CUM need of .01 mgd in 2020
.036	1.72	.051	2.5	3) According to the company, Walnut Heights system could possibly be tied into the City of Erie system
.032	6.9	.051	10.5	
.022	1.80	.030	2.15	
.095	18.6	.217	39.7	2) According to the company, the Greenbrier system could possibly be tied into the Westminster-Asbury system
.095	26.22	.217	42.16	3) Stream withdrawal creates a CUM need of .01 mgd in 1990 and .02 mgd in 2020. 1990 cost includes a 0.1 mgd capacity filtration plant.
.095	4.54	.217	10.4	
.003	.56	.035	2.4	
.564		1.206		1) The company has interconnection with the City of Erie and currently purchases water whenever needed
.564	27.0	1.206	57.6	
		.072	3.6	
				2) Stream withdrawal creates a CUM need of .01 mgd in 2020
		.151	34.8	
		.151	7.2	
		.151	28.5	
.019	1.70	.079	3.80	
.020	1.70	.026	2.0	

[c]Annual costs (1976 price level) are planning guidelines only, not to be used for project budgeting or design.

Note: The 2020 design capacity includes the 1990 design capacity, and long-term annual costs include the short-term annual costs unless otherwise noted in the remarks.

Table 16 (Cont.)

PUBLIC WATER SUPPLY SOLUTION ALTERNATIVES

Public Water Supplier Map Legend – (DER Code)	Existing Source and Projected Deficiencies[a]	Solution Alternatives[b]
City of Erie Bureau of Water 12 – (25001101)	Lake Erie 1990 AD = 22.7 2020 AD = 28.3	**1) Residential and industrial conservation should be used to partially reduce the allocation deficiency** **2) Increase allocation from Lake Erie**
North East Borough Water Department 14 – (25806101)	Bull Reservoir on the West Branch of French Creek, Smith Reservoir on the West Branch of Sixteenmile Creek, Grahamville Reservoir on the East Branch of Sixteenmile Creek and 1 spring 1990 FPD = 0.209 2020 FPD = 1.201	**1) Residential and industrial conservation should be used to partially reduce the filtration deficiency** **2) Expansion of existing filtration capacity**
Albion Borough 15 – (25909101)	3 wells & 3 springs 1990 YD = 0.001 2020 YD = 0.615	**1) Well development in the Cattaraugus Formation** **2) Construction of a reservoir on Temple Creek and an additional well**
Springboro Water Department 17 – (20936101)	2 wells 1990 SD = 0.003 2020 SD = 0.015	**1) Increase treated storage**

[a]Includes the following quantitative deficiencies only: YD - Yield deficiency (million gallons per day); SD - Storage deficiency (million gallons); FPD - Filtration plant deficiency (million gallons per day); AD - Allocation deficiency (million gallons per day).

[b]Storage alternatives apply to storage deficiencies only and are supplement to yield, allocation and filtration solution alternatives. **Boldface** indicates recommended or preferred.

1990 Increased Capacity Requirement	1990 Annual Cost ($1,000)[c]	2020 Increased Capacity Requirement	2020 Annual Cost ($1,000)[c]	Remarks
.209	8.53	1.201	31.04	
.058	1.75	.615	18.6	2) The company plans to implement these projects in their program to update & expand the system and has asked for Federal assistance. The cost for these projects are the company's estimate.
.001	29.0	.615	29.0	
.003	.560	.015	1.40	

[c]Annual costs (1976 price level) are planning guidelines only, not to be used for project budgeting or design. Where alternatives include development of both source and treatment facilities, costs for treatment facilities are listed separately and are in addition to source development costs.

Note: The 2020 design capacity includes the 1990 design capacity, and long-term annual costs include the short-term annual costs unless otherwise noted in the remarks.

Table 17

SCREENING ASSESSMENT OF WATER SUPPLY STRUCTURAL SOLUTION ALTERNATIVES

Alternative	Preliminary Estimate of Annual Benefit[a] ($1,000)	Preliminary Estimate of Annual Cost[a] ($1,000)	Major Beneficial Impacts	Major Adverse Impacts	Alternatives to This Proposal	Remarks
Small potential reservoir for Albion Borough Municipal Authority on Temple Creek		29.0 WS/t 1990 29.0 WS/t 2020	-Could serve as a public water supply source for Albion Borough in conjunction with an additional well	-Could affect aquatic life and fish habitat -Could affect some vegetation and some small game -Could alter aesthetic quality -Possible relocation of secondary roads -Could increase noise, dust and traffic interruption during construction -May inundate 2.5 acres of agri- ture and open-land	-Well development	Recommended
Withdrawal from Lake Erie with filtration		26.3 WS/t 1990 27.6 WS/t 2020	-Could serve as a public water supply source for Palmer Shores Water Company	-Could alter aquatic life & fish habitat -Could affect boating activities -Potential natural area -Could affect recrea- tional area -Potential mineral resource area	-Well development	Not recommended
Stream withdrawal from Walnut Creek with filtration		44.5 WS/t 2020	-Could serve as a public water supply source for Fairview Borough Water Authority	-Wild & Scenic River Candidate-1st priority "Recreational" -Could alter aquatic life & fish habitat -Potential natural area -Could affect recrea- tional area -Could affect old Ridge Road	-Well development	Not recommended

[a]Annual costs and benefits (1976 price level) are planning guidelines only, not to be used for project budgeting or design.
WS - Water Supply
WS/t - Water supply including treatment costs
FC - Flood Control

Table 17 (Cont.)

SCREENING ASSESSMENT OF WATER SUPPLY STRUCTURAL SOLUTION ALTERNATIVES

Alternative	Preliminary Estimate of Annual Benefit[a] ($1,000)	Preliminary Estimate of Annual Cost[a] ($1,000)	Major Beneficial Impacts	Major Adverse Impacts	Alternatives to This Proposal	Remarks
Withdrawal from Lake Erie with filtration		6.1 WS/t 1990 7.6 WS/t 2020	-Could serve as a public water supply source for Pa. Water Company-Whitehall Village Subdivision	-Could alter aquatic life & fish habitat -Potential natural area -Could affect recreational and boating areas -Potential mineral resource area	-Well development -Purchases water from the City of Erie	Recommended
Withdrawal from Lake Erie with filtration		54.93 WS/t 1990 73.70 WS/t 2020	-Could serve as a water supply source for Pa. Water Company-White Swan Subdivision	-Could alter aquatic life & fish habitat -Potential natural area -Could affect recreational and boating areas -Potential mineral resource area	-Well development -Purchases water from the City of Erie	Not recommended
Stream withdrawal from Walnut Creek with filtration		4.2 WS/t 1990 4.4 WS/t 2020	-Could serve as a public water supply source for Pa. Water Company-Walnut Heights Subdivision	-Wild & Scenic River Candidate-1st priority-"Recreational" -Could alter aquatic life & fish habitat -Could affect recreational area	-Well development -Purchases water from the City of Erie	Not recommended
Stream withdrawal from Walnut Creek with filtration		18.6 WS/t 1990 39.7 WS/t	-Could serve as a public water supply source for Pa. Water Company-Greenbrier Subdivision	-Wild & Scenic River Candidate-1st priority "Recreational" life & fish habitate -Could affect recreational area	-Well development -Purchases water from the City of Erie	Not recommended
Withdrawal from Lake Erie with filtration		34.8 WS/t 2020	-Could serve as a public water supply source for Lake Shore Maintenance Association	-Could alter aquatic life & fish habitat -Could affect boating and recreational area -Potential mineral resource area	-Well development -Purchases water from the City of Erie	Not recommended

[a] Annual costs and benefits (1976 price level) are planning guidelines only, not to be used for project budgeting or design.

WS - Water Supply
WS/t - Water supply including treatment costs
FC - Flood Control

Table 18

CONSUMPTIVE WATER USE MAKEUP NEEDS

Stream and (Watershed)	Public Water Supply[a] D.C.U. (mgd)	D.M.S.R. (mgd)	A.M.S.R. (mg)	Self-Supplied Industry[a] D.C.U. (mgd)	D.M.S.R. (mgd)	A.M.S.R. (mg)	Self-Supplied Power Cooling[a] D.C.U. (mgd)	D.M.S.R. (mgd)	A.M.S.R. (mg)
Subbasin Total									

[a]D.C.U. - Daily Consumptive Use; D.M.S.R. - Daily Makeup Source Requirement; A.M.S.R. - Annual Makeup Storage Requirement; mgd - million gallons per day; mg - million gallons.

[b]Includes all irrigation which is assumed to occur within two miles of the stream identified in Column 2.

[c]Includes all livestock, and the remainder of irrigation not assumed to occur within two miles of the streams identified in Column 2.

(6) Increase treated water storage capacity for 10 and 11 water suppliers with storage deficits in 1990 and 2020, respectively.
(7) Expansion of existing filtration capacities will meet the North East Borough Water Department's filtration capacity deficiencies in 1990 and 2020, and Pennsylvania Water Company-Whitehall Village Subdivision's filtration deficiencies in 2020.
(8) Increase the water allocation of the City of Erie immediately:

These recommendations are made as possible solutions to public water supply problems. Prior to actual construction of a project or implementation of a program, detailed studies of all environmental, social and economic factors must be completed to assure optimum benefits and results.

3. CONSUMPTIVE USE MAKEUP

a. *Problems*

The protection of water uses from future source depletion is a primary concern of water resources management. One facet of water resources management, which is important to the protection of both instream and withdrawal uses, is the careful management of consumptive water uses.

Consumptive water uses can be divided into two categories: (1) direct consumptive water - the quantity of water discharged to the atmosphere or incorporated in the product of a process such as vegetative growth, food processing or an industrial process, and (2) indirect consumptive water - the quantity of water transferred from a source watershed to another watershed and never returned, or water transferred from an upstream intake point to a downstream discharge point bypassing inbetween users.

Consumptive water use thus results in a depletion of natural streamflows downstream of the intake point. Although the effects of limited and in some cases even significant depletions may be negligible under normal streamflow conditions, the impacts on instream as well as downstream withdrawal uses can become critical during periods of low streamflow.

In order to adopt a policy by which water use can be specially managed during low flow conditions, it was necessary to first define some characteristic of streamflow which could be observed in order to identify when the low flow is occurring. Stream discharge is the obvious characteristic to monitor; and a discharge less than or equal to $Q_{7\text{-}10}$[24] was adopted as the definition of low flow. The 7-day 10-year low flow is the average low flow for a period of seven consecutive days, which would occur on the average once every ten years. Although that low flow definition is the subject of continuing investigation, it was initially adopted on the premise that it is generally high enough to protect water quality standards and instream ecological uses, while at the same time being low enough so that it would be economically, socially and environmentally possible to provide the makeup water necessary during critical drought periods. Until further research possibly leads to a more comprehensive guideline, the $Q_{7\text{-}10}$ is the adopted low flow level which should be protected against depletion by incremental consumptive water use.

In compiling past, present and future comsumptive water use information, it was recognized that while its impact on streamflows in the past was small, in the future, consumptive uses could cause significant instream problems during low flows. An objective was set stating that *existing* streamflows should be protected against the

[24]Average consecutive 7-day low flow having a 10-year return period of a 10 percent chance of occurrence each year.

Self-Supplied Irrigation[a,b]			Self-Supplied Agriculture[a,c] and Golf Courses			Total[a]		
D.C.U. (mgd)	D.M.S.R. (mgd)	A.M.S.R. (mg)	D.C.U. (mgd)	D.M.S.R. (mgd)	A.M.S.R. (mg)	D.C.U. (mgd)	D.M.S.R. (mgd)	A.M.S.R. (mg)
.288	0.36	13.68				.288	0.36	13.68

detrimental effects of consumptive use. As existing streamflow records already reflect past and present consumptive water uses, this plan addresses only new or increased consumptive uses. The analyses in this report assume a base year of 1970. Incremental consumptive use in any year is defined as the difference between consumptive use in that year and consumptive use in the base year; in other words, past consumptive water uses are "grandfathered".

Because the objective of consumptive use makeup is to protect the low flow against further depletion by consumptive use, a "trigger point" must be defined to indicate at what time a user must begin to make up his incremental consumption. When the flow is at a value equal to $Q_{7\text{-}10}$ plus the total consumptive use, the user would be depleting the flow below his taking point to exactly the $Q_{7\text{-}10}$ level; therefore, a flow equal to $Q_{7\text{-}10}$ plus the total consumptive use has been assigned as the trigger point to guarantee that consumptive withdrawal water uses never contribute to depletion of streamflows below $Q_{7\text{-}10}$.

It must be emphasized that consumptive use makeup is not intended to maintain $Q_{7\text{-}10}$; it is intended to maintain the natural flow when the streamflow drops below $Q_{7\text{-}10}$, whatever that natural flow may be. A user would never be required to return more water to the stream than was withdrawn. The user must only replace the water that was consumed, beyond the base year consumptive level. All makeup water should, however, be provided either at or upstream of the withdrawal point.

The 1990 consumptive water uses (including public water supply, self-supplied industry, power, agriculture and golf courses) were analyzed to determine makeup requirements along streams and stream reaches in Subbasin 15. The needs listed in Table 18 represent the total daily incremental consumption based on projected water usage for the five categories of water users. In order not to underestimate the aggregate compensating reservoir storage requirements in this preliminary planning stage, projected consumptive water use data were uniformly increased by 25 percent, thereby increasing the required storage estimates presented by a comparable amount. This has the effect of an overall safety factor to recognize both a) the difficulty in precise projection of total consumptive use for the subbasin and b) possible inaccuracies in necessarily preliminary estimates of yields or makeup period durations.

As shown in this table, only self-supplied irrigation is identified as having consumptive water use makeup needs, which total 0.36 mgd, representing an equivalent storage requirement of about 13.7 mg in 1990. It should be noted that most of the sources of supply in this subbasin are groundwater, groundwater reservoir combinations, or Lake Erie; therefore, in these cases makeup of incremental consumptive water use will not be required.

b. *Solution Alternatives*

When streamflows drop below the trigger point, consumptive users must be prepared to protect the natural streamflow. In order to avoid any additional depletion of streamflows, those users will be faced with a decision to either temporarily curtail consumptive uses until streamflows recover or else provide makeup water to replace what is being consumed. While curtailment or reduction of consumptive use may be the most desirable solution environmentally, it is not socially or economically the most effective because electric power generation and agricultural irrigation account for nearly all the significant consumptive use in Subbasin 15.

Consumptive users who are unable to curtail use will need to employ makeup techniques. The means by which makeup requirements can be met may be categorized as follows:

(1) Improved management of Existing Resources
   (a) Release from existing excess storage
   (b) Change in utilization of existing reservoirs

(c) Temporary modification of production techniques or output

(d) Effective use of alternate sources if more than one source is available.

(e) Development of more efficient water use technology.

(2) New Development

(a) Upstream reservoir storage

(b) Groundwater development

(c) Individual storage

(d) Others

Users may already have storage for normal water use purposes onsite or in-system. It may be possible for those which have excess storage to use part or all of that excess to provide the necessary makeup water. On a broader scale, changes in the utilization of existing reservoirs represent an alternative which deserves serious consideration. Many reservoirs already in existence could possibly be used more effectively. In most cases, consumptive use makeup releases would be compatible with design or authorized uses. Makeup releases would only be required on an infrequent basis on most streams and would most likely occur after the summer months and not interfere with recreational uses.

In the case of Federal dams, for which Congress originally provided authorization and/or appropriations, it would be necessary to obtain a reauthorization. This would be accomplished by first submitting to the responsible Federal agency a proposal for new use of the project. If it is determined that the proposed use is significantly different than presently authorized uses, then a request would be submitted to Congress for funding a reauthorization study. The study, which would include public hearings, would be similar to a study conducted for original authorization. If the study results were favorable, then recommendations for reauthorization would be presented to Congress; and if approved by Congress, reauthorized uses would be instituted.

Temporary modifications of production techniques or output may be possible for some industrial users or possibly even agricultural irrigation users. Production of some product lines could be curtailed temporarily with emphasis shifted to other lines. Output could be reduced, with increased levels of production compensating later to achieve the same long-term production totals. Irrigators may alter their irrigation schedules to decrease the consumptive levels.

Many water users have more than one source of water. Industries may have surface or groundwater sources in addition to connections to public water supply systems. Interconnections also exist between public water suppliers. Some users have excess capacity through combinations of surface and groundwater sources. Alternative sources may allow these users to continue operations if low flow conditions do not affect all their sources concurrently.

If improved management of existing resources is insufficient to provide for makeup needs, then it will become necessary to consider new development of structural measures. Users may develop storage individually or collectively. Irrigators could construct ponds or dams on small watersheds. Industries and utilities could construct dams to provide storage or may be able to increase storage behind existing structures. Several users could jointly construct upstream reservoir storage or may purchase storage from public reservoirs upstream. Groundwater development may be a viable alternative for some users. Combinations of alternatives may be preferable or even necessary for other users.

