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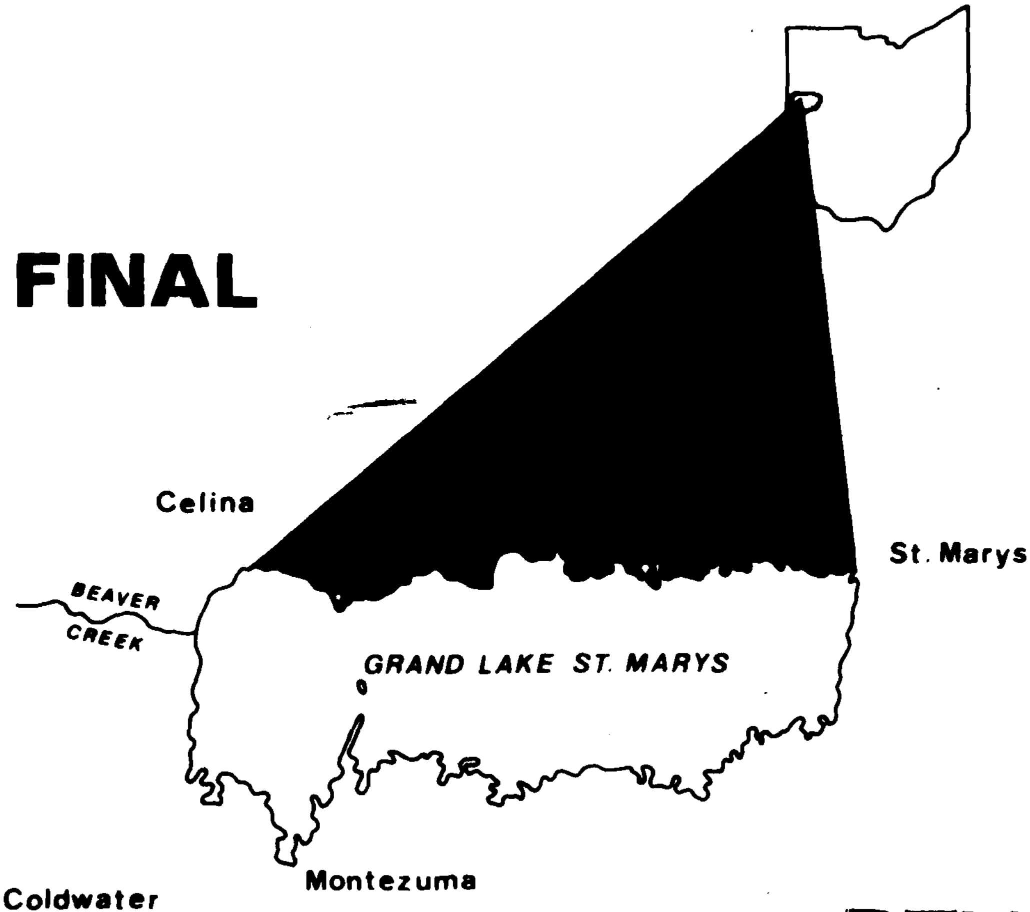

Survey Report for Flood Control and Allied Purposes

Volume 2 of 2 Technical Appendix

CORPS OF ENGINEERS
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.

AUGUST 1981

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER / 2. GOVT ACCESSION NO. AD-A112109	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Grand Lake St. Marys, Ohio: Survey Report for Flood Control and Allied Purposes.	5. TYPE OF REPORT & PERIOD COVERED Survey Report
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS USAED, Louisville, 600 Federal Place, Louisville, KY 40202	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS USAED, Louisvillle (ORLPD-F)	12. REPORT DATE August 1981
	13. NUMBER OF PAGES 2 vols.
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Volume 1—Main Report
Volume 2—Technical Appendix

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Grand Lake St. Marys, Ohio	Flood control
Auglaize County, Ohio	Grand Regional Sewer System
Mercer County, Ohio	Water quality
Beaver Creek, Ohio	Water resources development

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Grand Lake St. Marys shore flood problem is caused by the inability of the 10.6- mile long westerly outlet channel to discharge sufficient flood flows to keep pace with inflow to the lake during peak periods plus the effect of wind setup and wave runup on low-lying developed areas when lake levels are high.

Beaver Creek flood problems are caused by a combination of a limited flood control capability of Grand Lake St. Marys, poor surface drainage, low stream gradient, constriction to flow, and high stream stages for a long period of time

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) which cause inadequate outlet conditions for numerous artifical agricultural drains.

Lake water quality has been declining in recent years. Four seperate water quality problems have been identified as causing the deterioration. Bacterial contamination from human sources threatenes body contact recreation, particularly in areas of greatest development. The rich nutrient content of the lake results in excessive algae and suspended sediment, resulting in unattractive conditions for recreators, Accumulation of sediment, eroded from upland areas, and unprotected shoreline have reduced the lake depth.

A range of structural and nonstructural flood damage reduction measures were examined. Nonstructural measures investigated for Beaver Creek are not viable solutions because of the agricultural character of the flood plain. Structural measures considered for Beaver Creek including detention basins, diversion, clearing and cleaning, channel improvements, and agricultural levees were determined to be economically infeasible.

Nonstructural flood plain management measures generally will not improve the flood problems for existing structures on the south shore, but regulations adopted by local governments either voluntarily or as required by participation in the Flood Insurance program could be used to reduce damages to future development. Structural measures such as groins and shoreline levees (dikes) are not perceived to be economically feasible. Fixed breakwaters can be effective in reducing shoreline flooding and erosion, but economic benefits are derived primarily from the potential for increased visitation and not from flood damages reduced.

Lake water quality problems related to nutrient and algae control appear better resolved through reduction of nutrient loads to the lake and in particular control of agricultural and livestock waste sources rather than by in-lake treatment approaches.

Emphasis should be placed on the control of erosion and critical soil loss areas in the watershed and unprotected shoreline areas. An extensive lake-wide dredging program, besides being cost prohibitive, would result in no significant improvement in water quality or flood control storage. In-lake dredging of selected near-shore zones as is currently being performed should be contained for improving lake access and boater safety, public land development, and to keep pace with the current rate of sediment accumulation and redistribution.

Grand Lake St. Marys, Ohio

TECHNICAL APPENDIX

Volume 2 of 2

Survey Report
for
Flood Control
and
Allied Purposes

Louisville District Corps of Engineers
Department of the Army
August 1981

APPENDIX 1

THE TECHNICAL REPORT

SECTION A

THE STUDY AND REPORT

SECTION A

THE STUDY AND REPORT

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SECTION A

THE STUDY AND REPORT

This report incorporates the results of a study which evaluates the water and related land resources problems of the Grand Lake St. Marys, Ohio, area. The study was initiated in Fiscal Year 1979 (December 1978).

PURPOSE AND AUTHORITY

Because of the almost yearly flooding experienced in the Grand Lake St. Marys, Ohio, area and because of the threat of flooding of agricultural areas and lake shores, the Congress, at the request of state and local interests through their representatives, authorized a study, by Section 217 of the Flood Control Act of 1970 (Title II, Public Law 91-611, approved 31 December 1970) for flood control and allied purposes including channel and major drainage improvements. The applicable section is quoted, in part, as follows:

> "The Secretary of the Army is hereby authorized and directed to cause surveys for flood control and allied purposes, including channel and major drainage improvements, and floods aggravated by or due to wind or tidal effects, to be made under the direction of the Chief of Engineers, in drainage areas of the United States and its territorial possessions, which include the localities specifically named in this section. After the regular or formal reports made on any survey authorized by this section are submitted to Congress, no supplemental or additional report or estimate shall be made unless authorized by law except that the Secretary of the Army may cause a review or any examination or survey to be made and a report thereto submtted to Congress, if such review is required by the national defense or changed by physical or economic conditions."

The Grand Lake St. Marys, Ohio, study is one of 23 authorized under this section.

SCOPE OF THE STUDY

This study is confined to evaluating the advisability and economic feasibility of providing flood control and related water and land resource improvements in the vicinity of Grand Lake St. Marys, Ohio. Existing studies, published data, interviews, and field reconnaissance information were used extensively as sources of information in preparing this report. The overall aim of the study is to analyze water resource problems and the potential for solving such problems. Alternatives have been investigated in an attempt to resolve the area's water resource problems after considering all factors, including those expressed by concerned agencies, the State of Ohio, and local interests.

Current cost-benefit analysis was utilized to evaluate measures potentially available for Corps participation, i.e., flood control. Cost effectiveness, impacts and trade-off analysis were utilized in evaluating and displaying other measures not lending themselves to cost-benefit analysis. On these measures, i.e., water quality, sedimentation and erosion, this report is to conclude with a presentation and evaluation of alternatives from which local, regional, and state interests may select, implement, or further evaluate.

STUDY PARTICIPANTS AND COORDINATION

A news release announcing initiation of the study was issued to the appropriate news media in December 1978. Prior to the official news release, initial briefing sessions and coordination were effected with the Ohio Department of Natural Resources on 21 November 1978; and with local officials, private interests and concerned citizens on 22 November 1978, for the purpose of introduction, general discussion of study efforts and problem areas, exchange of information, and to obtain views concerning the study. The following agencies and organizations have been contacted and have provided input to the study:

Federal

Soil Conservation Service
Environmental Protection Agency
Heritage Conservation and Recreation Service
Fish and Wildlife Service
Geological Survey

State

Department of Natural Resources
Environmental Protection Agency
Department of Health
Department of Administrative Service
Department of Public Works

County

Mercer County Commissioners
Auglaize County Commissioners

City

Celina, Ohio
Coldwater, Ohio
St. Marys, Ohio
Montezuma, Ohio

Organizations

Lake Development Corporation
Lake Improvement Association

Public Meetings

A locally sponsored public meeting was held on 25 April 1979 in Celina, Ohio, at which the Louisville District was invited to make a presentation on study background, problems and needs, study efforts, coordination efforts, expectations, and to solicit information, confirmation of study issue, and views on study emphasis and participation. This meeting was attended by approximately 55 persons comprised of local, state and Congressional officials, representatives of Chambers of Commerce, private interests and the general public.

During the plan formulation stage of investigation, an informal public meeting, sponsored by the Lake Development Corporation, was held on 6 November 1980 to present alternatives and provide opportunity for public comment. Approximately 32 persons including private citizens and representatives of local and private organizations attended the meeting.

Information Brochure

An information brochure was prepared and presented at the November 1980 meeting for public evaluation, alternative solutions investigated for flood control, water quality improvement, erosion/sedimentation control, and associated needs in the Grand Lake St. Marys area.

OTHER STUDIES AND REPORTS

Wabash River Basin Comprehensive Study, Wabash River Coordinating Committee, Appendix A-M, June 1971. The study discussed the Grand Lake St. Marys area in terms of a cursory consideration of water and related land and institutional problems and concluded that the determination of solutions were beyond the scope and resources of the Wabash Comprehensive Study. The report recommended that "a detailed study be made to determine what measures should be undertaken to restore and enhance Grand Lake and its related and tributary areas as a viable natural resource."

Grand Lake Regional Sewer System Facilities Plan, Finkbeiner, Pettis, Strout, Ltd., June 1977. The report presents valuable background information on social, economic, environmental, and water quality aspects of the study area plus a sewerage system facilities plan for Celina, St. Marys, and portions of Mercer and Auglaize Counties.

U. S. Environmental Protection Agency. 1971. Report on Grand Lake St. Marys, National Eutrophication Survey. Working Paper No. 411. The report develops information on nutrient sources, concentrations, and impact on the lake as a basis for formulating management practices relating to point-source discharge reduction and non-point source pollution abatement in the lake watershed.

Ohio Department of Natural Resources, Division of Wildlife, Lake St. Marys and Its Management, by Clarence F. Clark, 1960. The report, although nearly 20 years old, contains a wealth of information on the study area and its physical, chemical, and biological problems, most of which is still pertinent. The study was basically an effort to compile available data concerning the fisheries of the lake's past, present, and future use in developing a fisheries program for this recreational area.

U. S. Geological Survey. Limnology of Selected Lakes in Ohio, Water Resources Investigations 77-105, 1975. This report is the result of a reconnaissance to gather baseline data, particularly water quality sampling, useful in appraising and managing Ohio's lakes. Grand Lake St. Marys was one of 17 Ohio lakes studied.