Table 18 lists storage requirements which would be necessary to provide the daily consumptive use makeup during the critical duration period of the low flow if a user were to choose storage as a preferred alternative. The critical duration period was determined from historical streamflow records and equals the largest total number of days that streamflows were below $Q_{7\text{-}10}$ during any year of record. Storage was computed as the product of daily consumptive use multiplied by the number of days of critical duration. That product was then increased by a 25 percent safety factor as before.

The solution alternatives investigated to meet the 1990 consumptive water use makeup needs are: (1) groundwater development in the Valley Train Deposits, Stratified Drift, Ice Contact Deposits and Pocono group and (2) Individual Storage. Because of the scattered and/or unknown locations of irrigation no reservoir solution can be justified.

B. FLOOD DAMAGE REDUCTION

Floods are natural occurrences that cause damages and loss of life, primarily as a result of man's use of, and encroachment upon, the floodplains. Because of this continued encroachment, flood damages have been increasing on a regular basis.

The State Water Plan has addressed the problems associated with riverine flooding. The damage figures utilized in the analyses are based on historical damages and do not consider damages which may result from future development. The Plan has not examined stormwater runoff on a community basis; however, it is recognized that the problems associated with stormwater runoff are becoming increasingly serious. Development actions such as the removal of vegetation and large scale resurfacing and drainage systems are increasing both the quantity and rate of runoff, resulting in many new localized flood problems, as well as exacerbating existing ones.

1. PROBLEMS

Subbasin 15 has experienced some flood damages during the past half century. However, flooding conditions in many communities and stream reaches have been averted by structural measures provided by Federal and State government.

In the past half century floods have occurred in the subbasin in 1915, 1936, 1941, and 1947. The largest amount of damage ever recorded in the subbasin was from the 1915 flood.

Table 19

FLOOD DAMAGE CENTERS

Legend (See Figure 11)	Damage Center – Stream	Highest Flood Damages Recorded Prior to 1969		"Agnes" 1972
		Flood Date	Damages[a] ($1,000)	Damages[b] ($1,000)
1	Conneautville Borough – Conneaut Creek	1936	291	
2	City of Erie – Mill Creek	1915	> 1,000	

[a] 1976 Price Level

[b] Damages (1976 price level) are based on zip code areas which may not strictly coincide with municipal boundaries.

Table 20

STUDY UNIT DAMAGES AND BENEFITS[a]

Study Unit	Drainage Area (Sq.Mi.)	Total Natural Annual Damages[b] ($1,000)	Total Annual Benefits of Existing Projects ($1,000)	Total Residual Annual Damages ($1,000)
Subbasin 15	512	189	7	182

[a] Based on tangible damages only. All dollar figures are listed at 1976 price level.

[b] Average annual damage without any flood protection measures.

a. *Flood Damage Centers and Reaches*

A damage center was identified wherever damages for one flood in a community totalled $25,000 or more at the 1969 price level ($45,000 or more at the 1976 price level). A damage reach was identified wherever the *average annual* flood damages per mile of stream length totalled $500 or more at the 1969 price level ($900 or more at the 1976 price level).

Only two damage centers (Conneautville Borough and the City of Erie) have been identified in this subbasin. These are listed in Table 19 and shown on Figure 11. The flood damages listed in this table are at 1976 price levels. No flood damage reach has been identified. The Lake Erie shoreline of Presque Isle Peninsula has suffered damages ($1,000,000 per year at the 1976 price level) due to beach erosion which has been caused by lake water waves.

b. *Existing Flood Damage Reduction Measures*

Flood damage reduction measures can be either structural or nonstructural. Structural measures which are already in use in this subbasin to control flood damages are shown on Figure 11 and are listed in Appendices C-1 and C-2. The Corps of Engineers has one completed snagging and clearing project in Conneaut Creek which has helped in reducing flood damages in the Conneautville area.

The Department of Environmental Resources has one completed local flood protection project which has been reducing flood damages in the Borough of Wesleyville in Erie County. A Soil Conservation Service study is being conducted on Thatcher Run in Conneautville, in connection with potential funding through the Northwest Pennsylvania Regional Resource Conservation and Development Agency. It is worthwhile to note that the Corps of Engineers has provided a Beach Erosion Control Project for the restoration and improvement of approximately five miles of the Lake Erie shoreline of Presque Isle Peninsula. This is not a flood control project; therefore, it is not included in the Appendix.

It should be noted that these structural measures are not total solutions to the flooding problem. A combination of increased runoff and more damage-prone investment in flood hazard areas erodes the effectiveness of structural measures. Flood protection projects are designed to protect a community against a certain design flood stage. If a flood occurs which exceeds the design criteria, flood damages will again occur. Another problem arises when the community fails to undertake effective stormwater planning and management. The results of such inaction may become obvious during periods of heavy rainfall.

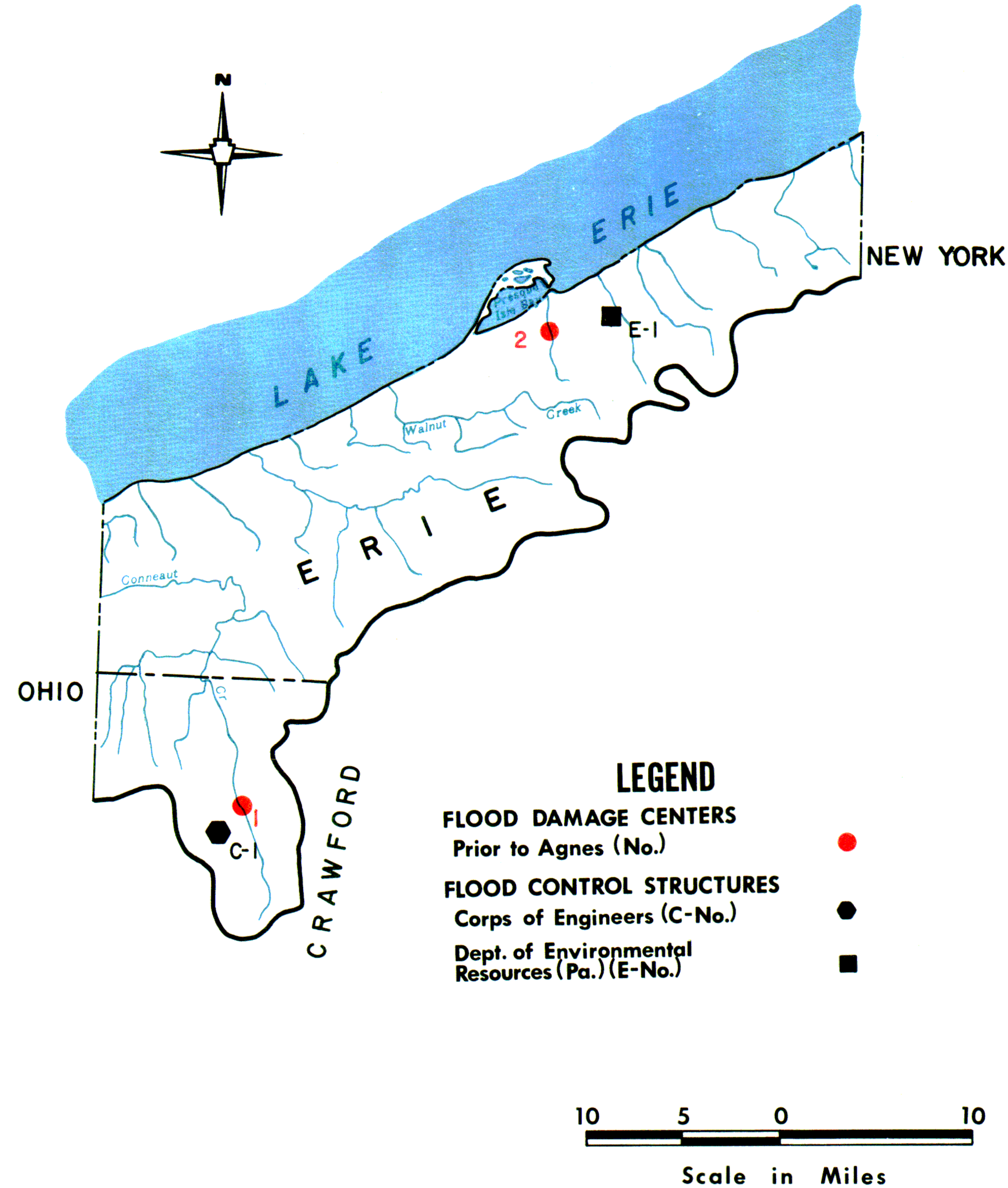


FIGURE 11. Flood Damage Areas and Flood Control Structures

c. *Residual Annual Damages*

Historical flood damage events and the frequency of their occurrence have been analyzed to develop the flood damage and frequency curve shown on Figure 12. This curve may be used to determine average annual flood damage. A weighted average of the frequent small flood events with the less frequent but larger flood events would yield *natural annual* flood damages, or the average damages that would occur on a yearly basis in the absence of existing flood control projects.

Existing flood control projects reduce the natural annual damage. By subtracting the total annual flood control benefits of all existing projects from the natural annual damage, the *residual* annual damage or the present day flood control need of the study unit was determined. The results of those analyses are presented in Table 20.

In the future, the residual annual flood damages will certainly increase if present action is not taken to manage floodplain development. Areas that warrant immediate attention are areas that have projected population increases. From a flood control viewpoint, intelligent and proper management of this population development is absolutely essential for a community which may be concerned about reducing its flood damages.

d. *Flood Plain Information and Flood Warning System*

Nonstructural measures such as floodplain regulation or flood proofing require adequate flood plain information. Another nonstructural measure, flood forecasting, requires a timely and accurate flood forecasting and warning system. A final measure, flood insurance, which is designed to reduce the financial impact of a flood, also requires floodplain delineation. At this time, the availability of this information is limited. The status of floodplain information prepared or under preparation by the U. S. Army Corps of Engineers and the floodplain mapping effort completed by the U. S. Geological Survey (U.S.G.S.) are listed in Appendices C-3 and C-4. Currently, the U.S.G.S. in cooperation with the State is mapping the damage centers and reaches within the State.

Another effort, currently being conducted by the U.S. Department of Housing and Urban Development (HUD), is known as a Type 15 Flood Insurance Study. This study has been or will be completed for those communities which have qualified for flood insurance (See Table 21) under the National Flood Insurance Program. Contained in the study will be the identification of flood hazard areas, the development of flood frequency data, and the computation and mapping of proposed floodway data. Because of their detailed information, these HUD studies should be used in place of any other mapping. A list of completed HUD studies is provided in Appendix C-5.

The Pennsylvania Department of Community Affairs is the State coordinative agency for Federal Flood Insurance and urban development programs. It provides advisory and financial assistance to municipalities in implementing and administering various municipal programs related to floodplain management. It has adopted regulations concerning flood-proofing of buildings in State-assisted redevelopment projects.

2. ALTERNATIVE SOLUTIONS TO EXISTING FLOOD DAMAGE PROBLEMS

Alternative measures were examined as possible means of reducing the flood damage threat to existing floodplain development. Future development on the floodplain should comply strictly with effective floodplain management objectives and regulations, and in no case should future development be used as justification for funding flood protection measures. The measures investigated for flood damage reduction are as follows:

a. Nonstructural Measures (Managing existing resources)
   (1) Floodplain regulation promotes proper management of and control over the type of development that occurs in the flood plain.
   (2) Flood insurance lessens economic burden on floodplain occupants and leads to reduction of future damage potential.
   (3) Permanent flood proofing aids floodplain occupants and reduces future damage potential in areas where major structural solutions are not feasible.
   (4) Flood forecasting provides time for warning and response in order to save life and property damage.

b. Structural Measures (New development)
   (1) Levee and/or Floodwall
   (2) Channel Modification
   (3) Reservoirs, including small potential and Corps of Engineers potential reservoir sites.

The principles, advantages and disadvantages of these measures are discussed in "Planning Principles". It must be emphasized that the measures listed above may be investigated and utilized individually or in combination. Indeed, a combination of several measures may furnish the most desirable solution.

One nonstructural measure which is applicable in all small stream watersheds is the Self-Help Flood Forecasting and Warning System. This system, designed to issue flood forecasts to flood-prone communities, utilizes the following information:

a. Precipitation – type, amount and intensity
b. Runoff rate
c. Measured streamflow
d. Flood crest travel time

The National Weather Service has assisted some communities in assembling this information into a useful format. When a threat of flooding occurs, local officials will have the ability to issue a flood warning. As the name "Self-Help" implies, the success of this system depends upon the willingness of the local people to get involved

Table 21

FLOOD DAMAGE REDUCTION SOLUTION ALTERNATIVES[a]

Legend (See Figure 11)	Damage Center or Reach (Stream)	Percentage Reduction In Natural Annual Damages Due to: Existing Projects or Projects Under Construction	Percentage Reduction In Natural Annual Damages Due to: Funded Proposed Projects	Residual Annual Damages ($1,000)	Nonstructural Measures: Flood Plain Regulation[b]	Nonstructural Measures: Eligible for Flood Insurance[c]	Nonstructural Measures: Permanent Flood Proofing	Nonstructural Measures: Flood Forecasting
1	Conneautville Borough (Conneaut Creek)	6		108.6	◆	◆	◆	
2	City of Erie (Mill Creek)			10.0	◆	◆		◆

[a]All numbers are DER estimates unless otherwise noted. See Appendix C-6 for more detailed explanation of this table.

[b]Applies to all damage centers and reaches, more particularly to future than existing development; however, flood plain mapping is required for effective implementation. Indicates that floodplain mapping has been completed by U.S.G.S., the U.S. Army Corps of Engineers, or a consulting firm. *Indicates that floodplain mapping has not been completed.

during an emergency situation and help themselves.

All the nonstructural and structural concepts were investigated in an attempt to identify possible flood damage reduction alternatives. However, in an initial screening evaluation, certain structural alternatives were eliminated because of major economic, physical, social or environmental restraints.

The solution alternatives investigated for flood damage reduction for Conneautville Borough and the City of Erie are listed in Table 21. The table lists the damage center, the damage reduction due to existing and funded proposed structures as a percentage of natural annual damage, the residual annual damage (or current annual damage), and nonstructural and structural measures. The entry of each column on this table is further explained in Appendix C-6.

3. RECOMMENDATIONS

The flood control measures were examined in greater detail in order to determine those which appeared most capable of solving or reducing the flood control problems. The recommendations include:

> Nonstructural measures including floodplain regulation, flood insurance, and permanent flood proofing are strongly recommended for Conneautville Borough and the City of Erie as listed in Table 21. In addition, relocation of flood-prone activities and acquisition of lands or easements to assure flood-compatible development are suggested for investigation at the damage center level. In all small stream watersheds, the Self-Help Flood Forecasting and Warning System is recommended. It is imperative that every community undertake an effective stormwater planning and management program.

These recommendations are made as possible solutions to the identified flood control problems. Prior to actual construction of a project or implementation of a program, detailed studies of all environmental, social and economic factors must be completed to assure optimum benefits and results.

C. WATER-RELATED OUTDOOR RECREATION

Pennsylvania's recreational needs were examined in the State Recreation Plan (formerly the State Comprehensive Outdoor Recreation Plan – SCORP), which was developed by the Governor's Office of State Planning and Development in conjunction with an Interagency Recreation Plan Committee[25] and published in report form in July 1976. Whereas the State Recreation Plan studied 19 outdoor recreation activities, the State Water Plan is addressing only those outdoor recreation activities which are water-related; swimming, boating and fishing. Picnicking is also included because of its common association with many other activities, in particular boating and swimming, and also because the picnicking experience itself is enhanced by the proximity of water. State Water Plan recreation analyses were performed

[25]Departments of Community Affairs, Education, Environmental Resources, Public Welfare and Transportation in addition to the Pennsylvania Fish, Game, and Historical and Museum Commissions.

Structural Measures (Estimated Average Annual Benefit)[d]				
Levee or Floodwall	Channel Modification	Small Potential Reservoir Site	Corps of Engineers Potential Reservoir Sites	Remarks
				Proposed COE study to determine the feasibility of Section 205 projects.

[c]Does not serve to reduce existing flood hazard, but rather lessens the economic burden of flooding on flood plain occupants. Land use regulations required for participation in HUD's National Flood Insurance Program will effectively reduce future damage potential and control future flood plain development. Indicates eligibility as of December, 1977.

[d]Average annual benefits in thousand dollars (1976 price level) are planning guidelines only, not to be used for project budgeting or design.

using data developed for the State Recreation Plan; however, the methods of analysis were developed separately because of the need to determine facilities usage directly at the watershed level.

Recreational opportunity may be derived from many sources including Federal, State and locally operated and maintained facilities, in addition to privately owned profit and nonprofit facilities. Water resources projects, including dams, usually offer excellent opportunities to develop associated recreation facilities. Floodplain management which results in relocation of development away from the floodplain provides new open space areas which can be used for recreational purposes with minimal risk of expensive losses due to future flooding.