U. S. Army Corps of Engineers, Grand Lake St. Marys, Ohio, Environmental Study July 1979. This report was prepared by WAPORA, Inc., Cincinnati, Ohio, under contract with the Louisville District Corps of Engineers. The report provides an assessment of the environmental resources and a discussion of environmental problems of Grand Lake St. Marys and the area surrounding it in Mercer and Auglaize Counties, Ohio. The report describes various aspects of the existing environment, environmental problems and hazard areas, possible solutions for existing identifiable problems, and environmental impacts of possible alternatives.

Fish and Wildlife Report, U. S. Department of the Interior, Fish and Wildlife Service, 17 August 1979. This is a preliminary report prepared under the authority of and in accordance with provisions of the Fish and Wildlife Coordination Act and in compliance with the intent of the National Environmental Policy Act of 1969. The report compiles existing information on the fish and wildlife resources of the Grand Lake St. Marys, Ohio, study area; discusses historical, current and future potential impacts on these resources due to identified water and land-related resources problems and needs; makes recommendations for improving the resource base; identifies and recommends additional studies that address data deficiencies.

U. S. Army Corps of Engineers. Development, Assessment and Evaluation of Water and Related Land Resources Alternatives. Grand Lake St. Marys, Ohio. November 1979. This report was prepared by GAI Consultants, Inc., Monroeville, Pa., under contract with the Louisville District Corps of Engineers. The main report and supporting technical appendix develop, assess, and evaluate alternatives that address certain water and related land resources problems in the Grand Lake St. Marys, Ohio, study area. Principal investigations were centered around lake water quality and erosion problem categories.

THE REPORT

This report is arranged into a main report and three appendices. The main report, a summary of Appendix 1 (the Technical Report) is meant to be readily understandable to the non-technical reader. The main report also contains material on summary of findings, conclusions and recommendations.

Appendix 1 presents for the technical reviewer more detailed technical aspects of the study and results. The main report and Appendix 1 generally follow the same format in presenting problems and developing alternatives.

Appendix 2 contains comments received as the result of coordination of the draft feasibility report. Responses to these comments received are also included in Appendix 2. Appendix 2 also contains public involvement activities and related coverage during the course of study.

Appendix 3 contains a report by the U. S. Fish and Wildlife Service.

SECTION B

RESOURCES AND ECONOMY OF THE STUDY AREA

SECTION B

RESOURCES AND ECONOMY OF THE STUDY AREA

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SECTION B
RESOURCES AND ECONOMY OF THE STUDY AREA

The purpose of this section is to provide basic information concerning environmental, natural, human resources and economic profiles in the general study area.

ENVIRONMENTAL SETTING AND NATURAL RESOURCES

General Study Area Description

The Grand Lake St. Marys area (Plate B-1) is situated in Mercer and Auglaize Counties in west-central Ohio on the watershed divide between the Wabash and St. Marys Rivers. The lake is formed by a dam at its west end on Beaver Creek which drains to the Wabash River and a dam at its east end on Chickasaw Creek which drains to the St. Marys River via the Miami-Erie feeder canal. The impoundment covers the low watershed divide forming a lake with a surface area of some 21 square miles at approximately 870 mean sea level (msl). The lake is approximately eight miles in length east to west and averages over two miles in width north and south. Average depth of the lake is 6.8 feet. The total drainage area to the lake is some 112.1 square miles, of which over 18 percent is lake surface (21 square miles). The State of Ohio owns the lake, together with a few small parcels of lakefront property. Lake operation is by the Ohio Department of Natural Resources and the Ohio Department of Public Works.

The Ohio Division of Wildlife operates the St. Marys Fish Hatchery and the Mercer County Waterfowl Refuge at the lake. Several areas along the lake are operated as part of the Grand Lake St Marys State Park. The lake is surrounded by a combination of agricultural, recreational, permanent and seasonal residential, and urban land uses. Principal urban areas include Celina and St. Marys, with 1970 populations of 8,072 and 7,699, respectively. The study area is approximately 95 air miles due north of Cincinnati, Ohio, and 92 air miles northwest of Columbus, Ohio.

Topography

The project area is situated in the Tills Plain Section, which extends from central Ohio to the Mississippi River and includes much of Indiana and Illinois. Gently rolling topography is characteristic of this area with greatest relative relief occurring in stream valleys where surface waters have eroded stream channels through soils. Elevations range from highs of 910 feet above mean sea level in the north-central and south-central regions to lows of approximately 850 feet occurring along the St. Marys River and Beaver Creek at, respectively, the northeast and west boundaries of the study area. The terrain falls, generally, toward Grand Lake which has a normal water surface elevation of 870 feet above mean sea level.

Geology

The study area lies in an area of west-central Ohio which was glaciated at least three times. The superficial material is till of a Wisconsin age ground moraine deposit. Till deposits bulldozed ahead by the advancing glacier were eventually left largely in place at the lows of farthest advance when the glacier began to retreat and melt. These land forms, known as terminal moraines, are prevalent in Mercer and Auglaize Counties. Remnants of a terminal moraine, known as the Wabash Moraine, lie along the north shore of the lake, and the deposit is 70 to 130 feet thick. The lake overlies the buried valley of the ancestral Teays River which is now filled with unconsolidated deposits of clay, sand and gravel. Depth to bedrock in the center of the buried valley is about 200 feet and up to 300 feet. The underlying bedrock is composed of Ordovician and Silurian sedimentary rocks consisting predominantly of limestone and dolomite deposits.

Soils

Plates B-2a and 2b show the general study area as dominantly Blount-Pewamo and Blount-Glynwood soil association. The Blount-Pewamo soils correspond to glacial drift areas. The Blount-Glynwood soils, as are found just north of the lake and through St. Henry and Chickasaw, frequently correspond with locations of terminal moraines. Glacial till deposits prevail throughout the study area as a predominantly clay material. The till is generally compact and unstratified, impervious, and contains gravel, cobbles, and boulders of all sizes. It acts as a confining layer or aquaclude for a number of artesian wells in the area. The till is predominantly Blount-Pewamo association soil type. This is a silty clay loam or clay loam on gently sloping terrain. It is poorly drained as are all other soils encountered in the study area.

The Blount soil is silty loam on the surface and clay in the subsoil with moderate agricultural productivity, moderately slow to slow permeability, and a poor bearing value for foundations. This is the most extensive soil found in the study area. The Pewamo is similar, being a silty clay loam on the surface and a silty clay subsoil. This soil is found in level or depressional areas, and has moderately slow to slow permeability, but is highly productive agriculturally.

Along the north shore of the lake from Celina to St. Marys is the Blount-Glynwood association soil. It is similar to the Blount-Pewamo except that it occurs on a sloping terrain. This soil is found also among the outer flood plain reaches of Beaver Creek, south of Montezuma. The Glynwood has a moderately slow permeability and a moderate agricultural productivity. It displays a moderate to severe erosion hazard. Runoff is rapid in the eroded areas.

The Montgomery-McGary association soil is found in some areas west of the lake and south of Celina along Beaver Creek. This soil is a depressional to gently sloping, very poorly drained, water-deposited sediment of former glacial lake basins. The soil has a slow to very slow permeability and high available water retention capacity. It is a silty clay loam to silty clay on the surface, and a silty clay in the subsoil. Productivity for agriculture is very high, and it is, like the Blount-Pewamo, very poor for septic tank systems because of its wetness and ponding hazards. Bearing value for foundations is poor to good.

Located south of Montezumza, along the inflowing portion of Beaver Creek, is found the Defiance-Wabash association. This soil type is on mostly flat lands, poorly drained with slow permeability, and formed from clayey, recently deposited stream sediments in flood plains.

Located along the St. Marys River at the east end of the study area is the Shoals-Genesee-Sloan association. This soil is poorly drained and occupies the flood plains along rivers and streams. These soils are recent alluvium and are subject to occasional flooding. They have poor bearing values for foundations and are unsuitable for septic tanks. Agricultural productivity is moderate to moderately high. In general, these soils drain poorly, but provide good farming when properly drained with tile.

Poor natural drainage plus a high water table has caused most of the upland Blount, Pewamo, and Glynwood soils to be seasonally wet. Erosion is a problem on sloping areas of Blount soils and a severe problem in cultivated soils.

A general description of each soil association is given in Table B-1.

The lake bottom for the most part is a fine gray silt or clay with numerous fine sand areas, widely scattered. Most are on the north side of the lake and extend outward into the lake to depths of about 5 feet of water. A few gravel bars exist in the vicinity of Montezuma Bay. Here, near the west portion of the bay mouth, are large gravel and rubble areas. Underlying the fine gray sediment on the bottom is a layer of from 1 to 4 feet of brownish-black muck, which grades from loose, undecomposed organic matter at the top to highly decomposed organic matter at the bottom. At other places, the silty sediment is

TABLE B-1

SOIL ASSOCIATION CLASSIFICATION
MERCER AND AUGLAIZE COUNTIES, OHIO

LEGEND

1 Blount-Pewamo Association. Nearly level to gently sloping, somewhat poorly drained to very poorly drained upland soils formed in silty clay loam or clay loam glacial till.

2 Blount-Glynwood Association. Gently sloping to sloping, somewhat poorly drained to moderately well drained upland soils formed in silty clay loam or clay loam glacial till.

3 Montgomery-McGary Association. Depressional to gently sloping, very poorly drained to somewhat poorly drained soils of upland flats formed in clayey, water-deposited sediments of former glacial lake basins.

4 Defiance-Wabash Association. Mostly level, somewhat poorly drained to very poorly drained soils formed in clayey, recently deposited sediments on flood plain.

5 Genesee-Shoals Association. (Mercer County) Mostly level, well drained to somewhat poorly drained soils formed in loamy, recently deposited stream sediments on flood plains.

Montgomery Association. (Auglaize County) Nearly level, very poorly drained soils formed in clayey, glacial lake-deposited sediments.

6 Sloan Association. Mostly level, very poorly drained soils formed in loamy, recently deposited stream sediments on flood plains.

7 Millgrove-Digby-Digby Variant Association. (Auglaize County) Nearly level, very poorly drained and somewhat poorly drained soils formed in loamy or clayey material overlying poorly sorted sand and gravel.

9 Shoals-Genesee-Sloan Association. (Auglaize County) Nearly level, somewhat poorly drained, well drained and very poorly drained soils formed in loamy and sandy, recently deposited alluvium.

underlain by a dark gray silty clay loam with a light gray subsoil. Overall, these conditions indicate that the area was poorly drained and swampy before the lake was formed.

Mineral Resources

The only minerals of significant economic importance in or near the general study area are limestone and sand and gravel. Limestone and dolomite are plentiful in this part of Ohio and are used for road material, concrete aggregate, agricultural lime, fluxing stone, chemical and industrial lime, cement manufacturing, riprap, and dimension stone. The minerals are readily available at or near the surface, and thickness of glacial overburden is a principal siting consideration for mining. The closest active quarries are at Covington in Miami County and near Lockington in Shelby County. The Karsh quarry, 4-1/4 miles west of the lake, is the only significant outcrop of rock in the immediate study area and is a source of riprap for lakeshore protection.

Sand and gravel operations are numerous in the area with the largest concentration of operation located in the outwash deposits along major streams. Nearby mining operations are located near Waynesfield, Wapakoneta, and the southern boundary of Auglaize County, and at Lake Loramie in Shelby County.

Climate

The study area climate is continental with warm summers and is characterized by abundant precipitation, fairly long growing seasons, and wide ranging annual and daily temperatures. Mean annual temperature over the area is 49.7° F in January to 85° F in July. Prevailing winds are from the west during winter and average 9 to 10 mph, and from the southwest in summer at an average velocity of about 7 mph. Approximately 37 inches of precipitation in the form of rain, snow, sleet, or hail fall annually over the region. Normally, rainfall is distributed fairly evenly throughout the year, with showers and thunderstorms furnishing much of the precipitation during the growing season. Heaviest rains usually occur in June. Estimated mean annual evaporation for the region around Grand Lake is between 33 and 34 inches. Annual snowfall varies widely from year to year, but averages between 20 to 25 inches and covers the ground for about 30 days. The number of days between last frost of spring and first frost of fall is approximately 160 days. The normal rainfall is such that the lake water level is relatively stable, with the normal fluctuations which occur in times of drought and heavy rainfall.

Surface Hydrology

Grand Lake St. Marys is a manmade lake situated on the watershed divide between the Wabash and Maumee River Basins in west central Ohio. The lake is reported to have a surface area of approximately 13,920 acres (21.75 square miles) at a surface elevation of 870.25 feet mean sea level and a drainage area of 112.1 square miles including the lake surface. However, another source reports its surface area to be 44.52 square kilometers (17.19 square miles). Grand Lake is very shallow. Although estimates do not agree exactly, its mean depth is believed to be 6.8 feet and maximum depth measured at 10 feet.

Nearly all of Grand Lake's drainage area lies to the south, as shown on Plate B-1. The lake is fed by six major tributary streams: Coldwater Creek, Beaver Creek, Prairie Creek, Chickasaw Creek, Little Chickasaw Creek, and Barnes Creek. The estimated mean flow and drainage area of each of these tributaries and of the other smaller creeks and direct drainage areas tributary to the lake are shown in Table B-2. The total estimated mean yearly flow to the lake is 2.9 cubic minutes (102.4 cfs).

TABLE B-2

TRIBUTARY STREAMS TO GRAND LAKE ST. MARYS

Tributary	Drainage Area (square miles)	Mean Discharge Cubic feet/second
Coldwater Creek	19.2	17.7
Beaver Creek	20.4	17.7
Prairie Creek	5.2	3.5
Chickasaw Creek	18.4	17.7
Little Chickasaw Creek	6.9	7.0
Barnes Creek	3.6	3.5
Minor Tributaries and Immediate Drainage	19.3	35.3
Totals	93.0	102.4
Outlet Streams from Grand Lake St. Marys		
Beaver Creek	66.2	56.5
Miami-Erie Feeder Canal	45.9	38.8
Totals	112.1	95.3

Source: Report on Grand Lake of St. Marys, Auglaize and Mercer Counties, Ohio, EPA Region V, Working Paper No. 411, June 1975.

The historic western 59 percent of the Grand Lake drainage area is within the Wabash River Basin, and the historic eastern 41 percent of the drainage area is within the Maumee River Basin. Flow is discharged from the western end of the lake to Beaver Creek and thence to the Wabash River, while the eastern discharge is tributary to the St. Marys River via the St. Marys feeder canal. Because of the lake's large volume (113.50 x 10^6 m^3, or 108,227 acre feet), in relation to its drainage area and flow, it is estimated to have a mean hydraulic retention time of 1.3 years.

Beaver Creek flows about 10.6 miles from the western end of Grand Lake to its confluence with the Wabash River which is approximately 2.8 miles east of the Indiana border. There are no flow gaging stations on Beaver Creek, but there is a USGS-maintained gage on the Wabash River near New Corydon, Indiana, which is on the Indiana-Ohio State line road bridge. At this station the drainage area of the Wabash River is 262 square miles, with the Beaver Creek portion being 125 square miles.

Groundwater

The two main groundwater aquifer types found within the study area are carbonate rock and buried valley. Regarding the former type, the general study area is underlain by massive Silurian age dolomite beds. Groundwater moves through these joints via a complex network of interconnected openings occurring as joints, fractures, and solution channels. Availability of water is dependent upon recharge potential. Infiltration of precipitation and surface waters down through the glacial till overburden in the general study area and, to an unknown extent, in undipped areas to the east, provides this recharge. Well fields located in limestone deposits yield widely varying amounts from one area to another, depending on percolation rates through overburden.

A branch of the ancient pre-glacial Teays River once flowed through the central portion of the general study area. Glaciers later filled the deep bedrock cut with well-sorted sands and gravels. These permeable materials provide exceptionally high groundwater yields due to favorable recharge properties and high storage coefficients. The city of St. Marys water system utilizes water from this high-yield buried valley aquifer. Some believe that the aquifer receives its main source of recharge in the study area from Grand Lake. Celina has no groundwater located immediately below it so the city uses Grand Lake as a water supply. However, studies are being considered to determine the feasibility of tapping the Teays River (located east of Celina) as an alternative water supply.

Archeological Values

There are no documented archeological sites, either prehistoric or historic, in the Grand Lake primary and general study area and no surveys have been undertaken on lands included in the Grand Lake study area; however, undocumented reports have indicated possible sites in or near Celina and St. Marys. There is high potential for the existence of undocumented prehistoric and historic archeological sites, especially in the vicinity of the Beaver Creek-Wabash River confluence; lands bordering the St. Marys River in St. Marys and northward; lands on a ridge extending towards Erastus along Beaver Creek; lands adjacent to Montezuma Bay; and lands bordering Chickasaw Creek and other creeks tributary to the lake.

A total of 248 historically or architecturally significant sites have been documented in the Grand Lake study area. Of these, three are listed in the National Register of Historic Places, one has been nominated to the National Register, and another is in the process of being nominated.

Historical Values and Lake Resource

Grand Lake came into being as a reservoir to supply water for the Miami-Erie Canal. Construction started in 1837 and was completed in

1845 at a cost of approximately $528,000. The then 17,500-acre reservoir was for many years the largest man-made body of water in the world. With a current estimated surface area of 13,500, it is the largest inland water body in the State of Ohio. The lake has a long and interesting history and played an important part in the development of the Northwest Territory. The St. Marys River served as a vital link between the Great Lakes and the Ohio River via the Miami-Erie Canal. The lake once supported a vast commercial fishery. The canal era, however, was short-lived as much of the business of transporting goods was taken over by the expanding railroads. The area experienced another boom in the late 1890's when oil was discovered and for a time the lake was dotted with oil derricks. Today a pile of rocks near the center of the lake marks the spot of the last producing well. The lake has gained growing popularity among recreationists and sportsmen since 1915 when the General Assembly of the State of Ohio passed an act through which this body of water and adjacent lands owned by the State were dedicated and set apart forever for the use of the public, as public parks or pleasure resorts.

Today the lake exists primarily for recreation purposes and is a favorite spot for thousands of vacationists from Ohio and neighboring states. It is also the principal water supply for Celina, Ohio, and St. Marys, Ohio, uses lake water for cooling purposes at their power plant. Primary recreational activities at the lake include boating, fishing, picnicking, swimming, winter sports, and camping. Several areas along the lake are operated as part of the Grand Lake St. Marys State Park. Grand Lake St. Marys State Park is located along the northeast shore of the lake and provides recreational activities such as camping, fishing, hiking, picnicking, swimming, and boating. Approximately 500,000 persons visit the park annually. In addition, the Ohio Division of Wildlife operates the St. Marys Fish Hatchery located at the extreme eastern edge of the lake. The Division also operates the 1,400-acre Mercer County Waterfowl Refuge at the southwest section of the lake which provides a haven for migrating as well as nesting Canada geese. Thousands of birds stop at this refuge during spring and autumn migrations.

The lake is fairly heavily used, having at least six major marinas, one state campground, a 4-H camp, and two church camps. Fishermen abound during early spring. Hunters vie for licenses and blind privileges during early winter. There are three public beaches on the lake and hundreds of private beach areas.

Vegetation

Terrestrial Plants

During presettlement times, Mercer and Auglaize Counties were covered by forests in which beech and sugar maple were predominant. This forest type occupied much of the till plains of Ohio and adjacent Indiana and portions of Pennsylvania, Michigan and Wisconsin. In Ohio the southern boundary of this forest type follows the southern limit of the Wisconsin drift.

The beech-maple forest region was characterized by its uniformity, consequently, no subdivisions of this type were recognized by Braun[2]. Generally, beech made up over 50 percent of the stand with the remainder consisting of sugar maple, tulip tree, black cherry, and a number of other species.

Presently, woodlands cover about 24 percent of the land area in the state; however, most of the totally wooded area is in the unglaciated plateau region of southeastern Ohio. In the 17-county area included in the Southwest Ohio Water Plan, an average of 11.5 percent of the land area was wooded; counties adjacent to and immediately south of Grand Lake St. Marys are less than 10 percent wooded. Except for a fringe of forest or woodland that remains along the shore of Grand Lake St. Marys, land away from the lake is extensively used for agricultural purposes.

The following statistics further emphasize this point:

County	Total Land Acreage	Total Acreage in Farms	Total Acreage in Woodlands
Mercer	290,700	277,067 (1,976) 1/	17,076 (909) 2/
Auglaize	255,900	229,331 (1,419) 1/	18,746 (750) 2/

1/ Total number of farms in 1974.
2/ Total number of farms with woodlots in 1974.

As of 1974, approximately 5.8 percent of Mercer County and 7.3 percent of Auglaize County were wooded; the average size of wooded lands in Mercer County and Auglaize County was 18.8 and 25.0 acres, respectively.

During July 1979 a survey was conducted at several locations within the study area to characterize vegetation growing near Grand Lake St. Marys, along tributaries, and in upland areas. The areas surveyed are identified in Plate B-3 and each area is described as follows:

Site 1. Riparian vegetation along Beaver Creek, immediately downstream of the dam, revealed that species comprising the canopy (> 25' in height) included cottonwood, sycamore, silver maple, and white ash; willow, flowering dogwood, slippery elm, red mulberry, catalpa, honey locust, and boxelder formed the understory (< 25' in height). Ground cover on Beaver Creek's banks included river grade, Canada thistle, Shepherd's purse, milkweed, mint, teasel, fleabane, Queen Ann's lace, burdock, and nettle.

Site 2. Adjacent to the west end of Grand Lake St. Marys between Brown and Monroe Streets, trees in the canopy in this wooded area included cottonwood, bur oak, and mockernut hickory; species in the understory included boxelder, flowering dogwood, mulberry, tree of heaven, weeping willow, and American elm. Raspberry was noted as ground cover.

Site 3. The area along Coldwater Creek, southwest of the west end of Grand Lake St. Marys, was assessed. All trees along the bank were less than 30 feet in height. Species with individuals ranging between 15 and 30 feet included peachleaf willow, red mulberry, honey locust, slippery elm, cottonwood, river birch, boxelder, and green ash. Ground cover included jewelweed, milkweed, mint, daisy fleabane, thistle, chickory, nightshade, white sweet clover, wild parsley, cockspur hawthorn, rose, burdock, Shepherd's purse, and smartweed.

Site 4. The vegetation of Windy Point State Park consisted of a canopy of cottonwood, and an understory of dogwood, silver maple, boxelder, mulberry, ash, elm, and sycamore. The ground cover in unmowed areas consisted of grape, goldenrod, fleabane, Canada thistle, raspberry, poison ivy, strawberry, milkweed, jewelweed, Virginia creeper, burdock, garlic mustard, and pokeweed.

Site 5. This study site lies adjacent to Karafit, Cottonwood and Kittle Roads near the south shore of Grand Lake St. Marys. Along Karafait Road the predominant vegetation was sedge and cattails; along Cottonwood Road, white oaks and cottonwoods were present; along Kittle Road, cottonwoods, bur oak, and willows were observed.

Site 6. A survey of vegetation along a channelized portion of Prairie Creek south of its confluence with Grand Lake St. Marys revealed that the dominant species growing along the creek was peachleaf willow; away from the creek's bank (approximately 20 feet) the following species were observed: cottonwood, mulberry, ash, elm, pignut hickory, dogwood, shagbark hickory, and honey locust.

Site 7. This site was an upland woodlot located near the intersection of Route 33 and Route 116, northeast of Grand Lake St. Marys. The canopy trees were approximately 50 feet in height and included mockernut hickory, white oak, and scarlet oak. The understory consisted of dogwood, black cherry, plum, white ash, slippery elm, silver maple, hawthorn, and red cedar; the ground cover included mayapple, Virginia creeper, Solomon's seal, raspberry, wood sorrel, and Canada moonseed.

Site 8. The vegetation at Sandy Beach, located along the north bank of Grand Lake St. Marys, consisted of mature individuals including the following species: pin oak, white oak, scarlet oak, bur oak, cottonwood, elm, ash, walnut, silver maple, dogwood, boxelder, hickory, and weeping willow. No understory was present and the ground cover consisted of river grape, cattail, jewelweed, and Virginia creeper.

Site 9. This study site was located at the intersection of Staeger Road and Route 703, along the north shore of Grand Lake St. Marys. Species in the canopy of this upland woodlot included scarlet oak, shagbark hickory, horse chestnut, bur oak, black walnut, beech, honey locust, and black locust; species in the understory included dogwood, ash, silver maple, sycamore, paw paw, and ironwood. The ground was covered by Virginia creeper.

Site 10. This upland woodlot was located along Weasch Road, southeast of Grand Lake St. Marys. Species forming the canopy in this woodlot included ash, shagbark hickory, bur oak, scarlet oak, black oak, beech, walnut, and Ohio buckeye; elm, dogwood, red cedar, maple, redbud, paw paw, and cherry were present in the understory. The ground was covered by Virginia creeper and raspberry.