Although this Plan does not propose the use of recreation as justification for water resources development, it is recognized that water resources management and structural development frequently provide excellent opportunity for associated recreational development or for enhancement of recreational experiences. Neither the data nor the methods of analysis used for this study were intended to determine recreational *demands* or *needs* in the traditional sense, but rather the attempt was to determine where existing or future potential recreational participation is sufficient to justify the development of additional recreational facilities. Where there is shown to be such justification, recreation should be included in other project planning and design. The discussion that follows is structured to follow the traditional *demand/supply* concept. The total potential recreational participation is discussed first in the context of "demands". Then existing facilities are examined as "supplies". The *residual* participation potential is then presented, representing the resultant "need" and finally the State share of that "need" is discussed. Again it must be emphasized that the residual potentials and State shares are *not* true needs but rather an indication of how many additional recreational facilities would be likely to be used if they were provided in conjunction with water resources projects or programs.

1. *Total Participation Potential*

Participation potential is a measure of the public's willingness or desire to participate in given recreational activities. Information developed for the State Recreation Plan indicates what percentages of Pennsylvania's citizens have an interest in the various activities studied and how frequently they participate in those activities, on a regional basis. From that information in conjunction with existing and projected county populations, total participation potential was assessed for each county in terms of seasonal activity-days. An activity-day represents one person's participation in an activity during one day; and *seasonal* activity-days indicate the total number of activity-days which would occur during the 13-week summer recreational season. Table 22 lists the participation potential for the counties in Subbasin 15, although those numbers reflect a reduction from the total potential to account for the percentage of participation which normally occurs in privately restricted facilities such as those in backyards.

In examining those numbers, it should be understood that participation desires vary according to the availability and quality of facilities, the amount of leisure time available, income levels and other factors. The State Recreation Plan studies measured varying levels of

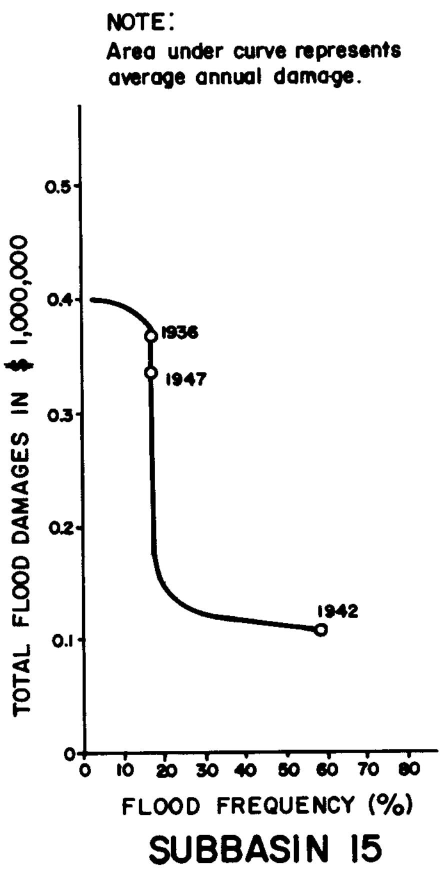


FIGURE 12. Flood Damage and Frequency Curve

Table 22

TOTAL RECREATIONAL PARTICIPATION POTENTIAL[a] BY COUNTY

		Seasonal Activity-days (1,000's)		
Activity	County	1970	1990	2020
Picnic	Erie	1,165	1,334	1,536
Swim	Erie	5,451	7,189	8,282
Boat	Erie	497	832	959
Fish	Erie	1,145	1,543	1,778

[a]Participation potentials listed are the activity-days that would result from the populations of the identified counties; they do not relate to the potential of the recreational resources in the counties.

Table 23

EXISTING RECREATION FACILITY UNITS BY COUNTY (1974)

County	Picnic Tables	Beach (Linear feet)	Pool (Square feet)	Power Boating (Acres)	Nonpower Boating (Acres)	Fishing (Man-days per year)
Erie	2,116	31,100	74,000	566.0	566.0	5,222,686
Crawford	2,690	4,700	285,000	18,367.5	21,632.3	1,787,020

participation depending upon different assumptions regarding those influencing factors. The minimum levels of participation determined by that study were used in this study, so in reality, participation potentials could be higher than those listed in the table.

2. *Existing Facility Supply*

Existing recreational facilities were inventoried for the State Recreation Plan in 1974. The total number of facility units in each county and watershed in Subbasin 15 are listed in Table 23 and the center column of Table 24, respectively. The supply totals include Federal, State and local, as well as private profit and nonprofit facilities which are available for public use.

Existing and proposed State parks are mapped on Figure 13. A corresponding listing of those parks is provided in Table 25. Presque Isle State Park provides picnicking, camping, swimming, boating and fishing opportunities for millions of Pennsylvanians and out-of-state visitors alike. It represents the heart of Pennsylvania's second largest resort area.

Cold- and warm-water fishing streams are shown on Figure 6 in the previous section entitled Fish, Waterfowl and Furbearer Resources. Fishing and boating lakes greater than ten acres, as well as fishing and boating access areas, are shown on Figure 13 and listed in Tables 26 and 27. Fishing opportunity in the subbasin is determined by either the presence of fish, water area or access, whichever is the limiting factor. Table 28 summarizes the fishing mileage and acreage by county. These numbers represent the physical presence of fishable water but do not imply any ready access.

Figure 14 shows boatable streams as delineated by the Pennsylvania Fish Commission. Stream and lake acreages by county are listed in Table 23. Again these numbers do not imply any ready access. Any body of water suitable for both fishing and boating is included in both Tables 23 and 28.

3. *Residual Participation Potential*

The residual participation potential is the amount by which total participation potential exceeds the participation capacity of existing facility units. It is a measure of the quantity of additional facilities which would be likely to be used if they were developed. The 1970, 1990 and 2020 potential participations expressed in terms of facility units for the watersheds in Subbasin 15 are listed in the left three columns of Table 24.

Residual participation potentials are also listed in Table 24. They were computed as the difference between the total participation potential and the existing facility units. The absence of a residual potential entry in the table

(Continued on page 65)

Table 24

TOTAL AND RESIDUAL PARTICIPATION POTENTIAL[a]

Activity Units	Watershed	Total Participation Potential			Existing Facility Units	Residual Participation Potential			State Share Residual Potential		
		1970	1990	2020		1970	1990	2020	1970	1990	2020
Picnic Tables (10's)	A	206	215	258	156	50	59	102	17	20	34
Beach Linear feet (100's)	A	8	12	14	254						
Pool Square feet (1,000's)	A	89	76	90	60	29	15	30	3	2	3
Power Boating Acres	A	7,580	13,790	16,932	31,998						
Nonpower Boating Acres	A	1,196	1,940	2,290	8,999						
Fishing Man-days/Year (1,000's)	A	259	308	317	1,117						

[a]Participation potentials listed are a function of population rather than physical resources. Residual potentials indicate the number of additional facilities which would be likely to be used if developed.

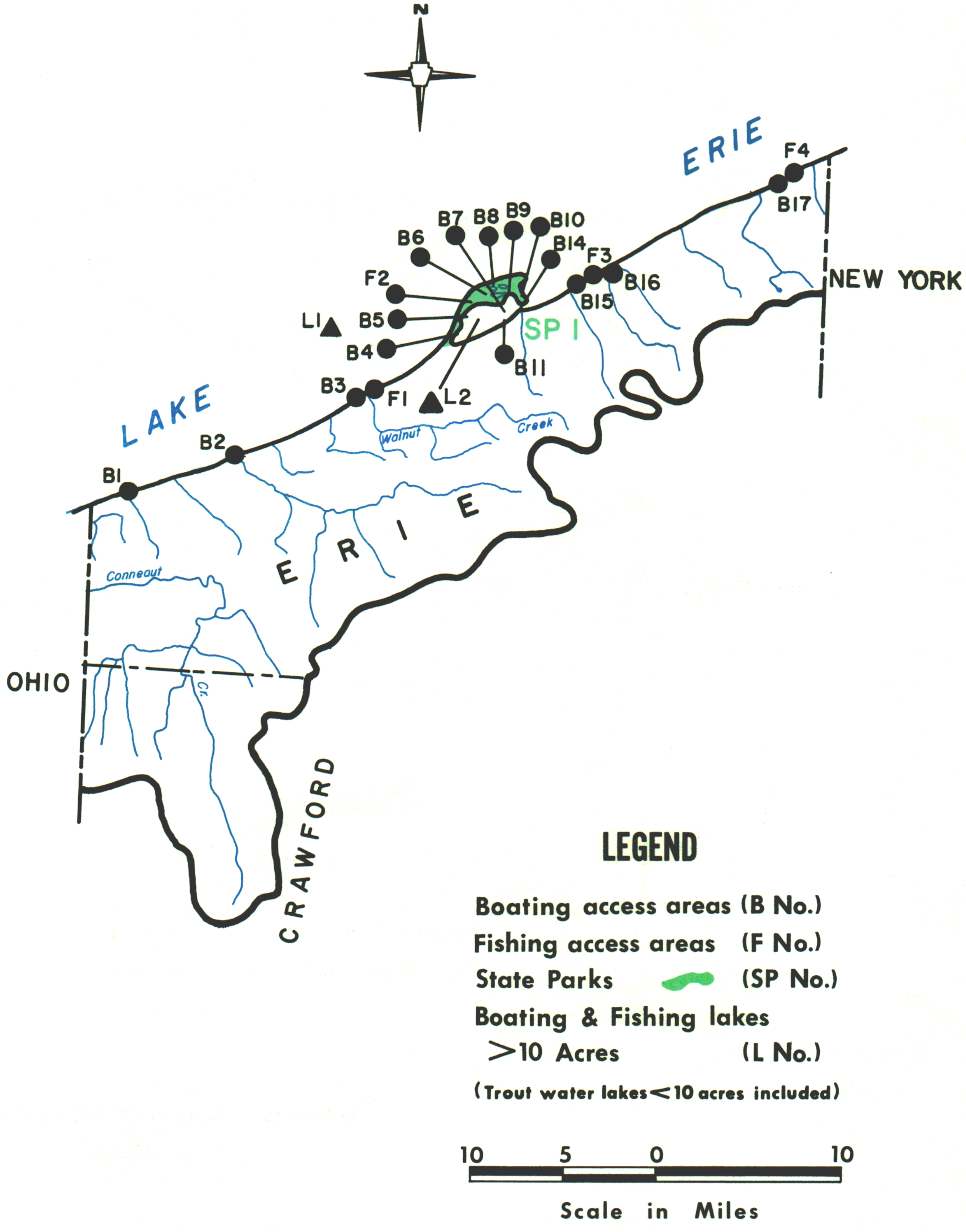


FIGURE 13. Recreation Areas and Facilities

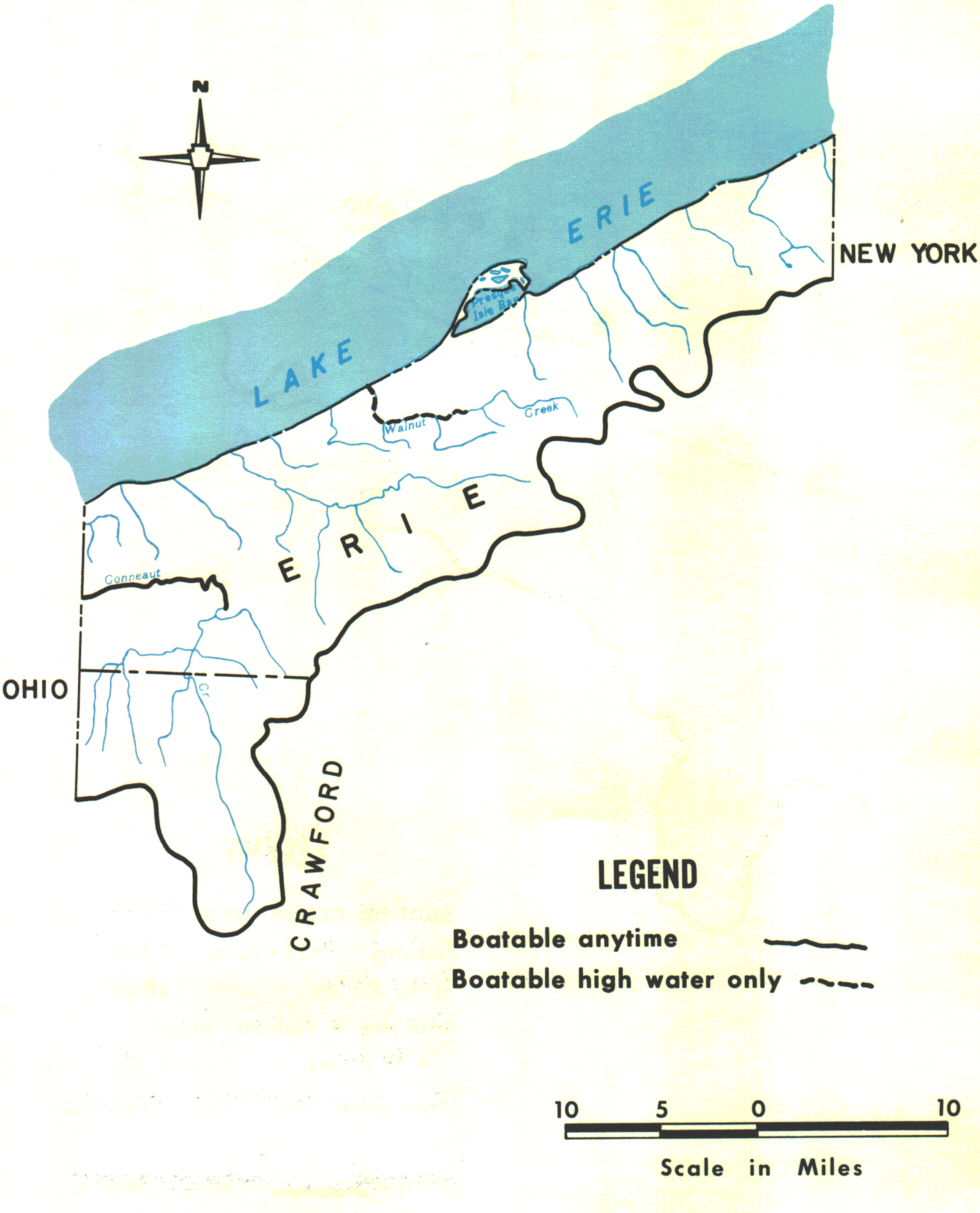


FIGURE 14. Boatable Streams

Table 25

STATE PARKS

Watershed	Legend (See Figure 13)	State Park	Land Area (Acres)	Water Area (Acres)	Total Area (Acres)	Facilities[a] Existing (1974)	Facilities[a] Proposed	Remarks
	SP1	Presque Isle	3,100	1,000[b]	4,100	A,C,D,E		Historical feature

[a]Facility Codes: A - Picnicking; B - Camping; C - Swimming; D - Boating; E - Fishing.
[b]Represents a portion of Lake Erie.

Table 26

EXISTING FISHING AND BOATING LAKES

Lake	County	Area (sq. mi.)	Ownership
Lake Erie	Erie	100[a]	Public

[a]For purposes of this study, boating area was assumed to extend 2 miles from shore along the entire Pennsylvania coastline.

Table 27

EXISTING FISHING AND BOATING ACCESS AREAS

Legend (See Figure 13)	Access	County	Stream or Water Body	Ownership[b]	Remarks
B1	Raccoon Co. Park 6 mi. W. of Lake City	Erie	Lake Erie	county	
B2	Elk Creek Ramp	Erie	Lake Erie	Private profit	camping facilities, fee
B3	Walnut Creek Access 4 mi. W. of Erie	Erie	Lake Erie	PFC	
B4	West Boat Livery	Erie	Presque Isle Bay (Lake Erie)		boat rentals
B5	Niagra Boat Ramp	Erie	Presque Isle Bay (Lake Erie)	DER	
B6	Presque Isle Yacht	Erie	Presque Isle Bay (Lake Erie)	Private non-profit	
B7	Marina Ramp	Erie	Presque Isle Bay (Lake Erie)	DER	
B8	Marina Dockage	Erie	Presque Isle Bay (Lake Erie)	DER	fee, season boat docking
B9	Lagoon Ramp	Erie	Presque Isle Bay (Lake Erie)	DER	
B10	East Boat Livery	Erie	Presque Isle Bay (Lake Erie)	DER	boat rentals
B11	Chestnut Street Launch Ramp City of Erie	Erie	Presque Isle Bay (Lake Erie)	DER	
[a] B12	East Avenue Ramp	Erie	Lake Erie		
[a] B13	Austin Ramp	Erie	Lake Erie	Private non-profit	

[a]Not shown on Figure.

[b]PFC - Pa.Fish Comm.;PGC - Pa.Game Comm.;DER - Pa.Dept. of Envir.Res.;COE - Corps of Engineers.

Source: OSPD, State Recreation Plan facilities inventory.

Table 27 (Cont.)