Aquatic Plants

Phytoplankton. Roach (cited in Clark, 1960) reported 19 genera of phytoplankton in samplings from Grand Lake St. Marys during 1932. Seven green algal taxa, six diatom taxa, four blue-green taxa, and Euglene, Synura, and Peridinium were identified at that time with diatoms being the dominant group. Algal densities for the period 1932-1936 averaged 4.5 blue-greens per milliliter, 15.9 greens per milliliter, and 129.8 diatoms per milliliter. The most productive year was 1935, when algal densities were at least five times those of the other years.

Higert, et al.[3] summarized the results of phytoplankton sampling conducted by the U.S. Environmental Protection Agency during the National Eutrophication Survey, a survey designed to determine the relaionship between algal characteristics and the trophic status of a lake. During spring, summer, and fall of 1973, water samples were collected from Grand Lake St. Marys. Algae in water samples were identified and enumerated and the lake's trophic status was assessed. Hilgert, et al.[3] reported that 128 taxa were collected from Grand Lake St. Marys, that phytoplankton densities were 116,460, 51,172, and 26,352 individuals per milliliter during May, August, and October, respectively, and that the lake was eutrophic. The taxonomic composition and relative abundance (percent of total individuals enumerated) found by Hilgert, et al.[3] is presented in Table B-3.

TABLE B-3

PHYTOPLANKTON IN GRAND LAKE ST. MARYS, OHIO DURING 1973

Date	Total Cells (per ml)	Phylum	Phylum (Percent of Total Cell Count)	Dominant Genera Within Phylum and Percent (%)[a] of Total Cell Count
5/4/73	116,460	Cyanophyta (blue green algae)	58.4	Oscillatoria spp. (1.0); O. limnetica (56.2); Microcystis spp. (1.0)
		Bacillariophyceae (diatoms)	21.9	Fragilaria spp. (13.2); Stephanodiscus spp. (5.8); Synedea spp. (2.9)
		Chlorophyta (green algae)	5.9	Ankistrodesmus spp. (1.6); Scenedesmus abuncans (1.3); S. bimorphos (1.2); S. quadricauda (1.8)
		Flagellates	6.5	
		Other	7.3	
8/1/73	51,172	Cyanophyta	76.9	Anabaenopsis philippinensis (18.3); Oscillatoria spp. (1.3); O. limnetica (10.9); Lyngbya limnetica (31.8); L. lagerheimi (6.5); Anabaena (3.8); Merismopedia tenuissmia (4.3)
		Bacillariophyceae (diatoms)	11.4	Stephanodiscus spp. (5.4); Nitzschia spp. (6.0)
		Flagellates	2.7	
		Chlorophyta (green algae)	1.8	Scenedesmus abuncans (1.8)
		Other	7.2	

TABLE B-3 (Continued)

Date	Total Cells (per ml)	Phylum	Phylum (Percent of Total Cell Count)	Dominant Genera Within Phylum and Percent (%)[1/] of Total Cell Count
10/11/73	26,352	Cyanophyta	80.6	Lyngbya spp. (12.2); L. contorta (25.9); Oscillatoria limnetica (7.3); Microcystis incerta (8.3); M. aeruginosa (2.8); Dactylococcopsis irregularis (10.4); Aphanizomenon flos-aquae (6.2); Merismopedia tenuissmia (1.8); Anabaenopsis spp. (1.3); Raphidiopsis curvata (4.4)
		Cryptophyta	4.9	Cryptomonas erosa (4.9)
		Chlorophyta (green algae)	4.6	Schroederia setigera (1.3); Scenedesmus quadricauda (1.0); Ankistrodesmus falcatus (1.0); Dictyosphaerium pulchellum (1.3)
		Bacillariophyceae (diatoms)	3.9	Synedra spp. (1.3); Melosira distans (2.6)
		Other	6.0	

1/ Less than one percent not given.

Source: Hilgert, et al., 1978.

Tobin and Younger [4] presented the results of phytoplankton studies conducted at Grand Lake St. Marys by the U. S. Geological Survey during 1975. The results of the May and August samplings, presented in Table B-4, indicate that blue-green algae dominated.

Since Roach's studies in the 1930's, phytoplankton density has increased by three to four orders of magnitude in Grand Lake St. Marys, and the taxonomic composition has changed from a diatom to a blue-green algae dominated community, indicative of eutrophication.

Aquatic Macrophytes. A wet prairie of tall grasses occupied most of the area now flooded by the lake. McMurrey (cited in (1)) stated, "The whole of what is now reservoir was covered with the accumulations of growth of years of decayed grasses, leaves, and fallen timber...". "This was bordered on each side by a growth of black willows, averaging a quarter of a mile in width." The conversion of the wet prairie and the marginal woodlands into an open lake was a gradual process. The uncut trees remained standing for many years along both the north and south shores.

In the early days of the lake, snags, stumps, and fallen timbers filled the shallow waters and logjams piled up along the east bank and in many of the shallow bays. The water was cool and clear. Waves were not a problem, for a blanket of "moss" and the thousands of stumps, snags and logs helped to keep them under control.

A series of events occurring in rapid succession or simultaneously between 1890 and 1900 resulted in dramatic changes in the aquatic vegetation of Grand Lake St. Marys. These events included:

Removal of timber from the watershed and subsequent initiation of intensive agriculture which produced large yields of sediment-laden runoff.

TABLE B-4

PHYTOPLANKTON IN GRAND LAKE ST. MARYS, OHIO DURING 1975

Date	Total Cells (per ml)	Phylum	Phylum (Percent of Total Cell Count)	Dominant Genera Within Phylum and Percent (%) 1/ of Total Cell Count
5/16/75	2,830,000	Cyanophyta	99	Lyngbya (93); Oscillatoria (3); Agmenellum (2); Anacystis (1); Aphanizomenon
		Chrysophyta	<1	Melosira
		Chlorophyta	<1	Tetrastrum; Scenedesmus
8/12/75	2,400,000	Cyanophyta	99	Anacystis (28); Cylindrospermum (19); Lyngbya (19); Agmenellum (10); Gomphosphaeria (9); Aphanizomenon (7); Oscellatoria (7)
		Chlorophyta	<1	Scenedesmus (1); Dictyosphaerium
		Chrysophyta	<1	Melosira; Nitzxchia

1/ Less than one percent not given.

Source: Tobin and Youger, 1977. (4)

Severe drought and lowering of the lake water level. This exposed the lake's bed and resulted in desiccation and loss of aquatic macrophytes.

During the drought, stumps and timber were removed from the margins, thereby removing the wind-break surrounding the lake.

Heavy ice occurred during the winters of the drought period and probably resulted in further loss of vegetation.

Carp were introduced and were thought to consume "moss," a plant growing in open water areas.

An oil field was developed on the lake's bed from which some pollution was noted. This resulted in the elimination of some aquatic vegetation.

These events resulted in: (1) the loss of the wet prairie that formerly filled the shallows of the lake (these meadows were replaced by cattail marshes); (2) the disappearance of submerged aquatic vegetation; (3) the initiation of wind-driven wave action and shore erosion; and (4) a change from a clear, cool body of water to a turbid, warm lake.

Tiffany (cited in (1)) described the aquatic vegetation of Grand Lake St. Marys in 1920 as consisting of large areas of cattails, rushes, bur weed, and pondweed; smaller areas of arrowhead, pickerel weed, water willow, smartweed, sedge, and pondweed were also present.

During 1940 and 1941, an attempt was made by the Ohio Division of Wildlife to control the rapid expansion of cattail marsh in many sections of the lake, and to create holes in the marsh for duck hunters and anglers. About 100 pools were created, primarily along the south shore, by means of a mechanical cutter. Due to heavy wave and ice action, the marsh has retreated, and only a few of these pools remain. "Moss" became established in the pools that were relatively clear.[1]

Clark[1] stated that the small beds of lotus and sweet flag occur along the south shore. Small patches of coontail, white water lily, yellow water lily, pondweed, star duckweed, lesser duckweed, bushy pondweeds, and bladderwort are scattered around the lake. Practically the entire south shore and a few stretches of the north shore were outlined by cattail marsh. In some areas, this marsh was a half-mile deep, but it has greatly receded in recent years. Today, Grand Lake St. Marys contains very little vegetation in the open water area. The largest beds are water milfoil in Riley Bay, located along the north shore. These beds provide habitat for benthic macroinvertebrates and a nursery area for young-of-the-year fish. Only a fringe of forest or woodland remains along the shores, and long openings exist in this fringe.[5]

Fish and Wildlife

Wildlife

The project area includes a range of habitat types conducive to supporting a diverse fauna. Habitats available in Mercer and Auglaize Counties include Grand Lake St. Marys, marsh adjacent to the lake; several streams; temporary pools adjacent to the lake and streams; and upland, bottomland, and riparian woodlands. All upland woodlots are separated and isolated by land under cultivation. Streams, with the associated riparian vegetation, provide continuous habitat as well as dispersal corridors for birds, mammals, reptiles, and some amphibians.

Macroinvertebrates

No recent survey of Grand Lake St. Marys macroinvertebrates has been conducted. Roach (cited in [1]) notes surveys conducted in the 1930's indicated an invertebrate fauna composed of midge larvae, crayfish, fairy shrimp, freshwater shrimp, bivalve mussels, leeches, freshwater sponges, and moss animals. Roach reported that, over four years of study, the average number of macroinvertebrates per square foot of bottom was 223. Presently, the benthic macroinvertebrate fauna is probably dominated by tubificid oligochaetes and larval midges; invertebrate density is probably comparable, if not higher, at present than that reported.

Herpetofauna

Clark [1] reported that five species of frogs -- chorus frog, cricket frog, bullfrog, green frog, and leopard frog-- and four species of turtles -- common snapping turtle, spiny softshell, stinkpot, and painted turtle -- have been collected from Grand Lake St. Marys or its tributaries. Additional records published by Walker (1946) and Conant (1938) document the distribution of amphibians and reptiles, respectively, in the study area.

Fish

Grand Lake St. Marys is Ohio's largest inland lake. One of the greatest values of the lake at present lies in its recreational importance to hundreds of thousands of users, particularly for anglers.[1] The Ohio Department of Natural Resources annually assesses the taxonomic composition of fishes at Grand Lake St. Marys, assesses the relative abundance of sport and rough fishes, and stocks sport fishes.

To date, 53 species of fish have been collected from the lake. Most species recorded probably occurred in tributary streams prior to lake construction; however, some species have been added to the fauna via introduction by man. Species introduced include the striped bass, carp, and the flathead catfish. Species most sought by anglers are bass, bluegills, crappies, catfish, sunfish, perch, and northern pike.

Clark[1] summarized the results of test netting conducted in Grand Lake St. Marys by the Division of Wildlife from 1932 through 1955. Crappie-channel catfish-shad-carp was the dominant combination of species in all years. In general, the catch increased from 1932 to

1947, decreased to 1953, and began a recovery that carried through 1955. The rise and fall in total net catch was chiefly due to fluctuations in the take of crappies. Although rough fish were considered by the public to be over-abundant, they did not dominate the net catches. The fluctuations in catch indicate that stability in populations is not the normal course of events, but that a continuous shifting and changing is the typical trend.

From 1956 through 1978, crappie-channel catfish-shad-carp-quillback-bullhead composed the dominant combination of species captured, although considerable fluctuation in the catch of a particular species occurred through time. Net catch between 1956 and 1978 ranged from a low of 6.9 to a high of 41.1 fish per hour, but did not attain the peak catch per hour (131.6) recorded in 1947.(1)

A rigorous stocking program for sport and forage fishes by the State of Ohio insures adequate fish populations in Grand Lake St. Marys. Sport species stocked include bass (largemouth, striped, white, and rock), crappie (black and white), sunfishes (bluegill, pumpkinseed, and green and orangespotted sunfish), catfish (channel and flathead), perch and northern pike.

Birds

Ohio lies within the Mississippi Flyway, a major north-south migratory route for many passerine species (perching birds), birds of prey (hawks and owls), and waterfowl (ducks and geese). Trautman and Trautman (1968) reported that a total of 355 species of birds have been recorded from Ohio, of which 286 species are observed annually or breed here, 50 species are accidental or irregular visitors, 12 species are exotics, and seven species have been extirpated or are extinct.

The Grand Lake area is considered to be one of the best areas in Ohio for studying birds. Clark and Sipe(5) reported 290 species of birds as having been observed in the Grand Lake St. Marys area.

Located in the southwest corner of the lake is the Mercer County Waterfowl Management Area. This 1,408-acre area, of which approximately 1,050 acres are water, is managed for waterfowl through a cooperative agreement with the Division of Parks and Recreation. Canadian geese, wood ducks, mallards, black ducks, and teal nest in the refuge and around the lake in considerable numbers. Peak fall populations of Canadian geese have numbered as high as 7,000 in recent years.[6]

Mammals

A large variety of mammals probably occur in Mercer and Auglaize Counties because of the farmland, forestland, and wetland habitats present in the area. Larger mammals that would commonly be observed on farmland include the cottontail rabbit, gray squirrel, fox squirrel, opossum, and raccoon; mammals of forests would include squirrels, deer, raccoon, and opossum. Muskrat, raccoon, mink, skunk, and fox would frequent wetland habitats. Many small mammals -- shrews, moles, mice, voles, and bats -- are common to the study area, but are observed infrequently.

Endangered Species

Three species of birds that are listed as endangered or threatened migrate through Ohio. These species are the Eskimo curlew, bald eagle and the American peregrine falcon. Of these species, only the bald eagle nests in Ohio and presently on islands in Lake Erie.

The range of one endangered mammal, the Indiana bat, is known to include the project area. In Indiana, this species has been observed clinging to the loose bark of trees in riparian habitats during daylight hours.[7]

SOCIO-ECONOMIC MEASURES

Study Area

Two counties in west central Ohio, Mercer and Auglaize, comprise the project study area. Included in this predominantly urbanized area are the cities of Celina, St. Marys, and Coldwater and the village of Montezuma. Portions of the townships of St. Marys and Noble in Auglaize County and Jefferson, Franklin, and Butler in Mercer County are included within the study area boundaries. The two counties encompass about 844 square miles, which includes approximately 21 square miles in Grand Lake. The study area is not located within any portion of a Standard Metropolitan Statistical Area (SMSA), and is actually some distance from surrounding SMSA's such as Ft. Wayne (about 50 miles) and Indianapolis (about 100 miles) in Indiana, and Dayton (about 60 miles) and Columbus (about 100 miles) in Ohio.

Population Characteristics

The combined population of the two counties was 80,703 in 1980, 38,242 in Mercer, and 42,461 in Auglaize. During the decade of 1970 to 1980, Mercer and Auglaize Counties had population gains of 20.4 and 1.0 percent, respectively. This can be compared to a 1.0 percent statewide population increase and an 11.4 percent national population growth during the same period. (See Table B-5).

Total population in the United States is currently projected to increase from the 1980 level of 226,504,825 to 263,830,000 by the year 2000, and to 297,146,000 by 2020. This represents projected increases of nearly 16.5 percent between 1980 and 2000 and over 12 percent between 2000 and 2020. The State of Ohio, population 10,758,421 in 1980, is projected to experience gains of 2,623,779, or 24.4 percent, between 1980 and 2000 and 1,385,000, some 9 percent, from 2000 to 2020, slightly below the nationally projected growth levels. Mercer and Auglaize Counties are also expected to show steady population gains during the 50-year period, 1980 to 2020, at somewhat greater rates of growth than the state and the nation. During the periods 1980 to 2000, Mercer

TABLE B-5

POPULATION, EMPLOYMENT, AND PER CAPITA INCOME
HISTORICAL 1/ AND PROJECTED 2/
SELECTED YEARS 1960-2020
GRAND LAKE ST. MARYS, OHIO

Item	1960	1970	1980	2000	2020
Mercer County, Ohio					
Population	32,559	35,265	38,242	43,011	47,322
Total Employment	11,585	13,310	17,760	19,051	20,609
Per Capita Income	-	2,540	3,580	6,225	10,116
Auglaize County, Ohio					
Population	36,147	38,602	42,461	46,504	51,016
Total Employment	12,737	15,014	18,725	21,972	23,842
Per Capita Income	-	2,668	3,760	6,539	10,626
Ohio					
Population	9,706,397	10,657,423	10,758,421	13,382,200	14,767,000
Total Employment	3,521,791	4,124,258	4,673,200	6,033,900	6,601,000
Per Capita Income	2,587	3,512	4,800	8,200	13,500
BEA Area No. 609					
Population	259,931	277,278	288,682	339,200	373,200
Total Employment	90,503	104,957	127,131	152,900	165,800
Per Capita Income	2,249	3,264	4,600	8,000	13,000
United States					
Population	179,323,175	203,304,863	226,504,825	263,830,000	297,146,000
Total Employment	64,639,252	76,553,599	97,801,000	117,891,000	130,534,000
Per Capita Income	2,499	3,476	4,700	8,100	13,200

1/ Historical data from County and City Data Books (1962, 1967, 1977) and U.S. Bureau of Census.

2/ Projected population and total employment for 2000-2020 and per capita income projections, 1980-2020 figures based on OBERS Series E.

County population is projected to increase 4,769, or 12.5 percent, and by 18,300, or 21 percent, between 2000 and 2020. Auglaize County population projections show gains of 4,043, or 9.5 percent, in the 20-year period, 1980 to 2000, and 10,460, or 20 percent, from 2000 to 2020. As of 1980, the principal cities in the study area, Celina and St. Marys, had populations of 9,127 and 8,368, respectively. Approximated population projections for these two cities, selected townships, and the village of Montezuma are shown in Table B-6.

The above population projections were derived from sources indicated by footnotes in Tables B-5 and B-6. It will be noted that data for BEA No. 69 is also presented in Table B-5. This is defined as the Lima, Ohio, Economic Area for OBERS 1/ studies and projections, and includes Mercer and Auglaize Counties in addition to Hardin, Allen, Van Wert, and Putnam Counties in Ohio. OBERS projection 2000 through 2020 for BEA No. 69 was disaggregated to derive projections for the two counties comprising the study area.

Employment and Labor Force

In 1980 total employment in Mercer County was 17,760, or 46.4 percent of its population. Auglaize County total employment was 15,014 in 1970, or 39 percent of the population. By the year 2000, total employment has been projected to increase 7.3 percent, to 19,051 in Mercer County, and by 17.3 percent, to 21,972, in Auglaize County. For the period between 2000 and 2020, Mercer County total employment projection shows an increase of 8 percent, lagging slightly behind a 9 percent projected increase for Auglaize County. Comparisons with projected state and national employment levels can be made by referring to Table B-5.

1/ Office of Business Economics, U.S. Department of Commerce and Economic Research Service, U.S. Department of Agriculture

TABLE B-6

PERMANENT POPULATION PROJECTIONS 1/

Study Areas	1970	1980	1985	1990	1995	2000
Celina (Mercer County)	8,072	9,127	9,318	9,775	10,252	10,750
St. Marys (Auglaize County)	7,699	8,368	8,885	9,320	9,780	10,250
Jefferson Township (Mercer County)	2,330	12,118	2,665	2,820	2,985	3,150
Franklin Township (Mercer County)	1,120	1,801	1,280	1,360	1,440	1,520
St. Marys Township (Auglaize County)	2,230	11,158	2,550	2,700	2,860	3,025
Montezuma	160	201	315	340	370	400
TOTAL	21,711	42,773	25,013	26,315	27,687	29,095

NOTE: Butler Township, which is not shown separately, permanent population represents less than 14.1% of 1980 total.

1/ Grand Lake Regional Sewer Facilities Plan, Finkbeiner, Pettis, and Strout, Ltd. Volume 1, P. 60, June 1977. Population projections 1985 - 2000.

Employment data, both historical and projected, were derived from the same sources as for population. A breakdown of civilian labor force employment by industry sectors in the two counties is presented in Table B-7 for 1960 and 1970. Table B-8 presents major industrial employers in Celina and St. Marys, Ohio.

TABLE B-7

CIVILIAN LABOR FORCE, EMPLOYMENT BY INDUSTRY
FOR SELECTED AREAS - 1960 AND 1970

Industry	Auglaize County Ohio, 1960	Mercer County Ohio, 1960	Auglaize County Ohio, 1970	Mercer County Ohio, 1970
Agriculture, Forestry and Fisheries	1,622	1,914	997	1,301
Mining	40	50	51	61
Construction	638	666	781	719
Manufacturing	4,908	3,850	6,467	4,750
Communication, Transportation, and Utilities	518	390	611	613
Public Administration	253	220	399	215
Legal, Engineering, and Misc. Professional Services	234	162	94	86
Education and Government	1,657	1,363	2,057	3,409
Wholesale and Retail Trade	2,238	1,826	2,778	2,649
Finance Insurance and Real Estate	254	357	273	435
Health Services 1/	254	171	531	428

1/ Primarily Hospitals

TABLE B-8

MAJOR INDUSTRIAL EMPLOYERS IN CELINA AND ST. MARYS, OHIO

Industry	Employees	Product 3/
Celina 1/		
Huffman Manufacturing Company	1,800	Bicycles
Mershman Tables	591	Curios; wall units; desks; occasional tables and furniture
Reynolds and Reynolds	451	Paper products Printing business forms and systems
Celina Insurance Group	452	Insurance; reinsurance, and insurance services
General Telephone Company	125	Utility communications
St. Marys 2/		
Goodyear Tire and Rubber Company	1,778	Molded and extruded rubber and plastic - pliofilm
Joint Township District Memorial Hospital	325	Health services
St. Marys Cotton Mills	255	Industrial textiles and wiping cloths
St. Marys Foundry	136	Gray iron castings

Source: 1/ West Ohio Gas Company, 1978a.

2/ West Ohio Gas Company, 1978b.

3/ St. Marys and Celina, Ohio Chamber of Commerce, personal communication with Gary R. Finni, WAPORA, Inc., July 1979.

Personal Income

Per capita income in 1970 was $2,540 in Mercer County and $2,668 in Auglaize County. During the decade 1970 to 1980, per capita income is projected to rise to $3,580 in Mercer County and to $3,760 in Auglaize County, or 41 percent in both counties. From 1980 to 2000, per capita income levels are expected to show steady gains of some 74 percent in both Mercer and Auglaize Counties. By 2020, the expected per capita income for Mercer County is $10,116 and $10,626 for Auglaize County. These per capita income figures, unadjusted for inflation, indicate about a three-fold increase in levels between the present and the year 2020 in both counties.

In comparison, per capita income in 1970 for the State of Ohio was $3,512, projected to increase some 36 percent by 1980, 71 percent between 1980 and 2000, and an additional 65 percent between 2000 and 2020. For the United States, per capita income was $3,476 in 1970. Projected national figures show an increase of about 35 percent to $4,700 by 1980, 72 percent from 1980 to 2000, and 63 percent from 2000 to 2020. Overall, the two-county per capita income levels are expected to rise at a faster rate, but remain some 20 to 30 percent below the state and national levels.

Historical and projected per capita income levels are presented in Table B-5 with footnoting as to sources of data.

Business and Industrial Activity

In 1980 the labor force of the two-county study area was enumerated at 41,548, about 39 percent of the total population. Of this number, 12.2 percent were unemployed, above unemployment levels statewide and nationally.

The major sectors of employment during 1970 were manufacturing (40 percent), service industries, including government and education (19.4

percent), wholesale and retail trade (19.2 percent), construction (5.3 percent), and agriculture forestry and fisheries (8.1 percent). Mining activities accounted for less than 1 percent of the two-county workforce. Table B-7 identifies the distribution of employment by industry categories for each county for the years 1960 and 1970. Sizable increases in the manufacturing, trade, and services sectors, with declining numbers in agricultural, forestry, and fishery occupations are typical of the statewide employment trends in recent decades.

Transportation Facilities

Transportation facilities are vital to the welfare of all sectors of the economy. The need for an efficient transportation system can easily be appreciated, even by those in the most rural settings. Ohio has historically been one of the leading states in the nation in the development of its transportation facilities.

Almost all regions of Ohio are well served by all types of transport. The road, rail, and airline networks all have east-west routes through the central part of the state. Three major north-south transportation routes are also discernable.

Ohio's road systems are more intensely developed than the national average. Its share of high quality, high cost primary and interstate highways exceed its share of secondary roads. Because of Ohio's highly industrialized economy, it also has a highly efficient trucking industry.

Ohio's share of the national rail mileage is three times its share of the Nation's land area. The density of the rail network is very high. Railroad usage in Ohio decreased at a slower rate than the Nation's, but faster than the east, north central region rate.

Because of Ohio's interior position in the United States, its air transportation industry cannot be developed to its fullest potential.

None of the Nation's domestic trunk or international airlines are based in Ohio. However, many private airports have been constructed to serve the needs of the population.