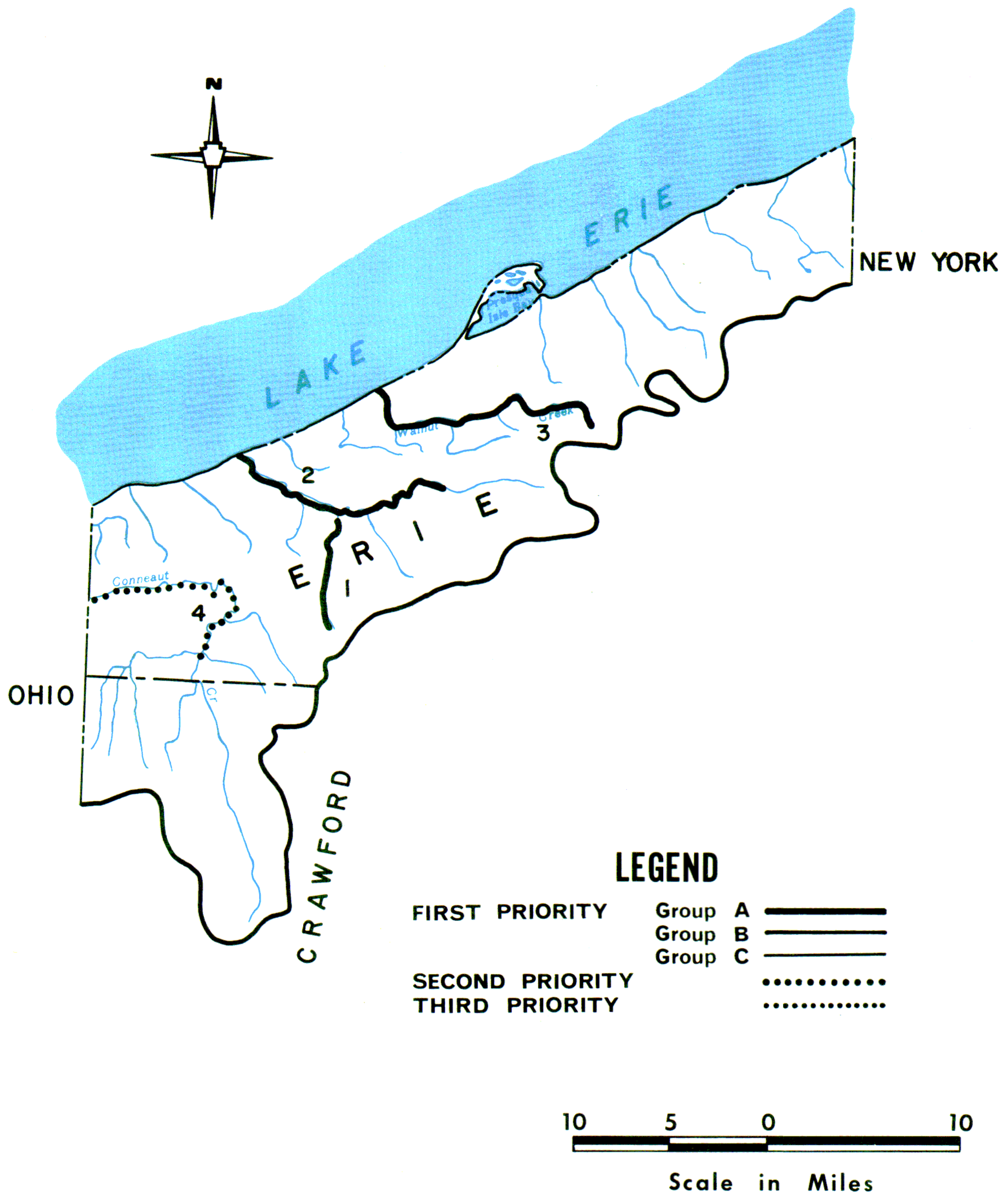
EXISTING FISHING AND BOATING ACCESS AREAS

Legend (See Figure 13)	Access	County	Stream or Water Body	Ownership[b]	Remarks
B14	Public Dock - City of Erie	Erie	Lake Erie	Private profit	
B15	Shades Co. Park 6 mi. E. of Erie	Erie	Lake Erie	PFC	Class A boats only
B16	Charlie's Livery 1 mi. E. Sixteenmile Creek	Erie	Lake Erie	Private profit	
B17	North East Access	Erie	Lake Erie	PFC	
F1	Walnut Creek Access Area	Erie	Lake Erie	PFC	mooring
F2	Presque Isle State Park	Eire	Lake Erie	DER	
F3	Shades Beach Co. Park	Erie	Lake Erie	Erie County	
F4	North East Access Area	Erie	Lake Erie	PFC	

[a]Not shown on Figure.

[b]PFC - Pa.Fish Comm.;PGC - Pa.Game Comm.;DER - Pa.Dept. of Envir.Res.;COE - Corps of Engineers.

Source: OSPD, State Recreation Plan facilities inventory.



Source:
Pennsylvania Scenic
Rivers Inventory

FIGURE 15. Pennsylvania Scenic Rivers Candidates

Table 28

POTENTIAL FISHING SUPPLY

County	Stream (Miles)	Lake (Acres)
Crawford	184.7	20,310.0
Erie	187.0	685.0

Source: Pennsylvania Fish Commission

indicates that existing facilities exceed the number needed to accommodate the total participation desires if the facilities were used in a manner conforming to standards. Any number in the residual column indicates how many additional facility units would potentially be used if provided in the watershed, again assuming that their use would conform to regional standards, and also that access to and quality of the facilities is sufficient to ensure that recreationists would travel to the facilities from distances which conform to the travel-time standards for the activities studied. Picnicking appears in Table 24 as the activity most in need of additional supply. An additional 500 tables are needed at present and needs will grow to over 1000 tables by 2020. Although the table does not indicate a need for additional boating acres, there is a growing need for additional access areas and launching facilities to satisfy both boating and fishing needs. It should again be emphasized that the residual potentials presented in the table represent conservative estimates, according to State Recreation Plan results.

4. *State Responsibility*

Pennsylvania has invested heavily in outdoor recreation over the past 15 years. In many areas, facilities for selected activities have been developed to nearly the maximum of which the resource is capable. Most forms of outdoor recreation involve a specific use of land or water; consequently, recreation finds itself competing for both land and water surface area against many other forms of incompatible use. The avenues through which the State can directly provide water-related outdoor recreation opportunity are limited primarily to State or Federal water resources projects and their environs, to State parks and, to a lesser degree, State forest picnic areas. Responsibility for all these lies primarily with the Department of Environmental Resources.

It is not expected that the State will provide additional facilities to accommodate all of the residual recreational participation potential. As stated previously, there are many sources of recreation facilities, the State being one of them. State-owned or operated facilities currently account for approximately the following percentages of facilities usage:

a. picnicking – approximately 33 percent

b. pool swimming – approximately 10 percent

c. beach swimming, power and nonpower boating, and fishing – nearly 100 percent

Although the State provides only about 60 percent of existing fishing and boating access facilities, State Water Plan analyses are concerned with the future development of additional potential fishing or boating surface areas, which can only be accomplished by construction of lakes and will, therefore, be wholly accessible to the State for recreational development. The percentages shown reflect present usages and are not policy; they may vary in the future. The last two columns in Table 24 list the share of residual participation potential for which the State may be likely to provide additional facilities based on those percentages.

5. *Recommendations*

Presque Isle State Park is presently developed to capacity and offers no possibilities of future increases in supply of picnicking facilities or access to the lake for boating or fishing. The Pennsylvania Coastal Zone Management Program is examining several locations for possible acquisition of lands to provide additional access to Lake Erie, however no areas have been officially adopted at this time. In the absence of any State development of picnicking opportunity, private enterprise and regional or local government will need to share the responsibility for providing further picnicking opportunity.

It is strongly recommended that recreational development or enhancement be considered as an integral part of any local floodplain management projects and programs. It is also recommended that the subbasin's recreation potential be justly considered in the formulation of plans for any State, regional or local water resources development activities; however, this report does not propose the use of recreation as a sole factor for the justification of water resources projects.

D. WILD AND SCENIC RIVERS

The Commonwealth's policy is to protect and enhance those river segments representative of Pennsylvania's natural and cultural river heritage for the purposes of environmental protection and the general recreational enjoyment and educational benefit of the public. Toward this end the Governor signed into law in December 1972, Act No. 283, which authorized the establishment of the Pennsylvania Scenic Rivers System.

The Scenic Rivers Act established four classifications into which candidate streams could be assigned:

1. Wild river areas – those rivers or sections of rivers that are free of impoundments and generally inaccessible except by trail, with watersheds or shorelines essentially primitive and waters unpolluted.

2. Scenic river areas – those rivers or sections of rivers that are free of impoundments, with shorelines or watersheds still largely primitive and undeveloped, but accessible in places by roads.

3. Recreational rivers – those rivers or sections of rivers that are readily accessible, that may have some development along their shorelines and may have

Table 29

PENNSYLVANIA SCENIC RIVERS CANDIDATES[a]

Legend (See Figure 15)	Stream Name	Priority Group	Proposed Segment Limits	Approx. Segment Length (miles)	Proposed Class	Water Quality
1	Little Elk Creek	1-B	Headwaters - Elk Creek	6	S	2
2	Elk Creek	1-B	McKean, Pa. - Lake Erie	25	S	2
3	Walnut Creek	1-B	Headwaters - Lake Erie	20	R	2
4	Conneaut Creek	2	Crawford/Erie County - Ohio Border	21	S	2

[a]For explanation of columns see Appendix D-1.

undergone some impoundment or diversion in the past.

4. Modified recreational rivers – those rivers or sections of rivers in which the flow may be regulated by control devices located upstream. Low dams are permitted in the reach so long as they do not increase the river beyond bank-full width. These reaches are used for human activities which do not substantially interfere with public use of the streams or the enjoyment of their surroundings.

Using this classification system, the Department of Environmental Resources[26] compiled and published in July 1975 the "Pennsylvania Scenic Rivers Inventory"[27] That inventory is a listing of all candidate streams which were recommended for future study to determine their eligibility for inclusion by law in the Scenic Rivers System. Since it was recognized that the completion of such detailed studies statewide would require many years, possibly several decades, the candidate streams were further categorized according to relative priority as assigned by the Wild and Scenic Rivers Task Force. These priority assignments were based on the stream's recognition as having national, statewide or primarily local significance. Under the first priority, or those with statewide and in some cases even national significance, the streams were subdivided into three subgroups (A, B, and C). First priority group "A" streams are those which have most immediate need for protection and urgent need for additional study.

The streams or stream segments in Subbasin 15 which have been nominated for inclusion in the Scenic Rivers System are listed in Table 29 according to priority ranking. Priorities were assigned to stream segments regardless of their classifications; consequently several classifications may appear within a priority group. The same stream segments are mapped on Figure 15. Four stream segments have been nominated from this area in the three priority groups with one of the nominations, the Susquehanna River, falling in the Priority 1 group.

While responsibility for development of management programs to protect the Commonwealth's designated stream segments lies with the Wild and Scenic Rivers Program, the development of these management programs requires close coordination with the State Water Plan. The State Water Plan will not address management of the candidate streams as wild and scenic rivers; however, those stream nominations have been and will continue to be accounted for in all management schemes devised to solve the water resources problems presented in this report. Until a candidate stream becomes designated by the State Legislature and is a legally adopted component of the Pennsylvania Scenic Rivers System, its nomination must be treated as an environmental constraint to any structural solution identified within the candidate segment. This does not represent a moratorium on development within the candidate segment, but does indicate a need for special emphasis on the examination of all factors when considering a possible structure within the area. After designation by the State Legislature, mandated restrictions on development within the segment would apply to any recommended structural solutions to water resources problems and would be strictly adhered to by the State Water Plan.

Future coordination between the State Water Plan and the Wild and Scenic Rivers Program is required to insure that State Water Plan decisions account for any stream segments which may be nominated at future dates. The Wild and Scenic Rivers Program will provide annual updates of the Scenic Rivers Inventory so that streams which meet eligibility requirements in the future are not forgotten or ignored and so that existing classifications and priorities may be reviewed.

[26]The Department of Environmental Resources is the agency mandated by The General Assembly to administer the Pennsylvania Scenic Rivers Program.

[27]Pennsylvania Department of Environmental Resources, *Pennsylvania Scenic Rivers Inventory*, (December, 1975).

E. WATER QUALITY

The following information was derived primarily from the Comprehensive Water Quality Management Plan (COWAMP) program. More detailed information on the problems and their solutions discussed herein can be found in the individual COWAMP study area reports.

A major problem in determining the quality of subbasin streams is the sparse distribution of quantitative sampling locations. Although there may be considerable information regarding water quality in a given stream, the geographical distribution of the monitoring stations limits the ability to derive general conclusions regarding water quality throughout the subbasin.

Figure 16 shows the location of stream reaches having a degraded water quality. Degraded reaches were determined by the Pennsylvania Department of Environmental Resources (DER) and the Pennsylvania Fish Commission. DER aquatic biologists considered a stream seriously degraded if it did not possess a diverse population of invertebrates and if the majority of invertebrates found were pollution tolerant species. Other indications of poor stream quality include low pH and dissolved oxygen values, high iron values, and the presence of acidity. Fish Commission personnel based their evaluation of degradation on the presence of a low population of game fish in the presence of industrial, municipal, or acid mine drainage discharges.

Figure 16 also shows the location of DER water quality monitoring stations. Further information on the monitoring station data and the aquatic biologists' reports is available from DER's Bureau of Water Quality Management. Monitoring samples are collected under a variety of conditions and are not designed to provide detailed knowledge of water quality in a number of stream reaches or the daily variations of quality. However, they do provide an overall view of the water quality over an extended period of time.

The aquatic biologists' reports describe the biological condition of a stream during the sampling period. They include information on the variety and number of biological species, limited chemical analyses, and a qualitative description of the stream condition. The biological reports provide information regarding a given stream's biological condition produced by events occurring over a period of time. In contrast, the chemical analyses of the samples collected at the monitoring stations reflect water quality only at the time of sampling.

Groundwater presents a much less dynamic picture than a normal surface stream does. In a frequently pumped well, water quality would change over a much longer period than that of a surface stream. Thus, data values for a groundwater station are less dependent on sampling frequency than those collected from a surface stream. Nevertheless, there can be a considerable variation of sampling results from a given aquifer due primarily to monitoring a number of wells at various depths in that aquifer. Also, a given aquifer can possess a wide range of water quality because of variations in the infiltrated soil and strata.

In order to quantitatively evaluate the quality of a given stream, certain stream criteria must be examined. Values of specific water quality criteria established by the Commonwealth are contained in Chapter 93 of DER's "Rules and Regulations". In most cases, more than one criterion has been established for each constituent to reflect permissible variations, depending on water use.

Chapter 93 also contains streams having a conservation area water use classification. A recently recommended revision to the definition of conservation area is as follows:

> Waters used within and suitable for the maintenance of an area now or in the future to be kept in a relatively primitive condition.

Subbasin streams or watersheds having a conservation area[28] classification are listed in Table 30.

Table 30

CONSERVATION AREAS

1. Crooked Creek Basin
2. Godfrey Run Basin
3. Twelvemile Creek Basin

To aid in the understanding of the following discussion, a glossary of water quality terms, a table listing chemical constituents in groundwater and their effects on water use, and a brief list of various pollutants and their effects are found in Appendices E-1 through E-3. Surface water quality is discussed first, followed by groundwater quality.

Lake Erie and its various bays and harbors are currently undergoing eutrophication due to degraded water quality. However, this has improved recently and can improve further provided a viable water quality management program is developed through an evaluation of the interaction of water circulation, sediment quality, the biota and external inputs to the lake. The International Joint Commission, a permanent unitary body consisting of representatives from Canada and the United States, has attempted to do this by initiating pollution prevention programs through the Great Lakes Water Quality Agreement.

(Continued on page 71)

[28]Effective October 8, 1979, the *Conservation Area* stream designation was replaced by a *Special Protection* classification which consists of the categories *High Quality Waters* and *Exceptional Value Waters*. The Pennsylvania Fish Commission's *Wilderness Trout Streams* are considered *Exceptional Value Waters*.