Ohio is served by two major water routes, the Ohio River on the southern border and Lake Erie on the northern border; the Ohio River carrying more gross annual tonnage of the two. Since most of the river traffic originates outside Ohio, the effect on its economy is slight compared to several other states, although tonnage of Ohio River traffic has been steadily increasing since 1940.

On a regional level, high population densities and urbanization have made necessary the development of many short routes which may best be served by truck transport.

As for transportation facilities in the study area, Mercer County is served by the Norfolk and Western and Penn Central Railroads, forming a north-south route near the easternmost end of Grand Lake and branching off in an easterly direction across Auglaize County.

Mercer County is also served by U.S. Route 27, a heavily traveled route running north-south through Celina, the main city in that county, and branching off to the west into Auglaize County. The other main arteries in the county are classified as medium duty state roads. These roads, the majority of which run into Celina and become a part of U.S. Route 127, include State Routes 197, 703, and 29. (Plate B-4)

Mercer County is also traversed by four oil and gas pipelines. The State of Ohio is also a pioneer in the transport of coal by pipeline. The same pipelines serving Mercer County serve Auglaize County as well and continue onward in a northeasterly direction.

Auglaize County is served by the Norfolk and Western Railroad line running into the city of St. Marys, Ohio, the main city in that county.

U.S. Route 33 crosses the county from the northeast and runs into St. Marys, branching off into numerous state routes serving Auglaize

County. These include State Routes 29 and 116 -- many of which branch off into medium-duty routes serving the less traveled areas of the county.

Recreation Population

To date, no completely accurate data have been gathered which would give any good indication of what might be expected insofar as the weekend summer recreational or seasonal population of the Grand Lake area.

However, a method was developed by the engineering consulting firm of Finkbeiner, Pettis, and Strout, Ltd., which determines with a reasonable amount of accuracy what to expect in lake area seasonal populations. In addition to the recreational population figures, data on seasonal type cottage owners were obtained through review of various maps plus a physical survey along with a comparison with permanent population figures. Included in this seasonal category are persons visiting the lake area permanent population.

In projecting this seasonal population, the consulting firm assumed in view of the high availability of land, and the fact that a building ban has been in effect since 1971, that the seasonal population of the lake area should increase at a greater rate than the permanent population projected by the U.S. Bureau of the Census. These permanent and seasonal population projections are shown in Tables B-6 and B-9, respectively.

TABLE B-9

SEASONAL POPULATION PROJECTIONS 1/
(Peak Weekend)

Township	1970 2/	1980	1985	1990	1995	2000
Jefferson Township	3,000	3,450	3,700	3,960	4,250	4,550
Franklin Township	8,000	9,200	9,900	10,600	11,400	12,200
St. Marys Township	6,800	7,820	8,400	8,990	9,640	10,300
TOTAL	17,800	20,470	22,000	23,550	25,290	27,050

1/ Grand Lake Regional Sewer Facilities Plan, Finkbeiner, Pettis, and Strout, Ltd., Volume 1, Page 64, June 1977.
2/ Estimated.

Land Use Patterns

Celina

Most of Celina is residential, with the major portion of homes being single-family. Residential areas predominate to the southwest, north, and northeast of the central business district. As indicated in Table B-10, multiple family development represents less than one percent of the total land area in Celina.

Celina's commercial areas are generally in the southern part of town along Main Street. A shopping center to the north of town and businesses along State Route 29 account for the remaining commercial uses, except for a few isolated stores. The industrial areas of Celina are located along the two railroads that run through the town in north-south and west-southwest directions.(6) A land use map of the Celina area is presented in Plate B-5.

TABLE B-10

LAND USE IN CELINA AND ST. MARYS

Land Use Category	Celina: Land Used (Acres)	Celina: Percent Total Land
Residential		
a. Single-family	468.42	32.6
b. Two-family	8.14	0.6
c. Multi-family	3.70	0.3
d. Seasonal	3.88	0.3
Commercial		
a. Retail or services	28.49	2.0
b. Highway or auto	11.28	0.8
c. Parking	8.14	0.6
Industrial		
a. Restricted	29.78	2.1
b. General	84.54	5.9
c. Reserve or parking	25.97	1.8
Subtotal Private Development	672.34	46.7
Railroad	24.79	1.7
Community Service		
a. Public	95.53	6.6
b. Institutional	29.74	2.1
c. Recreation	29.22	2.0
Streets	369.43	25.7
Subtotal Public and Semi-Public Development	559.71	38.9
Subtotal Developed Land	1,232.05	85.6
Vacant	206.82	14.4
TOTAL	1,438.87	100.0

TABLE B-10 (Continued)

Land Use Category	St. Marys	
	Land Used (Acres)	Percent Total Land
Residential		
a. Single-family	356.7	25.6
b. 2, 3, and 4 family	4.6	0.3
c. Multi-family	1.9	0.1
Commercial	17.9	1.3
Industrial		
a. Light industry (including railroads)	47.7	3.4
b. Heavy industry	74.7	5.4
Subtotal Private Development	503.5	36.2
Parks and Playgrounds	9.8	0.7
Schools and Public Buildings	22.2	1.6
Other Public and Semi-Public Buildings	3.6	0.3
Cemeteries	52.9	3.8
Streets and Alleys	272.9	19.6
Subtotal Public and Semi-Public Development	361.3	25.9
Subtotal Developed Land	864.8	62.09
Vacant Land, including agricultural and wooded	527.9	37.9
Gross City Area	1,392.7	100.0

Source: Finkbeiner, Pettis & Strout, 1977.

St. Marys

As in Celina, most of the land area in St. Marys is developed in single family homes. Residential areas are located to the northwest, east, and southwest of the central business district. As indicated in Table B-10 there is little multi-family development in St. Marys.

The commercial area of St. Marys is concentrated in the central business district along Main Street. Some land to the east and west of town along U.S. Route 33 and State Route 29 is also in commercial use. St. Marys' industrial district extends from directly south of the town to the northeast edge of the urban development. Goodyear, the largest industry in St. Marys, is south of town.

Celina and St. Marys are expected to continue to develop in line with current zoning. Areas zoned as residential are expected to reach a population density comparable to those areas already developed.(6)

Lake Area

The land surrounding Grand Lake St. Marys is predominantly agricultural except for those areas immediately adjacent to the lake (Plate B-5). A great portion of the Grand Lake drainage area is classified as prime farmland. The land adjacent to the lake consists of many private and commercial establishments that are used mostly for recreational purposes. Cottages, campgrounds, and trailer parks are found around the lake, with highest concentrations on the south side. Large areas of undeveloped land remain to the north of Grand Lake St. Marys. Adjacent to the lake are several permanent, year-round residential subdivisions. However, the year-round population constitutes a very small part of the population that is present during the summer months.

Land around the lake is presently unzoned, and current growth has been random, with no efforts made to control lot sizes or land use. Consequently, developed land abuts areas of undeveloped agricultural land. Because of its attractiveness for recreational use, the land immediately adjacent to Grand Lake St. Marys is anticipated to be used largely for residential and recreational purposes in the future.(6)

Environmental and Recreational Areas

The Ohio Department of Natural Resources, Division of Wildlife, operates the Mercer County Waterfowl Management Area and the State Fish Farm, two unique management sites located in the primary study area (Plate B-6). In addition, more than 100 acres of pond area exist along a stretch of the Miami-Erie Canal system north of St. Marys. This scenic area is predominantly wooded and provides fishing and informal recreation.(6) Hiking is also popular along the Miami-Erie Canal Tow Path.

Grand Lake St. Marys Park is located along the northeast shore of the lake (Plate B-6) and provides recreational activities such as camping, fishing, hiking, picnicking, swimming, and boating. Approximately 500,000 persons visit the park annually.

Numerous local parks exist in the Grand Lake St. Marys area. There are four city parks in Celina and four in St. Marys, as well as one city park in the village of Montezuma. Adjacent to Grand Lake St. Marys are more than 60 private recreational sites for seasonal overnight rental or camping (Plate B-6).

The population of the Grand Lake St. Marys area increases by approximately 20,000 persons during the summer weekends, when recreational activity around the lake is at its peak. However, Grand Lake St. Marys has not developed to its full recreational potential for a variety of reasons that are discussed in Section C.

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SECTION B

PLATES

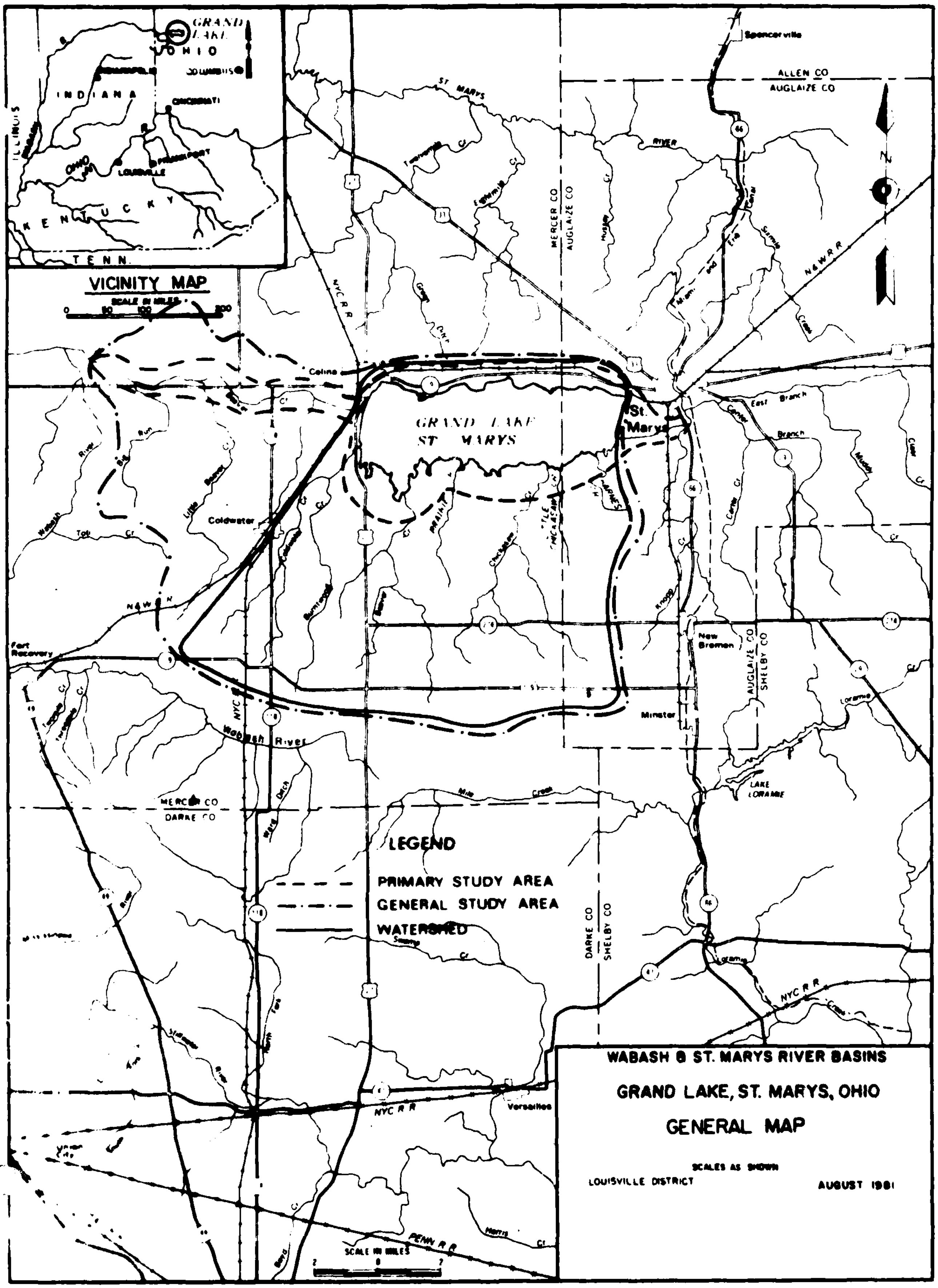
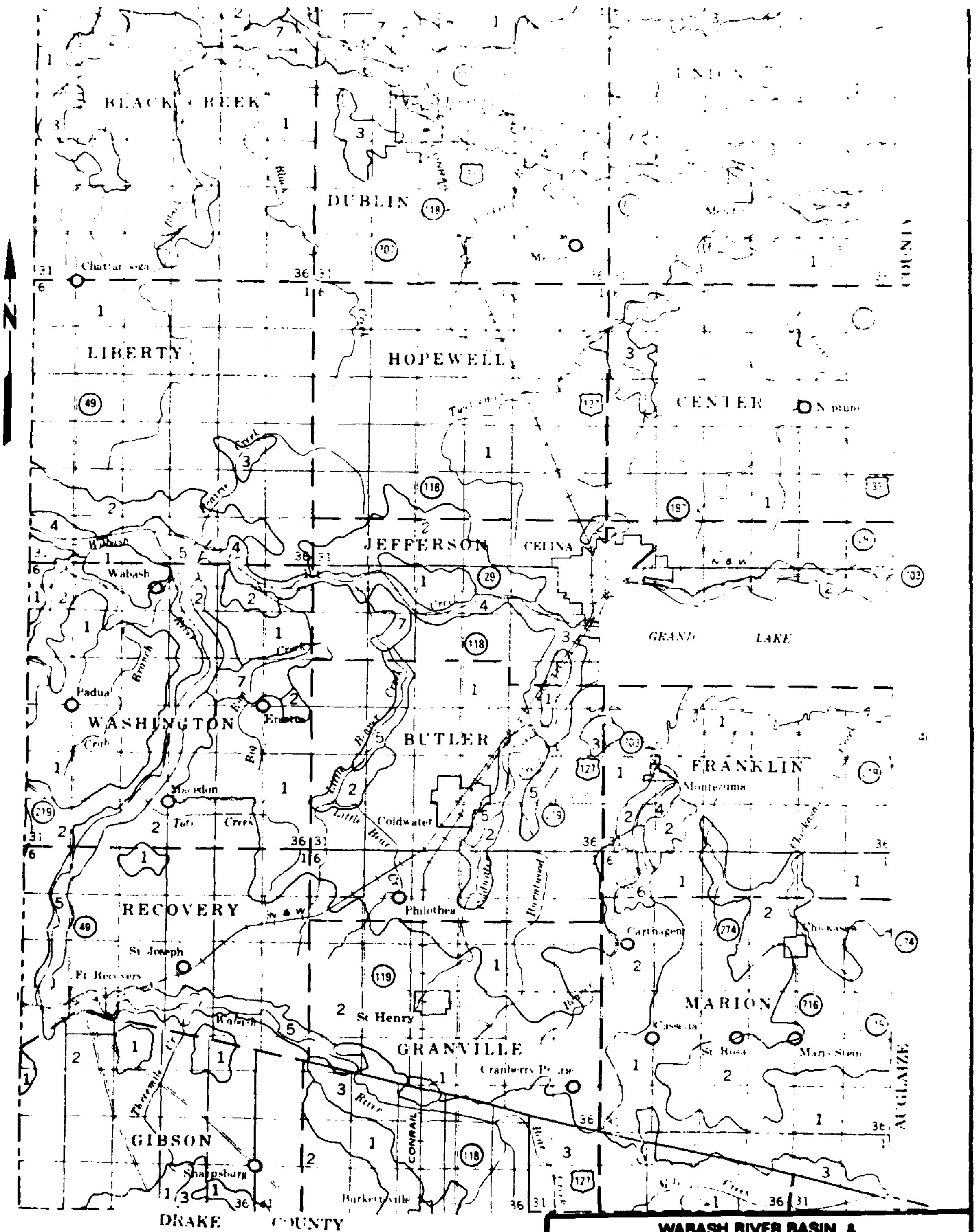