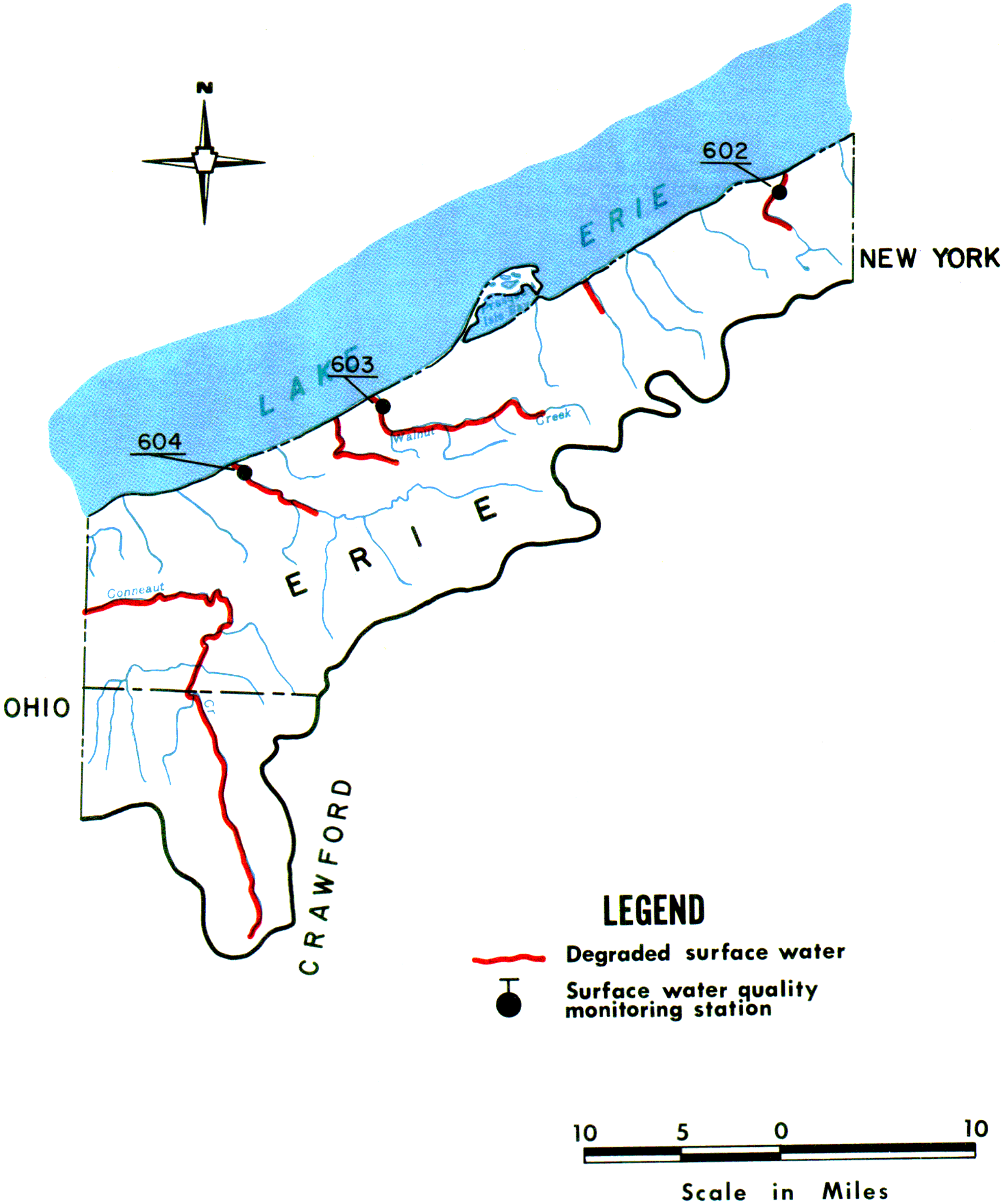


FIGURE 16. Water Quality

Table 31

GROUNDWATER QUALITY BY AQUIFER
(Concentrations In mg/1)

Aquifer	pH	Total Solids	Hard-ness	Alka-linity	SO_4	Cl	NO_3	NH_3	P	F	Na	Fe	Mn
Glacial Deposits													
Outwash													
Range:	5.7—8.4	105—4120	80—345	12—324	8—60	0—122	.08—5.72	.00—.020	.01—11.97	.00—38	2.5—81.0	.00—124.0	.00—2.5
Average:	7.7	525	183	148	31	17	1.05	0.002	0.76	0.17	21.0	5.12	0.30
Median:	7.8	236	165	136	32	10	.42	0.000	0.01	0.17	9.2	0.32	0.06
# Samples:	43	24	40	34	20	44	33	21	18	9	17	35	20
Beach													
Range:	6.4—8.3	139—2760	36—660	30—398	16—420	1.6—270	.10—14.0	.000—.400	.01—.28	.00—.60	0.9—675.0	.00—56.0	.00—4.0
Average:	7.4	477	233	144	80	48	2.12	0.052	0.04	0.14	49.3	3.82	0.37
Median:	7.4	348	226	145	66	27	1.00	0.000	0.03	0.12	11.0	0.30	0.03
# Samples:	69	39	65	56	37	76	61	29	24	32	30	61	36
Ice—Contact													
Range:	7.6—8.4	168—506	88—230	49—212	8—80	2—98	.22—3.96	.000—.100	.01—.08	.00—.34	0.7—122.5	.01—1.08	.00—.20
Average:	8.0	290	137	130	38	32	1.09	0.013	0.03	0.18	35.9	0.32	0.04
Median:	8.0	255	168	130	37	15	0.52	0.000	0.03	0.17	16.2	0.29	0.03
# Samples:	16	16	13	16	14	16	16	15	15	15	15	16	15
Ashtabula Till													
Range:	6.6—8.8	180—2768	108-302	97—244	.76—113	3—328	.10—7.00	.000—.182	.01—1.05	.10—.33	4.3—197.0	.00—61.50	.00—7.40
Average:	7.6	523	214	165	53	24	0.96	0.057	0.23	0.15	54.7	5.71	0.86
Median:	7.6	344	214	168	42	12	0.30	0.022	0.06	0.11	9.2	0.50	0.09
# Samples:	37	16	33	32	11	36	29	10	7	8	5	34	11
Hiram Till													
Range:	6.7—8.2	200—254	16—215	73—228	20—58	6—86	.30—5.00	.000—.200	.03—.04	.14—.24	2.0—12.5	.08—3.9	.00—.30
Average:	7.3	235	169	110	39	29	1.74	0.062	0.03	0.17	7.0	0.76	0.09
Median:	7.1	248	185	85	35	38	1.00	0.020	0.03	0.14	6.4	0.30	0.06
# Samples:	11	5	9	9	5	11	12	15	3	3	3	9	5
Kent Till													
Range:	6.5—8.4	54—844	116—200	14—214	0—58	1.384	.24—1.30	.000—.200	.01—.27	.00—1.10	2.4—146.0	.03—19.25	.00—1.75
Average:	8.0	304	166	93	29	42	0.57	0.026	0.06	0.25	27.1	1.33	0.15
Median:	8.0	222	165	78	28	7	0.46	0.000	0.04	0.21	12.0	0.12	0.04
# Samples:	19	19	19	19	19	19	19	19	19	19	19	19	19
Lavery Till													
Range:	7.2—8.0	184—379	60—284	78—242	9—72	3—138	.22—.64	.00—.300	.04—.11	.00—.81	5.0—107.5	.18—4.90	.03—.75
Average:	7.5	294	156	228	33	49	0.38	0.200	0.08	0.34	53.9	1.68	0.21
Median:	7.4	306	139	196	25	28	0.31	0.250	0.08	0.28	52.0	0.82	0.03
# Samples:	44	4	4	4	4	4	4	4	4	4	4	4	4

Source: DER, Bureau of Water Quality Management.

Table 31 (Cont.)

GROUNDWATER QUALITY BY AQUIFER
(Concentrations In mg/1)

Aquifer	pH	Total Solids	Hard-ness	Alka-linity	SO_4	Cl	NO_3	NH_3	P	F	Na	Fe	Mn
Geologic Formation													
Canadaway													
Range:	6.9—8.0	137—1304	96—382	22—354	41—480	3—77	.20—14.08	.000—.300	.01—.24	.10—.49	3.3—103.8	.00—10.25	.01—2.0
Average:	7.5	459	215	135	140	21	3.23	0.044	0.09	0.19	23.8	2.80	0.52
Median:	7.7	400	193	132	89	13	0.58	0.000	0.04	0.16	9.2	0.10	0.03
# Samples:	10	10	10	10	10	10	10	9	7	9	10	10	9
Cattaraugus													
Range:	7.2—8.4	122—1598	16—270	59—330	0—99	1—118	.24—5.28	.000—.300	.00—.25	.00—1.80	4.4—626.3	.04—1.93	.00—.7
Average:	8.0	333	124	181	32	23	0.78	0.040	0.03	0.39	62.4	0.42	0.06
Median:	8.0	284	134	166	29	8	0.50	0.000	0.01	0.28	24.0	0.28	0.01
# Samples:	35	35	28	35	35	35	35	35	35	35	35	35	35
Conneaut													
Range:	7.2—8.5	168—1488	34—388	21—406	0—280	2—716	.20—25.92	.000—.3001	.01—5.82	.00—.70	3.2–596.0	.01—575.0	.00—25
Average:	7.9	432	175	170	50	119	2.54	0.036	0.22	0.24	82.2	16.97	0.81
Median:	7.9	370	144	144	41	43	0.54	0.000	0.03	0.21	31.2	0.29	0.03
# Samples:	35	37	28	38	38	38	38	33	38	35	38	36	33
Pocono													
Range:	7.1—8.4	76—360	64—200	20—256	7—52	0–38	.32—1.44	.000—.100	.01—.15	.04—.46	3.9—76.0	.00—4.50	.00—.05
Average:	7.8	228	157	148	34	7	0.68	0.015	0.05	0.23	17.5	0.67	0.02
Median:	7.7	240	158	166	40	2	0.46	0.000	0.03	0.21	8.4	0.14	0.01
# Samples:	13	13	11	13	13	13	13	13	13	13	13	13	13
Riceville													
Range:	7.8—8.5	120—426	0—246	63—226	5—72	1—76	.30—.64	.000—.100	.00—.05	.20—1.10	7.2—124.0	.03—2.45	.00—.13
Average:	8.0	269	110	164	37	14	0.40	0.13	0.02	0.38	43.1	0.50	0.06
Median:	7.9	256	157	166	34	16	0.35	0.000	0.01	0.26	15.6	0.10	0.05
# Samples:	8	8	6	8	8	8	8	8	8	8	8	8	8

Source: DER, Bureau of Water Quality Management.

In Presque Isle Bay, water quality is best along the north shore where dissolved oxygen values approach saturation. Total coliform concentrations in the bay, particularly during the summer and along the south shore, are usually higher than the water quality criterion of 1,000 MPN/100 ml. An estimated 89 percent of this loading is due to combined sewer overflow, while the remainder is caused by urban runoff from the Erie Metropolitan Area. Removing the sewer overflow would reduce the input of the coliform concentrations to a level capable of supporting water contact sports.

Subbasin 15 streams are characteristically small and short in length, with a maximum travel time of two days for average flows to reach Lake Erie. The short travel time means that strongly deleterious materials will have a serious effect upon the resident biota before they are detected, while slightly or nondeleterious materials will not remain in the stream long enough to cause any long term effects. In any event, Lake Erie will serve as the major mixing bowl for the material carried by these streams.

Of all the subbasin streams, only Crooked Creek, Little Elk Creek, Twelvemile Creek and Twentymile Creek have met or exceeded the water quality criteria for all available sampling observations. The most widespread water quality problem is high coliform bacteria contamination. This is followed in level of importance by ammonia, iron, phosphate and pH. The coliform bacteria result from domestic waste discharges, septic tank effluents, combined sewer overflows, and urban and agricultural runoff. Dissolved oxygen is usually not a problem since the short travel times do not allow sufficient time for the streams to respond to BOD (biological oxygen demand) loadings.

Walnut Creek, however, is an exception to this in that relatively low values of dissolved oxygen have been consistently monitored in certain reaches. This is due to discharges from several private treatment facilities and an industrial discharger being located just upstream from the point of measurement.

As indicated by Table 31, extensive groundwater sampling has been conducted in this subbasin. Samples were analyzed for pH, hardness, sodium, chloride, sulfate, nitrate, ammonia, fluoride, phosphorus, iron and manganese. The results were related to the geological and geographical location of the wells and springs sampled. In 80 percent of the samples, the recommended USPHS drinking water standards were exceeded for at least one constituent. Generally, the water was found to have excessive iron, manganese and hardness. At least 50 percent of the wells had hardness greater than 150 mg/1. The best quality water was found in the Pocono formation, followed by the Riceville formation, Hiram till and Lavery till.

Possible groundwater contamination was observed in 45 percent of the wells sampled. Natural contamination from salt water brine was identified in 17 to 51 percent of the affected wells, sewage contamination was found to be a potential source in 16 to 47 percent, road salt in from 20 to 78 percent, and fertilizer in from 2 to 7 percent of the contaminated wells. These percentages vary according to the geologic unit sampled.

Data on septic tank malfunctions indicate that there are problem areas in the suburban townships around the City of Erie and along Lake Erie, as well as localized areas such as Cranesville and McKean Borough. It is the poor soil and groundwater conditions which have led to the present problem, in that many of the septic tanks in the subbasin were designed to lower specifications and installed prior to the DER regulations for on-lot disposal. As the population density increases in these areas, additional problems may occur. However, completion of treatment plants currently under construction and those proposed will alleviate some of the sewage pollution problem.

F. EROSION AND SEDIMENTATION

1. Sheet And Rill Erosion

Sediment is generally regarded as the greatest pollutant by volume in the waters of the Commonwealth. Because of this, participants in earthmoving activities are required to develop and follow an erosion and sedimentation plan designed to prevent accelerated runoff and erosion. When an area to be disturbed is over 25 acres, they are required to file the plan with DER and obtain a permit prior to commencing the activity. Farmers are exempt from the permitting requirement. However, they must still have a workable plan.

Sediment has several adverse impacts. One of the more widespread of these is its deleterious effect on the aquatic ecosystem. In addition, sediment can decrease the capacity of reservoirs through siltation and also cause clogging of filters in public water supply systems. Although sediment is produced by soil loss from streambanks, roadsides, gullies, and sheet and rill erosion[29], only sheet and rill erosion will be discussed here quantitatively.

The rate of sheet and rill erosion, and consequently the amount of sediment being produced, is significantly influenced by land use. Much of the state's land is used for agriculture or forests. Thus, on the basis of land area, cropland and pasture are potentially large contributors of sediment, with cropland being the major contributor. Due to the extensive area they cover, forests are also potentially large sources.

Of the subbasin's 113,506 acres in agriculture, 82 percent is used as cropland, with 21 percent of this being in row crops, which have the highest soil loss potential of all crops. In this subbasin, cropland has an average annual soil loss rate of 3.5 tons per acre and a gross loss of 333,000 tons (See Appendix F-2, Tables 1 and 2).

Only a portion of this gross loss is transported into the subbasin's streams, while the remainder is deposited as colluvium at the base of slopes and in swales. However, over a period of years this colluvium moves in stages to the stream system due to further erosion and soil creep. The amount of eroded material transported from the subbasin by water is the subbasin's sediment yield. For Subbasin 15

[29]For a detailed methodology on determining soil loss by sheet and rill erosion see Appendix F-1.

Table 32

LAND CAPABILITY CLASSES

Land Use	Acres	Capability Class (Percent) I	II	III	IV	V	VI	VII	VIII	I – IV	V – VIII
Cropland	95,024	0.1	26.2	52.1	21.5	0.0	0.1	0.0	0.0	99.9	0.1
Pasture	18,482	0.0	15.0	58.5	26.0	0.0	0.0	0.5	0.0	99.5	0.5
Forest	119,087	0.1	16.4	49.0	26.3	0.0	0.4	7.2	0.6	91.8	8.2

DEFINITIONS OF LAND CAPABILITY CLASSES

Land Suited for Cultivation and Other Uses

Class I — Soils have few limitations that restrict their use.

Class II — Soils have some limitations that reduce the choice of plants or require moderate conservation practices.

Class III — Soils have severe limitations that reduce the choice of plants, or require special conservation tactics, or both.

Class IV — Soils have very severe limitations that restrict the choice of plants, require very careful management, or both.

Land Limited In Use – Generally Not Suited for Cultivation

Class V — Soils subject to little or no erosion but have other limitations such as rocks, impractical to remove, that limit their use largely to pasture, woodland, or wildlife food and cover.

Class VI — Soils have severe limitations that make them generally unsuited to cultivation and limit their use largely to pasture, woodland, or wildlife food and cover.

Class VII — Soils have very severe limitations that make them unsuited to cultivation and that restrict their use largely to grazing, woodland, or wildlife.

Class VIII — Soils and land forms have limitations that preclude their use for commercial plant production and restrict their use to recreation, wildlife or water supply; or to aesthetic purposes.

Source: U.S. Department of Agriculture, Soil Conservation Service this averages 37,000 tons of soil per year (See Appendix F-2, Table 3), but may be significantly higher or lower depending upon rainfall characteristics and subsequent streamflow.

As stated previously, sheet and rill erosion are not the only mechanisms of soil loss. Gully and bank erosion are also responsible for a considerable amount of soil removal. In addition, soil loss and sediment yield are not equivalent. Sediment yield is the amount of soil actually transported from a watershed or subbasin by water, while soil loss is simply the removal of soil particles from their point of origin. Therefore, Table 2 (Appendix F-2) will show a greater amount of gross soil loss for the subbasin than is listed as sediment yield in Table 3 (Appendix F-2).

The soil loss from cropland may be reduced by the use of conservation practices such as minimum tillage, strip-cropping, contour farming, crop rotations, and the installation of sod waterways and diversion terraces. However, since a farm is an individual management unit, the methods used to control erosion must be part of the farming operation and will be influenced by the owner's economic limitations. Erosion control measures and practices must be selected, designed and installed to meet the situation on individual farms, with soil loss being reduced to feasible and acceptable levels. It should be noted that agricultural erosion control involves both environmental and economic common sense. Erosion control protects the farmer's investment in crops, fertilizers and the soil, while at the same time improving water quality in the Commonwealth's streams. For the most part, agricultural erosion control practices are more a matter of good crop rotations, cultural practices and tillage activity control than expensive investment in physical facilities.

As indicated in Table 32, only 0.1 percent of the subbasin's cropland is in Capability Classes V through VIII. Capability groupings indicate, in a general way, the suitability of soils for most kinds of field crops, and are made according to the limitations of the soils when used in this capacity. Land in Classes I through IV is suited for cultivation and other uses, while land in Classes V through VIII is generally not suited for cultivation and should be limited as to its use. Thus, less than 100 acres of existing cropland in the subbasin is not suitable for use as cropland and should be converted to less intensive uses to reduce erosion to acceptable levels.

A second component of agricultural land use is pasture. This has an average annual soil loss rate of 3.0 tons per acre and an average annual gross loss of 230,000 tons. In comparison to cropland, the potential for sediment pollution from pasture is low. However, heavy grazing on the steeper slopes, which are generally used for pasture, and in small areas close to streams greatly increases the erodibility of pasture land.

Only 0.5 percent or 92 acres of the subbasin's pastureland is in the least desirable capability classes. Although this land is generally suited for pasture, special care must be taken to insure that proper management is used to prevent excessive erosion.

Forestland, comprising 36 percent of the subbasin's total land area, is normally very resistant to erosion. However, disturbances, either natural or man-made, to a forest ecosystem can create conditions with a large pollution potential. For example, fire can destroy both the vegetative cover and the organic material covering the forest floor, thus severely reducing the forest's erosion resistant nature. Improper road and skid trail location during timber harvesting can also have a similar detrimental effect. Normally, though, the effects of these disturbances last only for part of one growing season or until the natural succession of lesser vegetation takes place.

An additional activity contributing significant amounts of sediment to the Commonwealth's streams is construction and mining. Grading and excavation for construction projects expose soil that is then easily eroded and provides the potential for the production of significant amounts of sediment. Construction activities having the potential for contributing large amounts of sediment include the development of industrial parks, shopping centers, residential areas, dams and pipelines, in addition to highway construction. Contractors engaged in these activities are required by DER to prepare erosion and sedimentation plans as discussed previously.

Erosion from construction sites can be restricted through numerous techniques ranging from selecting the proper season for construction to the building of engineering works. Basically, these techniques include (1) reducing the area and duration of exposure of soils to erosion, (2) covering exposed soils with mulch or vegetation, (3) mechanically reducing the rates of storm runoff, (4) trapping sediment carried by the storm runoff, and (5) planning land clearing operations to coincide with periods of minimum rainfall.

Specific erosion and sedimentation control practices that are adaptable to various sites and situations can be found in the "Directory of Soil Erosion and Sedimentation Control Practices" published by the Pennsylvania Department of Environmental Resources. These practices include both vegetative methods such as seeding and mulching, and structural methods such as constructing sediment traps and interceptor channels. In addition, simply minimizing the amount of disturbed and impervious areas results in significant decreases in erosion and sedimentation.

2. *Shoreline Erosion*

The most critical areas are in Springfield, Millcreek, and North East Townships. The Townships of Girard, Fairview, and Harborcreek are in somewhat less danger, but are still subject to significant damage within 25 years. The City of Erie and Lawrence Park Township have the least degree of hazard, due to the protection offered by Presque Isle Peninsula. Outer Presque Isle Peninsula is also experiencing a significant loss of beach material. This loss is due to normal longshore transport of sediment and high water levels. Past methods of beach protection have done little to reduce the net loss of sand, and in some instances have even aggrevated the problem.

The CZM Program, because of the associated problems with structural protection methods, encourages the use of nonstructural protection methods. This

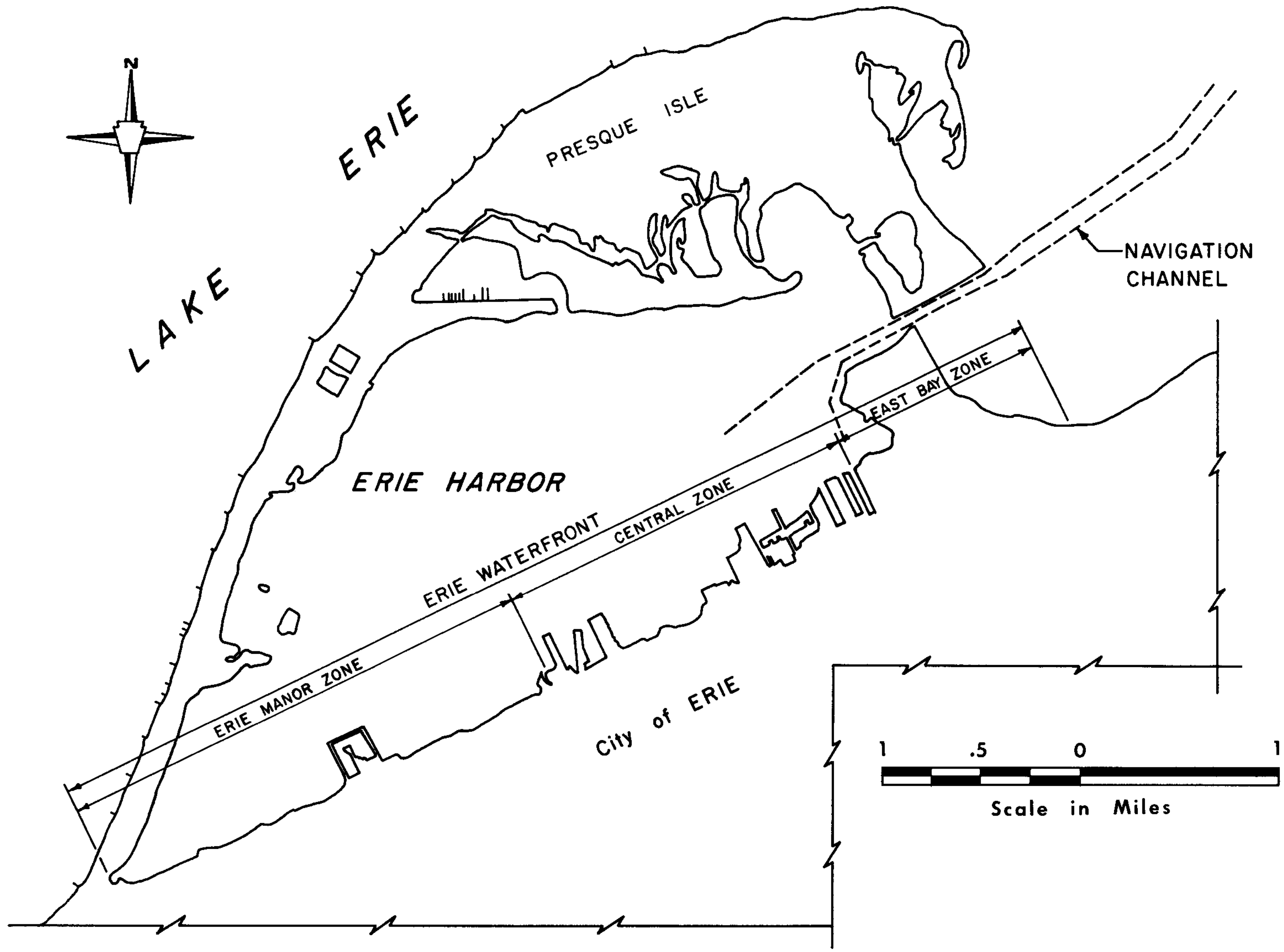


FIGURE 17. Erie Harbor and Waterfront

objective will be accomplished by providing technical assistance and advice to local municipalities, concerning the benefits and dollar savings of nonstructural methods for shore protection.

Due to higher than normal water levels in the Great Lakes Basin since 1972, there has been accelerated shoreline erosion and bluff recession along Lake Erie. As part of the Coastal Zone Management Program in Pennsylvania, a study of the Erie County shoreline was made between January and June, 1975.

The most immediate threat on the lakeshore is flooding and erosion in low-lying cottage areas. Over two dozen cottages have already been completely destroyed and over 100 cottages have suffered damage. The rate of recession of the bluff has increased significantly along the entire shoreline during the past three years, and if the current rates continue over the next 25 years, several hundred homes and cottages will be endangered.

G. NAVIGATION

Erie Harbor is on the south side of a bay formed by Presque Isle Peninsula, a sand spit which juts out into Lake Erie. The topography on the waterfront is an obstacle to the development of proper access, which in turn has limited the development potential of Erie Harbor. In Erie Harbor, flooding has occurred at certain waterfront areas which are only four to six feet above low water datum. High winds have had a devastating affect on the unprotected beaches and road system of Presque Isle Peninsula. In 1973, record high lake levels caused severe damage along the shoreline of Lake Erie and the Presque Isle Peninsula.

The National Oceanic and Atmospheric Administration Lake Survey Center indicates that Presque Isle Bay covers 5–1/2 square miles as an almost completely enclosed body of water on Lake Erie's southern shore. Sheltered by Presque Isle on the north and the neck on the west, the harbor is entered from the east through a man-made inlet as indicated on Figure 17. The harbor averages 4.5 miles in length and more than one mile in width. The Entrance Channel begins at a point approximately five miles in Lake Erie and runs at a 29 foot depth and a width of 500 feet to a point approximately 1,000 feet east of the north pier, where it narrows to 250 feet at the east end of the south pier. The final 2,000 feet of the Entrance Channel is maintained at a 28-foot depth. The channel then widens into Erie Harbor Basin approximately 3,000 feet west of the inlet. The harbor basin varies in depth from 28 feet at the eastern extremity where a turning basin and channels are maintained by the Corps of Engineers, to one foot at the western extremity near the neck of the Peninsula.

Total tonnage of freight through Erie Harbor fell from over nine million short tons in 1945 to a low of less than one million short tons in 1966. Bulk shipping of iron ore and coal formed the major portion of the traffic through Erie Harbor from the mid-1930's through the mid-50's. By 1968, coal and iron ore were all but nonexistent in terms of the total freight traffic using Erie Harbor. Comparative traffic figures for waterborne commerce through Erie Harbor is shown in Table 33. Since 1966, the majority of Erie Harbor traffic has been in bulk construction materials and petroleum products including limestone, sand, gravel, crushed rock and gasoline. The freight traffic by major commodity for the years 1968–1973 is shown in Table 34.

Table 33

COMPARATIVE STATEMENT OF TRAFFIC IN ERIE HARBOR (1959–1973)

Year	Traffic (Short Tons)
1959	3,910
1960	2,578
1961	2,543
1962	2,550
1963	2,546
1964	1,932
1965	1,187
1966	975
1967	1,144
1968	1,250
1969	1,087
1970	1,092
1971	1,249
1972	1,360
1973	1,283

Source: *Waterborne Commerce Of The United States:* Part 3 - Waterways and Harbors, Great Lakes, *(Comparative Statement of Traffic).*

Historically, domestic traffic has accounted for a high percentage of the total traffic through Erie Harbor. Foreign imports and exports made up, on the average, only 15 percent of the total annual harbor traffic during the period 1968–1973. Domestic shipments to other Great Lakes ports have been almost nonexistent in recent years. Bulk cargo (limestone, sand and gravel, nonmetallic minerals and gasoline) make up a high percentage of total traffic coming into Erie Harbor. Exports or shipments from Erie Harbor have ranged from four percent to nine percent of the total annual traffic over the last six years.

General cargo through Erie Harbor is handled mostly at the Erie International Marine Terminal. The number of ships calling at the terminal and the tonnage of cargo handled exclusively through the marine terminal are shown in Table 35. Shipping through the International Marine Terminal has ranged from a high of 92,000 tons in 1973 to a low of 37,000 tons in 1970. The only overall pattern is that imports have consistently (except for 1969) accounted for a greater percentage of shipping than exports. Machinery and steel products accounted for most of the export tonnage over the eight-year period, while pig iron, steel products and ore accounted for most of the imports. The Port Authority is looking to their new 300-ton crane to substantially increase shipping through the marine terminal, particularly in the categories of steel products and machinery.

Table 34

FREIGHT TRAFFIC IN ERIE HARBOR, BY COMMODITY
(1,000 Short Tons)

Commodity	Year 1968	1969	1970	1971	1972	1973
Limestone	466	370	376	474	491	436
Sand, Gravel, Rock	394	365	294	389	422	361
Clay	36	26	29	36	18	47
Nonmetallic Minerals	120	92	191	146	85	116
Gasoline	108	101	124	122	147	128
Distillate Fuel Oil	30	11	12	9	81	60
Residual Fuel Oil	17	24	–	–	–	–
Pig Iron	25	22	25	4	19	30
Iron and Steel Plates	–	32	–	1	6	17
Iron and Steel Scrap	30	19	15	17	6	-
Barley and Rye	–	–	–	–	63	49
All Others	24	25	26	51	22	39

Source: *Waterborne Commerce Of The United States:* Part 3 - Waterways and Harbors, Great Lakes, *1968–73 (Freight Traffic).*

The prospective future trade through the Erie port is contingent on a series of complex variables. Only some of these variables can be controlled at the local level. The key is the transportation rate structure. A shipper's selection of a port is based on the gross cost for terminal switching changes, docking charges, stevedoring rates, labor and equipment rates for extra service, warehouse rates, etc. For too long, Erie depended on bulk cargo (especially coal and iron ore) for most of its shipping to the detriment of its general cargo movement capabilities. General cargo requires sophisticated equipment to move it more efficiently and thus cheaper than competitive ports. When the iron ore and coal business was lost to Conneaut and Ashtabula, Ohio, Erie did not yet have the general cargo facilities to compete. The Port Authority has now committed itself to the finest general cargo facilities and equipment on the Great Lakes. They are confident that Erie will be able to compete effectively with neighboring ports in the movement of general cargo.

Many manufacturing items are so large that they can only be moved by ship. However, until recently, the Erie port's lack of a heavy lift capability frequently deterred local industries from bidding on jobs because of limited shipping capability. In other instances, local companies have been forced to bid knockdown conditions with field erection on large items. This approach has invariably resulted in lost bids because of the extra costs involved. In 1970 and 1971 nearly 3,000 tons of business bid on and lost by local industries can be attributed to the lack of a heavy lift capability. The total machinery, equipment and fabricated metal products actually shipped in these two years was only 6,700 tons. Companies from Erie, North East, Meadville, Sharon, Akron and as far away as Pittsburgh have made inquiries about the Port's heavy lift capabilities. Shipment of manufactured durable goods appears to be an area where Erie could compete in the port business. With the proper facilities, port officials expect shipping tonnage to increase in future years. If the Port Authority is successful in attracting just 10 percent of the traffic from other ports, tonnage would be up by 50 percent over recent levels.

Table 35

WATERBORNE TRAFFIC
ERIE INTERNATIONAL MARINE TERMINAL
(Long Tons)

	Year					
	1969	1970	1971	1972	1973	1974
Ships	51	31	45	44	44	38
Domestic Exports	433	25	–	–	–	536
Foreign Exports	45,358	14,658	21,049	19,721	20,324	7,619
Oil Products	1,197	759	272	111	–	–
Lumber	202	305	16	14	329	855
Machinery	1,284	593	2,817	1,233	1,380	1,578
Steel Products	42,487	12,829	10,115	16,498	17,541	3,923
Roofing Materials	–	–	–	172	516	882
Others	188	172	7,829	1,693	558	381
Total Exports	45,791	14,683	21,049	19,721	20,524	8,255
Domestic Imports	–	–	24,500	–	22,000	21,906
Foreign Imports	29,847	22,594	30,800	19,921	49,529	31,765
Pig Iron	19,691	16,050	11,300	9,957	19,088	15,152
Ore	–	1,197	6,240	5,021	9,973	13,401
Aluminum	4,365	–	2,003	1,011	82	–
Tin	2,221	1,783	1,725	1,470	1,120	890
Steel Products	–	565	476	2,009	18,875	2,262
Autos	–	–	2,427	–	–	–
Rubber & Syn.	597	723	5,124	–	–	–
Machinery	1,732	1,086	705	71	64	–
Others	1,241	1,190	800	382	327	60
Total Imports	29,847	22,594	55,300	19,921	71,529	53,665
Total Cargo	75,638	37,277	76,349	39,642	91,853	61,820

Source: Erie-Western Pennsylvania Port Authority.

Note: Long ton equals 2,240 pounds.

VI. PRINCIPAL PHYSICAL CHARACTERISTICS AND ENVIRONMENTAL AND SOCIAL IMPACTS OF STRUCTURAL ALTERNATIVES

Many water resources projects have been examined as possible solutions to existing or future problems in Subbasin 15. While considerable staff effort was devoted to the investigation of alternatives and professional engineering judgment was applied during that effort, these important activities are not afforded any degree of visibility or exposure to the reader of this report. Specific project or program proposals were rejected before they even reached the "alternative" stage, because of overwhelmingly negative economic, environmental, social or physical constraints, if it was obvious that more acceptable alternatives were available.