VICINITY MAP
OHIO
INDIANA
KENTUCKY
TENN.
ILLINOIS
CINCINNATI
LOUISVILLE
COLUMBUS
GRAND LAKE
Spencerville
ALLEN CO
AUGLAIZE CO
MERCER CO
AUGLAIZE CO
ST MARYS
RIVER
Celina
GRAND LAKE ST MARYS
St. Marys
Coldwater
Fort Recovery
Wabash River
New Bremen
Minster
AUGLAIZE CO
SHELBY CO
LAKE LORAMIE
MERCER CO
DARKE CO
DARKE CO
SHELBY CO
Versailles
NYC R R
PENN R R
N&W R R
LEGEND
PRIMARY STUDY AREA
GENERAL STUDY AREA
WATERSHED
WABASH & ST. MARYS RIVER BASINS
GRAND LAKE, ST. MARYS, OHIO
GENERAL MAP
SCALES AS SHOWN
LOUISVILLE DISTRICT
AUGUST 1981
SCALE IN MILES

PLATE B-1



SOURCE: Adapted from "General Soil Map, Mercer County, Ohio," U.S. Soil Conservation Service and Ohio Department of Natural Resources, 1978.

See Legend, Table B-1

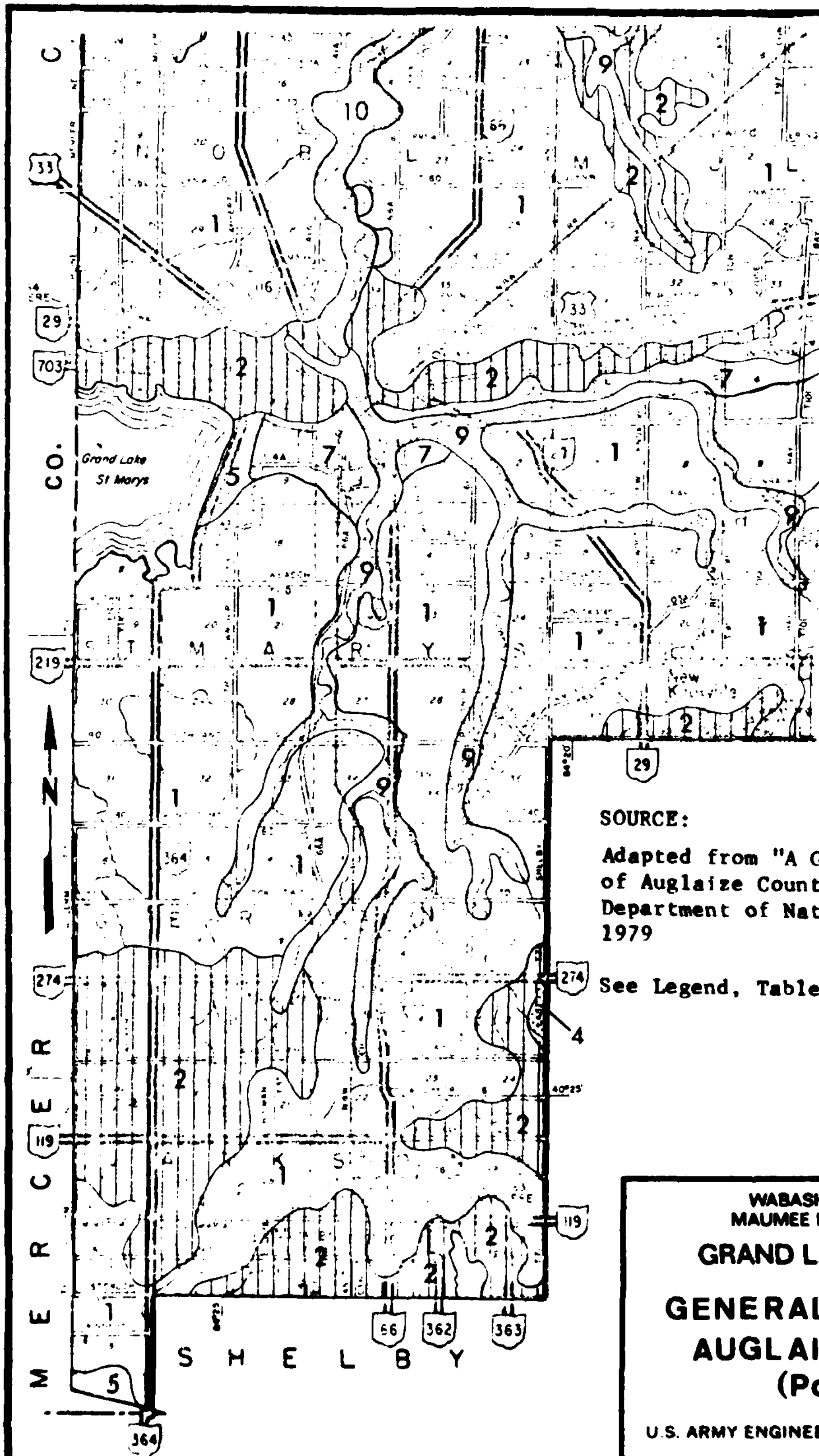
WABASH RIVER BASIN & MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

GENERAL SOIL MAP
MERCER COUNTY, OHIO

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLPD-F AUGUST 1981

PLATE B-2 a



SOURCE:

Adapted from "A General Soil Map of Auglaize County, Ohio" Department of Natural Resources, 1979

See Legend, Table B-1

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

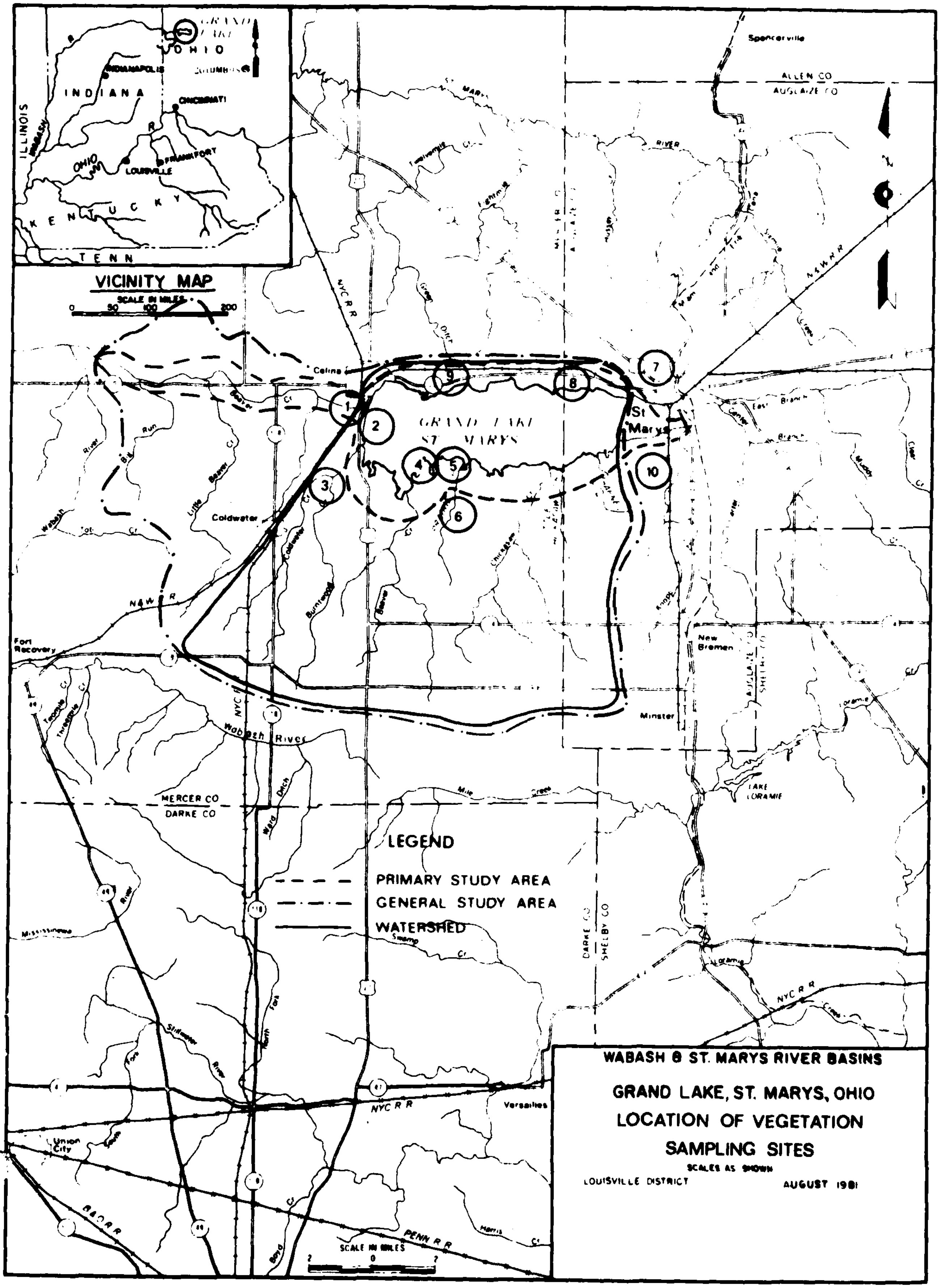
GRAND LAKE ST. MARYS

GENERAL SOILS MAP
AUGLAIZE COUNTY
(Portion)

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.