This chapter provides a description of the basic characteristics and impacts which were considered in the examination of alternative structural solutions to the problems in this subbasin. The discussion includes the alternatives which were *recommended* for public water supply.

The consideration and analyses of impacts only deals with those which are direct; there is no discussion of impacts which may be considered secondary or tertiary, such as development pressures which may follow the construction of a major project, or economic or social benefits which may accrue as a result of the direct benefits.

A. PROJECTS RECOMMENDED FOR WATER SUPPLY

Several structural measures were examined as possible solutions to public water supply problems in Subbasin 15. In the interest of brevity, only the following structure, which is recommended for further study, is discussed here. No discussion is presented for surface water intakes or additional groundwater development for public water supply or for alternatives which have not been recommended.

1. *Small Potential Reservoir*

A small potential reservoir for Albion Borough Municipal Water Authority would be located on Temple Creek, Elk Creek Township, Erie County. The damsite is located approximately 5 miles upstream from Albion Borough. The proposed impoundment has been investigated as a possible source of public water supply for the Albion Borough Municipal Water Authority. The 10-foot high dam would be an earthfill structure and would control runoff from a drainage area of 0.55 square miles. The dam, as proposed, would have a total storage of 23 acre-feet. The estimated construction cost of the project would be $350,000.

Environmental and social consideration of this dam would include periodic inundation of approximately 2.5 acres of agricultural and open land when the dam is at full storage capacity. This may result in possible losses of vegetation and small game from the damsite and the lake area; however, this could be partially offset by adequate watershed management to mitigate these losses. The dam's obstruction to the free-flowing nature of the stream may have an adverse effect on fishing and aquatic life. The project-occassioned soil erosion and resulting stream siltation and eutrophication may have some effect on surface water quality and aquatic life and fish habitat, which could be minimized by adequate control during the construction of the project. Also, temporary increases in noise and dust as well as traffic interruptions may be experienced during the construction stage. The project may be aesthetically intrusive; however, this can be minimized by the use of environmentally oriented design concepts. Construction of this impoundment may result in possible relocation of secondary roads.

APPENDIX A

SOILS

Appendix A-1

CHARACTERISTICS OF SOILS

Soil Assn. Symbol	Soil Association Name	Percent of Each Soil in Assn.[a]	Percent of Each Assn. In the Subbasin	Dominant Slope (Percent)	Drainage Class[b]	Depth of Soil (Inches)	Hydro-logic Group
D2b	Erie	60	28.9	0–15	SWP	72+	C
	Langford	10		3–20	MW	72+	C
D2f	Sheffield	70	29.7	0–3	P	60+	D
	Platea	5		0–12	SWP	60+	C
D2h	Venango	50	2.6	0–15	SWP	60+	C
	Cambridge	15		3–20	MW	60+	C
E1b	Conotton	40	29.7	0–15	W	72+	B
	Birdsall	15		0–8	P	72+	D
E1f	Wayland	30	4.8	0–3	P	60+	C/D
	Chenango	15		0–20	W	60+	A
	Braceville	10		0–8	SWP	60+	C
E2a	Canadice	55	4.3	0–5	P	72+	D
	Canadea	35		0–8	SWP	72+	D

[a]Percentages do not total 100 because of minor soils in each association.

[b]W - Well drained; MW - Moderately well drained; SWP - Somewhat poorly drained; P - Poorly drained

Source: Soil Conservation Service

APPENDIX B

WATER USE

Appendix B-1

WATER CONSERVATION

The Commonwealth enjoys a relatively abundant supply of water when compared to many other states in the Nation. During the past ten years, normal and above normal annual precipitation totals have provided many of Pennsylvania's water suppliers with the quantities of water needed to support growth in service populations, increased use of water-using household conveniences, and the general growth in per capita daily usages associated with the rising standard of living of a society largely unaccustomed to conserving resources.

Unfortunately, many suppliers have just been able to keep one step ahead of rising demands, by relying on existing streamflow or groundwater conditions during relatively good times. Thus, many of those suppliers have rendered themselves extremely vulnerable to the ill effects of even a mild drought. Several areas in the state would be subject to extreme social and economic disruption if a severe or prolonged drought were to occur at this time.

Because of the continually growing demands being placed upon this finite resource by an innovative society driven by the urge to attain a high standard of living, it is becoming increasingly important that, as more citizens are able to avail themselves of modern conveniences, they realize the water "pie", in a sense, is being shared by more people. Therefore, each person will be required to accept a smaller share.

By practicing effective conservation techniques it will be possible for more of society to enjoy the benefits of modern technology without placing any additional immediate demands upon the resource. It is strongly recommended that all water users in Pennsylvania strive to practice good conservation. Good conservation can accomplish the following:

1. Buy time for planners to formulate detailed studies which would determine the adequacy of system facilities and existing sources.
2. Delay the need for expansion of both water supply facilities and sewage treatment plants. Highly successful conservation campaigns may even eliminate any need for expansion, which would eliminate possible degradation of the environment associated with new development.
3. Save water – This is the major area in which the general public can really get involved. By saving water, one can also reduce energy consumption and, therefore, realize not only a monetary reward for himself but also the companies involved in supplying the water. Energy utilized in supplying water is consumed in treatment processes, transmission of water in both untreated and treated form and in heating processes. Because power plants are major water users, any reduction in power requirements will result in even further reduction of water use.

Conservation measures are generally not emphasized to any great degree unless an emergency such as a drought or a flood arises. During periods of drought, water supplies become critically low. During periods of flooding, water is plentiful but often is unsafe to drink. Existing supplies become contaminated, and treatment plants inundated with high waters are unable to treat the water. In either case, as potable water supplies decrease, water users may pass through three phases of cutbacks or curtailments. These are 1) voluntary water conservation, 2) mandatory water conservation and 3) mandatory water rationing. In order to comply with either Phase 1 or Phase 2, the water user must not only be willing to save but must know how to save. If water conservation is already being practiced, the user may find it much easier to adjust to further curtailment during an emergency situation. However, if the user has no idea about the best ways to conserve water, Phase 3 conditions could be imposed very early during a crisis. Therefore, it is imperative that water conservation be encouraged immediately.

Consider the following example of how water is used in a typical household, and how much water could be saved. Assume that one household, or a family of four people, uses 255 gallons of water per day (gpd). The initial usage breakdown is listed in Table 1. Also assume that this family wants to conserve water and decides to introduce two water-saving devices into their household. These devices, with a comparison of usage before and after installation, are as follows:

1. Maximum 3.0 gallon per minute (gpm) shower head.

   Present conventional system: 5 gpm x 4 minutes/day x 4 persons = 80 gpd.

   New system: 3 gpm x 4 minutes/day x 4 persons = 48 gpd. If this device were installed, a 12 percent savings would be made as noted in Table 1.

2. 3.5 gallons per flush water closet.

   Present conventional system: 5 gallons/flush x 5 flushes/day x 4 persons = 100 gpd.

   New system: 3.5 gallons/flush x 5 flushes/day x 4 persons = 70 gpd. If this device were installed, a 12 percent savings would be made as noted in Table 1.

A combination of these devices would result in a savings of 62 gpd, or a 24 percent reduction in total water use. Based on a system serving 1,000 people or 250 households, 566,000 gallons of water could be saved each year, if only

Table 1

TYPICAL HOUSEHOLD WATER USAGE AND POTENTIAL REDUCTION

	Initial Usage (gpd)	Usage With 3.0 GPM Shower Head (gpd)	Usage With 3.5 Gal./Flush Water Closet (gpd)
Toilet Flush	100	100	70
Bathing/Showers	80	48	80
Laundry	35	35	35
Kitchen	27	27	27
Lavatory	8	8	8
Utility Sink	5	5	5
Total	255	223	225
Total Savings		32	30
% Savings		12%	12%

10 percent of the customers would use these devices (See Table 2).

It should be emphasized that these figures are used only as an example. A household may be able to save more or less water than indicated in these tables, depending upon its present usage. However, the fact remains that water will be conserved. In certain communities, the new water closet may not be applicable because of potential sewer problems associated with decreased flows. Nevertheless, a water company should consider encouraging the installation of these devices wherever possible.

In addition to these devices, there are other water-saving devices which may be utilized. These would include faucet aerators, spray taps, flow control devices and toilet tank inserts. In general, installation of these devices is very easy and quite inexpensive.

There are many other areas throughout the house where water conservation could be practiced. The following list will point out just a few of these:

1. Repair any leaky faucets, connections, pipes or toilets. To check for toilet leaks, put a few drops of food coloring in the tank; then check to see if the coloring appears in the bowl.
2. Check for leaks between the water meter and the home. Turn off all water uses in the home; then observe the meter to see if it continues to register any water usage.
3. Do not use the toilet for trash disposal. Approximately 5 to 7 gallons of water are used per flush in a conventional toilet.
4. Do not wash dishes, shave, brush teeth, or wash hands utilizing an open faucet. Use a stopper as often as possible.
5. Take shorter showers. Use a timer and time your showers. Remember, the longer the shower, the more water used. If practical, turn off shower while soaping up.
6. Dislodge particles of dirt with a brush or wash cloth instead of using the force of the water.
7. Operate a washing machine or dishwasher only with a full load. If the washing machine has a suds saver, use it and save 16–19 gallons of water per load. Avoid long pre-wash and scrub cycles for automatic dishwashers.
8. Avoid using the garbage disposal on items that could be used for composting or disposed of in the garbage can.
9. Keep a container of drinking water cold in the refrigerator instead of allowing the water to run to obtain a cold drink.
10. Reuse washwater to water plants, lawns, gardens or even to wash cars.
11. Do not water the driveways/sidewalk along with the lawn or garden.
12. When watering the lawn or garden, do it in the early morning to reduce evaporation losses.

Table 2

TYPICAL ANNUAL WATER SAVINGS
PER 1000 PERSONS (Million Gallons)

Percentage of Customers Using Water-Saving Devices	Savings Utilizing Device "A" (3 GPM Shower Head)	Savings Utilizing Device "B" (3.5 Gallon/Flush Water Closet)	Savings Utilizing "A" and "B"
10	0.292	0.274	0.566
20	0.584	0.548	1.132
30	0.876	0.821	1.697
40	1.168	1.095	2.263
50	1.460	1.369	2.829
60	1.752	1.643	3.395
70	2.044	1.916	3.960
80	2.336	2.190	4.526
90	2.628	2.464	5.092
100	2.920	2.738	5.658

Appendix B-2

PUBLIC WATER SUPPLY SOLUTION ALTERNATIVES

Table 16 in Chapter V lists the alternatives which were examined as solutions to public water supply deficiencies in Subbasin 15. The columns in Table 16 are explained here.

Column 1: Public Water Supplier Name, Map Legend Number and DER Numerical Code.

Column 2: List of present sources and projected deficiencies for 1990 and 2020. Deficiencies include yield, allocation, treatment plant (filtration) and storage deficiencies.

Column 3: List of solution alternatives which could serve to decrease or eliminate deficiencies. Increased storage alternatives apply only to storage deficiencies and will not help to solve other deficiencies. They are supplemental to yield, allocation and treatment solution alternatives.

Column 4: Increased capacity which would be required to provide for projected 1990 usages, measured against existing capacity.

Column 5: 1990 Annual Costs in 1976 dollars for alternatives listed in Column 3.

Column 6: Increased capacity which would be required to provide for projected 2020 usages, measured against existing capacity.

Column 7: 2020 Annual Costs in 1976 dollars for alternatives listed in Column 3.

Column 8: Remarks applicable to specific solution alternatives.

APPENDIX C

FLOOD DAMAGE REDUCTION

Appendix C-1

CORPS OF ENGINEERS PROJECT

Legend (See Figure 11)	Location	Status	Purpose	Type of Structure	Drainage Area (sq.mi.)	Design Life-time (Year)	Length (ft.)	Width (feet)	Height or Depth (ft.)	Diameter (feet)	Flood Pool Surface Area (acres)	Flood Control Volume (Acre-Feet)	Total Construc-tion Cost ($1,000)[a]	Total Annual Cost ($1,000)[a]	Beneficial Area (See Figure 11)
C-1	Conneaut Creek	Completed 1949	Flood Protection	Snagging & Clearing Project		25							78	7	1

[a]1976 Price Level

[b]Total annual cost (1976 price level) consists of annual construction cost amortized at the rate of 5.25% over the respective life periods plus annual operation and maintenance cost.

Note: In some cases, for fiscal or other reasons, flood control projects are designed and constructed as two or more units; however, all units acting in tandem are required to achieve the design flood damage reduction. Units are listed separately.

Appendix C-2

DEPARTMENT OF ENVIRONMENTAL RESOURCES PROJECT

Legend (See Figure 11)	Location	Status	Purpose	Type of Structure	Drainage Area (sq.mi.)	Design Life-time (Year)	Length (ft.)	Width (feet)	Height or Depth (ft.)	Diameter (feet)	Flood Pool Surface Area (acres)	Flood Control Volume (Acre-Feet)	Total Construc-tion Cost ($1,000)[a]	Total Annual Cost ($1,000)[a]	Beneficial Area (See Figure 11)
E-1	Fourmile Creek C25:2	Completed 6/1959	Flood Protection	Channel Improvement Concrete Slab Variable width Cut-off walls		50	380						101	7	Wesleyville Borough

[a]1976 Price Level

[b]Total annual cost (1976 price level) consists of annual construction cost amortized at the rate of 5.25% over the respective life periods plus annual operation and maintenance cost.

Note: In some cases, for fiscal or other reasons, flood control projects are designed and constructed as two or more units; however, all units acting in tandem are required to achieve the design flood damage reduction. Units are listed separately.

Appendix C-3

FLOOD PLAIN INFORMATION REPORTS BY
U.S. ARMY CORPS OF ENGINEERS

Watershed	Report	Date Completed
A	Conneaut Creek at and in the vicinity of Conneautville (to determine the feasibility of Section 205 projects)	In progress

Appendix C-4

FLOOD PRONE AREAS MAPPED BY
U.S. GEOLOGICAL SURVEY

Watershed	Stream(s)	U.S.G.S. Topographic Map	Date Completed
A	Elk Creek	Fairview	1973
A	Elk Creek, Porter Run, Goodban Run, Falk Run & Lamson Run	Edinboro North	1974
A	Cascade Creek & Fourmile Creek	Erie North	1974
A	Sixmile Creek, Sevenmile Creek & Twelvemile Creek	Harborcreek	1973
A	Walnut Creek, Bear Run, Trout Run & Elk Creek	Swanville	1974
A	Crooked Creek & Conneaut Creek	East Springfield	1973
A	Elk Creek, East Branch Conneaut Creek, Conneaut Creek & Temple Run	Albion	1973
A	West Branch Conneaut Creek, Middle Branch Conneaut Creek, East Branch Conneaut Creek, Mud Run & Conneaut Creek	Beaver Center	1973
A	Elk Creek, Walnut Creek & Mill Creek	Erie South	1974

Appendix C-5

FLOOD INSURANCE STUDIES COMPLETED FOR U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT FEDERAL INSURANCE ADMINISTRATION[a]

Watershed	Location of Study
A	Millcreek Township
A	Girard Borough
A	Lawrence Park Township
A	Fairview Borough
A	Fairview Township
A	Girard Township
A	Lake City Borough
A	McKean Borough

[a]Includes studies completed as of February, 1978.

Appendix C-6

FLOOD DAMAGE REDUCTION SOLUTION ALTERNATIVES

Table 21 in Chapter V lists the alternatives which were identified as possible solutions or partial solutions to existing flood damage problems in Subbasin 15. The columns in that table are described here.

Column 1: Legend No. of a damage center or reach (See Figure 11)

Column 2: Name of a damage center or reach and name of streams identified as causing the damage. For each damage center or reach, the first row identifies the name and the second row identifies the stream.

Column 3: Damage reduction due to existing or funded proposed structures expressed as a percentage of natural annual damage in a damage center or reach.

Column 4: Need expressed as residual annual damage (damage remaining after completion of existing flood control structures, structures currently under construction and funded proposed structures) in thousands of dollars (1976 price level).

Column 5: Nonstructural Solution

A. Floodplain regulation: requires floodplain information, as well as workable and strong legislative action (more applicable to future than existing development).

B. Flood Insurance: does nothing to reduce flood hazard or damages, but rather lessens the economic burden of flooding on floodplain occupants. However, the land use regulations required to participate in HUD's National Flood Insurance Program will effectively reduce future damage potential and control future floodplain development.

C. Permanent Flood Proofing: applicable primarily to existing residential, industrial and commercial developments on the floodplain, where structural flood control measures cannot be economically justified.

D. Flood Forecasting: applicable only where upstream gaging is sufficient to provide accurate forecasts of flood stages downstream. Effective along the main stem of a river but not in headwater areas or small tributaries, where there is insufficient time for warning and response.

Column 6: Structural Solutions includes levees or flood walls, channel modifications and potential small and Corps of Engineers reservoir sites. The average annual benefit in thousand dollars (1976 price level) for each damage center or reach resulting from each alternative structural solution is shown.

Column 7: Any remarks applicable to specific solution alternatives.

APPENDIX D

WILD AND SCENIC RIVERS

Appendix D-1

PENNSYLVANIA SCENIC RIVERS CANDIDATES

Table 29 in Chapter V lists the streams and stream reaches which were identified in the *Pennsylvania Scenic Rivers Inventory* as candidates for wild, scenic, recreational or modified recreational designation by the General Assembly. The columns in that table are described here.

Column 1: Legend – Number code shown in this column corresponds with number code shown on Figure 15.

Column 2: Stream Name – Name of stream on which proposed segment is located.

Column 3: Priority Group – Waterways have been categorized into three priority groups. First priority waterways are considered to be of statewide, and in some instances, even national significance. Second and third priority waterways exhibit some outstanding values, yet not enough in quantity or quality to merit statewide recognition. These are primarily locally and regionally significant. First priority waterways have been further divided into three priority subgroups (A, B and C) based upon degrees of environmental quality, resource endangerment and recreational potential. First priority "A" group waterways are those which have the most urgent need for protection and immediate need for additional study. First priority "B" and "C" groups are of less than immediate concern; however, lower priority ratings should not be equated with a de-emphasized need for protection.

Column 4: Proposed Segment Limits – Upstream and downstream limits of the candidate segment.

Column 6: Proposed Class – Candidate segments have been designated according to the following classes:

W - Wild river areas—those rivers or sections of rivers that are free of impoundments and generally inaccessible except by trail, with watersheds or shorelines essentially primitive and waters unpolluted.

S - Scenic river areas—those rivers or sections of rivers that are free of impoundments, with shorelines or watersheds still largely primitive and undeveloped but accessible in places by roads.

R - Recreational rivers—those rivers or sections of rivers that are readily accessible, that may have some development along their shorelines and that may have undergone some impoundment or diversion in the past.

MR - Modified recreational rivers-those rivers or sections of rivers in which the flow may be regulated by control devices located upstream. Low dams are permitted in the reach so long as they do not increase the river beyond bank-full width. These reaches are used for human activities which do not substantially interfere with public use of the streams or the enjoyment of their surroundings.

Column 7: Water Quality – As part of the scenic rivers inventory and evaluation process, the DER Bureau of Water Quality Management provided information related to the water quality of each nominated stream. All waterways have been placed in one of the following three groups:

Group 1 - Stream presently meets or exceeds state water quality standards.

Group 2 - Stream does not presently meet state water quality standards, but will within 10 years.

Group 3 - Stream does not presently meet state water quality standards, but will beyond 10 years.

APPENDIX E

WATER QUALITY

Appendix E-1

GLOSSARY OF WATER QUALITY TERMS

Term		Definition
Acidity (Mineral)	–	The capacity of an aqueous media to neutralize a base; usually reported in mg/1 as $CaCO_3$.
Alkalinity	–	The capacity of an aqueous media to neutralize an acid; usually reported in terms of mg/1 as $CaCO_3$.
Ammonia-Nitrogen	–	A gas (NH_3) released by the microbiological decay of plant and animal proteins. Reported in the study as mg/1 of nitrogen.
Biochemical Oxygen Demand (BOD)	–	A measure of the quantity of oxygen used in the oxidation of organic matter by natural biological processes in a specified time under standard conditions. For the purposes of this report, all values are expressed as oxygen demand in mg/1 exerted over a period of five days.
Chlorides	–	A measure of the concentration of chloride ions, predominately Cl, expressed in this report as mg/1.
Dissolved Oxygen (DO)	–	A measure of the quantity of oxygen gas in solution; generally expressed in mg/1.
Hardness	–	A characteristic of water caused by divalent cations, primarily calcium and magnesium, that are capable of reacting with soap to form precipitates.
Nitrate-Nitrogen	–	The final decomposition product (NO_3) of the organic nitrogen compounds, expressed in this study as mg/1 of nitrogen.
pH	–	The reciprocal of the log of the hydrogen ion activity coefficient. It ranges from 0 (acidic) to 14 (basic) with neutral water having a value of 7.
Sulfate	–	The final decomposition product (SO_4) of organic sulfur compounds; generally occurs in areas affected by acid mine drainage and expressed in this report as mg/1.
Total Phosphorus	–	Primarily the total of the complexed forms of phosphorus, orthophosphate, polyphosphate, as well as organic phosphorus (P). In this report, concentrations of phosphorus compounds are expressed as mg/1 of phosphorus. Phosphorus compounds are normally found in domestic and agricultural wastewater and many forms of industrial wastewater.
Turbidity	–	A condition caused by the presence of suspended matter in water resulting in the scattering and absorption of light; generally expressed in Jackson Turbidity Units (JTU).

Appendix E-2

CHEMICAL CONSTITUENTS IN GROUNDWATER AND THEIR CHARACTERISTIC EFFECTS ON WATER USE

Constituents	*Concentration*	*Characteristic Effects On Water Use*
Iron (Fe)	Less than 0.3 mg/1 in the eastern and southwestern sections of the Plateau regions; elsewhere on Plateau and throughout folded Appalachians, approximately half the formations yield ground-water with excessive concentrations.	More than 0.3 mg/1 stains laundry, utensils and fixtures reddish brown.
Manganese (Mn)	Commonly less than 0.05 mg/1, but as high as 0.29 mg/1 in the far northern Plateau, 0.19 mg/1 in the southwestern Plateau, and up to 0.26 in sections of the folded Appalachians.	Iron and manganese together should not exceed 0.3 mg/1. Concentrations of Mn in excess of 0.05 mg/1 may cause laundry stains and impair taste of beverages.
Sulfate (SO_4)	Rarely less than 1 mg/1 or more than 100 mg/1 commonly one to 20 mg/1.	Concentrations in regions are not high enough to cause trouble.
Chloride (Cl)	Seldom less than one mg/1 or more than 40 mg/1, commonly one to 20 mg/1.	Salty taste to water having more than a few hundred milligrams per liter.
Nitrate (NO_3)	Rarely more than 5.0 mg/1, commonly less than 1.0 mg/1.	Where concentration is greater than 4.5 mg/1, contamination from sewage may be suspected. Water of concentrations greater than 10 mg/1 may be harmful to babies.
Dissolved Solids	Total of all mineral matter rarely more than 300 mg/1, commonly 100 to 300 mg/1.	Water containing more than 1,000 mg/1 of dissolved solids is unsuitable for most purposes.
Hardness as equivalent $CaCO_3$	Rarely less than 10 mg/1 or more than 300 mg/1, commonly 70 to 300 mg/1.	Causes consumption of soap before lather will form. Hard water forms scale in boilers and hot water heaters. Water whose hardness is less than 60 mg/1 is considered soft; 61 to 120 mg/1, moderately hard; 121 to 180 mg/1, hard; more than 180 mg/1, very hard.

Appendix E-3

WATER POLLUTANTS

Municipal Wastewater

This normally consists of domestic wastewater plus nominal amounts of commercial and industrial wastewater. Following treatment, the remaining portions of organic matter and nutrients in the effluent are discharged to subbasin streams. These pollutants can produce depressed dissolved oxygen levels, promote algae growths that cause fish kills and create overall degradation of the aquatic environment. Where municipal wastewater is held in leaking lagoons or where inadequate septic systems or spray irrigation systems are used, the groundwater system may be polluted.

Industrial Wastewater

The types of materials processed during manufacturing determine the composition of this wastewater. Toxic compounds, organic matter and metals may be released and produce conditions deleterious to aquatic life and surface water quality. The groundwater system may also be polluted where leaking waste lagoons are used or where spray irrigation or septic systems are inadequate or malfunctioning.

Acid Mine Drainage

This is formed in both active and abandoned surface and deep coal mines when iron sulfide chemically reacts with water and oxygen. The reaction produces acid, sulfate and iron which commonly pollute both surface and groundwaters.

Urban Runoff Pollutants

These come from debris, animal wastes, fertilizers, fallout from air pollution, stockpiled materials, automobile wastes and other sources. Pollutants on impervious areas are washed off during the initial part of a storm, resulting in a high initial pollutant concentration that decreases as the storm progresses. Long intervals between storms will result in large amounts of pollutants collected on urban surfaces, with resultant higher concentrations of the pollutants during runoff. Where combined sewers are used, heavy storms often cause a large portion of the total waste load (municipal wastewater and urban runoff) to overflow or bypass the treatment processes, resulting in the passage of urban runoff and untreated wastewater to the subbasin streams.

Solid Waste Leachate

This is highly contaminated water contained in or associated with refuse disposal sites such as dumps and sanitary landfills. Leachate is produced when solid waste decomposes and the products are dissolved and carried with the water that infiltrates the landfill or dump. Once the disposal site reaches its water holding capacity, the leachate flows from it into the groundwater or nearby surface water. Municipal refuse leachate is highly variable in its chemical composition, but commonly shows high values for BOD, COD, iron, ammonia-nitrogen, chloride and sulfate.

Septic System Wastewater

On-lot disposal systems, commonly in the form of septic systems, currently serve the wastewater needs of most rural areas, many suburban single-family dwellings and some small industries. Effluent from these systems percolates through the soil, and a portion of the effluent, carrying those pollutants that have not been filtered out in the soil, eventually reaches the groundwater system. Given the proper soil thickness and soil properties, many pollutants are removed; however, certain dissolved solids may infiltrate to the local groundwater system.

Thermal Wastes

These may cause a significant increase in overall stream temperature and can seriously alter biological communities in the receiving streams. Thermal discharges can originate from nuclear and coal-fired power plants and from certain industrial processes.

Agricultural Runoff

This may carry sediment, fertilizers, animal wastes and pesticides into streams. Sediment problems in agricultural areas can be a problem especially when ground disturbance coincides with heavy rains. Fertilizer nutrients constitute a problem when the runoff carries them away before they can be used by the crops. Animal wastes can become a particular problem where animals are grouped in feedlots and poultry farms. Pesticides and insecticides can be a pollution hazard when precipitation occurs soon after their application.

APPENDIX F

EROSION AND SEDIMENTATION

Appendix F-1

METHODOLOGY

Erosion Rates

The rates of sheet and rill erosion for each of the 20 subbasins in the state were calculated using methods described in Technical Release No. 51 (Rev.), USDA, Soil Conservation Service. This publication outlines methods of using the Universal Soil-Loss Equation (USLE) to estimate soil loss for Soil Conservation Service projects such as watershed and river basin studies.

The complete USLE is A = RKLSCP where A is the computed loss in tons per acre; R is the rainfall factor; K is the soil-erodibility factor; L is the slope-length factor; S is the slope-gradient factor; C is the cropping management factor; and P is the erosion-control practice factor.

To determine the factors to be used in the USLE for each of the 20 subbasins, methods were devised to obtain average values for an entire subbasin. The following discussion is an explanation of how these factors were determined.

Rainfall Factor (R)

The average annual "R" factor values for each subbasin were obtained from Figure 1 of Technical Release No. 51 (TR-51).

Soil-Erodibility Factor (K)

The "K" factor values are assigned to named kinds of soil and are given in the Pennsylvania Technical Guide, Section III-B. The "General Soils Information", published earlier as part of the Pennsylvania Analytical Summary, lists each soil association and percent of each association in the subbasin. To obtain a "K" value for an entire subbasin, an average "K" value was computed for each soil association. The average "K" value for each soil association and the percent of each association in the individual subbasin were used to calculate a "weighted" average "K" value for the subbasin. These "K" values were then correlated with the "K" values for "forest soils" prepared by the Forest Service of the USDA.

Slope Length (L) and Slope Gradient (S)

The "weighted" average "S" factors for cropland, forest and pasture in each subbasin were computed by using land use percentage by capability class and the average slope assigned to each capability. An average slope was assigned to each capability class according to the following table.

Class	*Avg. Slope*	*Class*	*Avg. Slope*
I	2%	V	2%
II	5%	VI	20%
III	12%	VII	35%
IV	20%	VIII	15%

The "L" factor was determined based on the "weighted" average slope according to the following table.

Slope (%)	*Slope Length (Feet)*
0–10	400
11–19	300
20	200

For convenience in the application of these factors, they are combined into a single topographic factor (LS). The "LS" factor was obtained from Table 1, TR-51, using calculated "S" and corresponding "L" factors.

Crop Cover or Cropping Management Factor (C)

The "C" factor values for cropland in each subbasin were estimated based on cropping sequence and management. A theoretical crop rotation was determined for an entire subbasin by analysis of the percent of row crops, small grains and hayland in the subbasin. Using this theoretical crop rotation, "C" values were obtained from Table 6 of the Technical Guide, Section III-B.

The "C" factor values for forestland were assumed to be similar for the entire state. An average condition, that would represent the majority of forestland across the state, was determined to be tree canopy on 40 to 70 percent of the area and forest litter on 75 to 85 percent of the area. Assuming this average condition, a "C" value of 0.002 for forestland was obtained from Table 3 of TR-51.

The "C" factor values for pastureland were also assumed to be similar for the entire state. An average condition, that would represent the majority of the pastureland in the state, was determined to be trees, but no appreciable low brush, with canopy covering less than 25 percent of the area and 80 percent ground cover with up to two inches of litter and mostly broadleaf herbaceous plants. Assuming this average condition, a "C" value of 0.025 was obtained from Table 2 of TR-51.

Erosion-Control Practice Factor (P)

The "P" factor values for cropland were determined assuming contouring as an average condition across the state and using the appropriate value based on land slopes as given in the following table.

Land Slope (%)	*"P" Value*
2–7	0.5
8–12	0.6
13–18	0.8
19–24	0.9

The "P" factor values for forest and pastureland are by definition equal to 1.0.

Appendix F-2

SOIL LOSS AND SEDIMENT YIELD

Table 1

RATES OF AVERAGE ANNUAL SOIL LOSS FROM SHEET AND RILL EROSION[a]
(Tons Per Acre)

	Land Use		
Subbasin	Cropland	Forest[b]	Pasture and Other Land
1	3.0	0.2	3.7
2	12.2	0.2	3.7
3	15.3	0.2	5.2
4	4.2	0.8	2.7
5	7.2	0.8	4.4
6	10.0	0.8	5.3
7	7.3	0.8	4.8
8	8.4	0.3	3.7
9	6.1	0.8	3.6
10	5.8	0.8	4.0
11	6.1	0.3	4.6
12	11.6	0.8	4.1
13	7.1	0.5	3.8
14 & 16	7.5	0.4	2.9
15	3.5	0.2	3.0
17	3.9	0.3	4.2
18	3.8	0.3	5.2
19	6.5	0.3	5.4
20	3.8	0.3	5.4

[a]Soil Conservation Service draft report *Erosion and Sediment Pollution Potential*, 1976.

[b]U.S. Forest Service

Table 2

GROSS AVERAGE ANNUAL SOIL LOSS FROM SHEET AND RILL EROSION[a]
(Thousand Tons)

	Land Use			
Subbasin	Cropland	Forest[b]	Pasture And Other Land	Total Loss
1	446	160	515	1,121
2	3,185	117	348	3,650
3	6,247	108	1,268	7,623
4	2,060	1,506	1,027	4,593
5	1,604	565	461	2,630
6	2,412	528	379	3,319
7	8,494	889	1,736	11,119
8	693	465	268	1,426
9	898	1,193	211	2,302
10	1,219	730	381	2,330
11	1,362	265	436	2,063
12	2,387	576	315	3,278
13	1,789	413	458	2,660
14 & 16	1,312	681	710	2,703
15	333	35	230	598
17	1,017	613	589	2,219
18	1,132	359	1,266	2,757
19	1,921	492	1,933	4,346
20	1,648	397	2,146	4,191
Totals	40,159	10,092	14,677	64,928

[a]Soil Conservation Service draft report *Erosion and Sediment Pollution Potential*, 1976.

[b]U.S. Forest Service

Appendix F-2 (Cont.)

SOIL LOSS AND SEDIMENT YIELD

Table 3

SUBBASIN LAND USE AND SEDIMENT YIELD

Subbasin	Area (Sq.Mi.)	Land Use (%) Cropland	Pasture	Forest	Other	Average Annual Sediment Yield (1000 Tons)
1	1,816	13	6	64	17	273
2	1,943	21	2	46	31	491
3	2,708	24	7	28	41	722
4	3,286	23	12	53	12	630
5	1,759	20	3	56	21	382
6	1,448	26	4	57	13	327
7	4,157	44	7	32	17	1,017
8	2,631	5	1	85	9	295
9	2,539	9	2	84	5	287
10	1,809	18	3	66	13	219
11	1,943	18	4	61	17	174
12	1,462	22	4	66	8	138
13	1,584	25	7	54	14	319
14 & 16	4,573	13	5	62	20	460
15	511	29	6	36	29	37
17	2,931	14	3	64	19	512
18	2,393	20	5	53	22	436
19	2,736	17	8	48	27	485
20	3,080	21	10	37	32	533
State	45,309	20	5	55	20	7,737