ORLPD-F AUGUST 1981

PLATE B-2 b



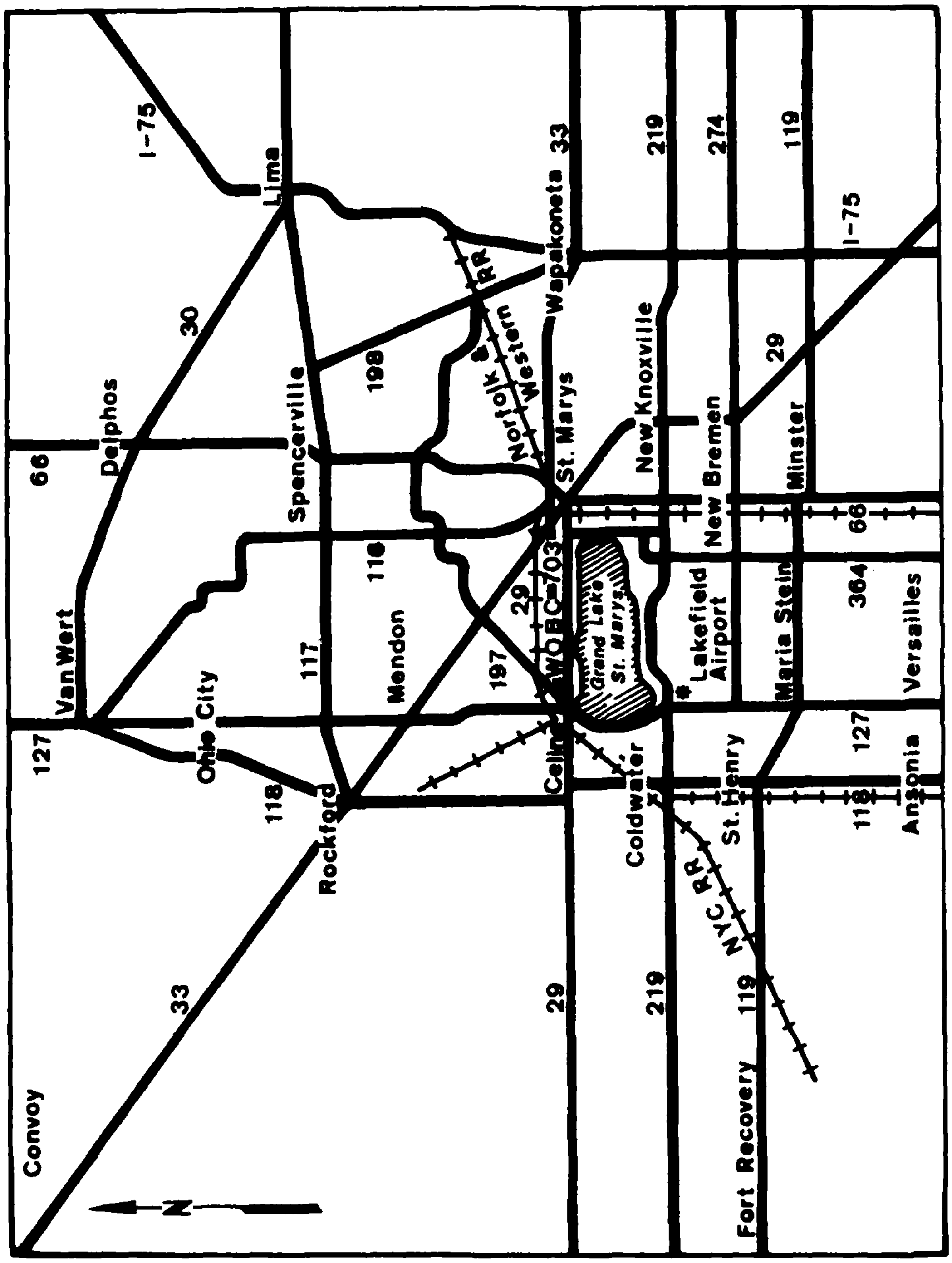
WABASH & ST. MARYS RIVER BASINS

GRAND LAKE, ST. MARYS, OHIO
LOCATION OF VEGETATION
SAMPLING SITES

SCALES AS SHOWN

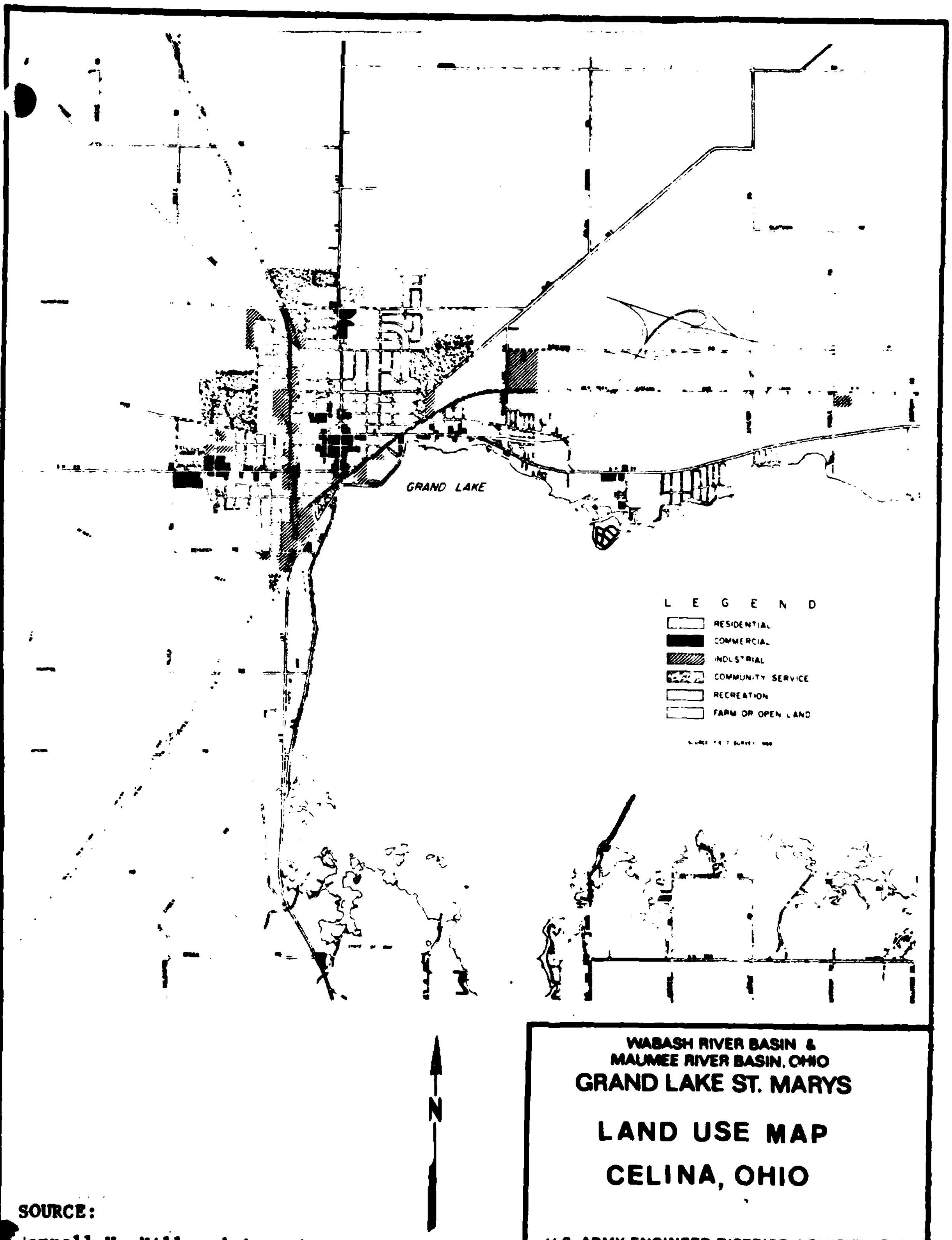
LOUISVILLE DISTRICT AUGUST 1981

PLATE B-3



MAJOR TRANSPORTATION ROUTES IN THE
GRAND LAKE—ST. MARYS STUDY AREA

PLATE B-4



SOURCE:
Carroll V. Hill and Associates

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

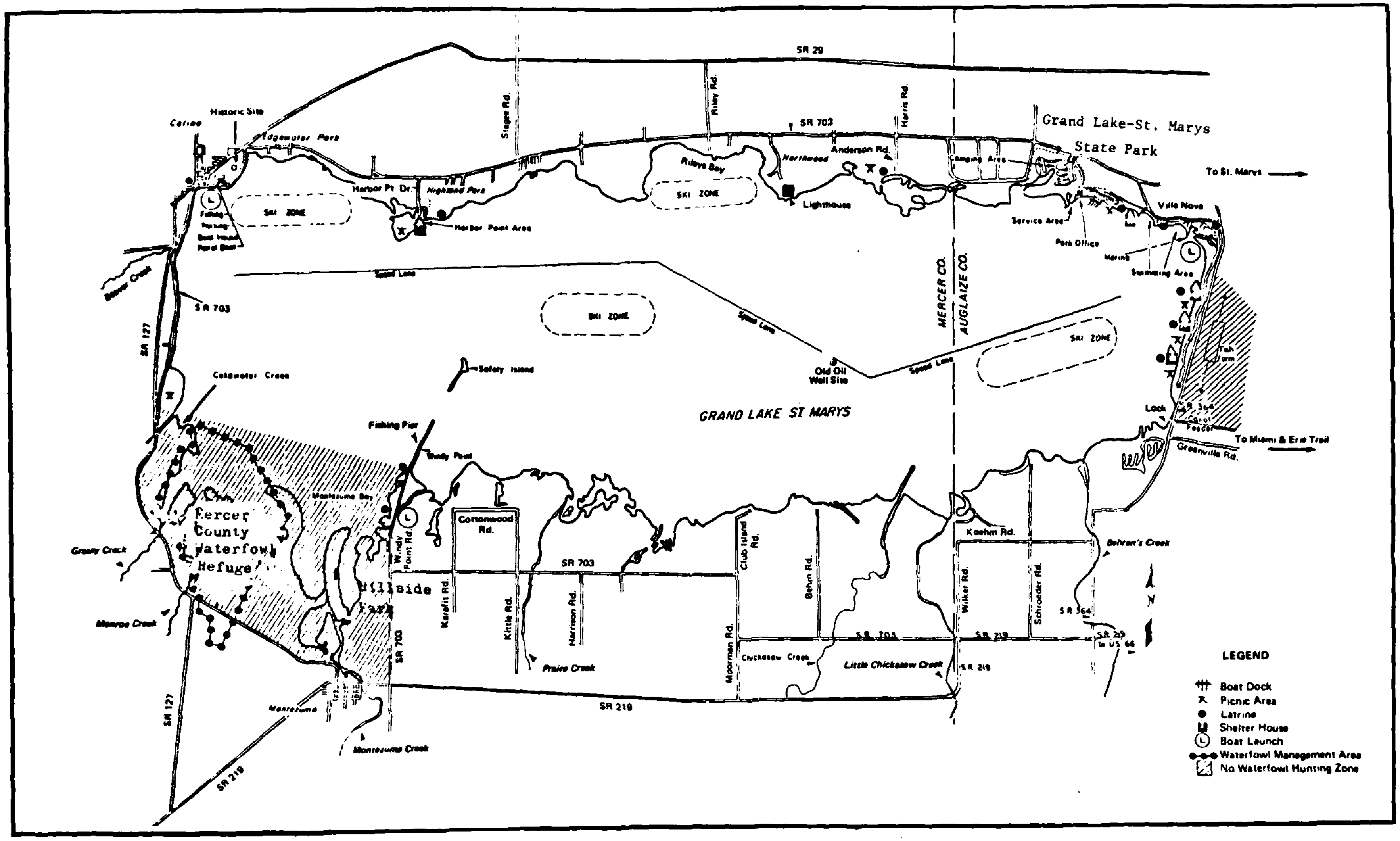
LAND USE MAP

CELINA, OHIO

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.

ORLPD-F AUGUST 1981

PLATE B-5



SOURCE: Ohio Department of Natural Resources, April 1976

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

ENVIRONMENTAL & RECREATIONAL AREAS

US ARMY ENGINEER DISTRICT, LOUISVILLE, KY
ORLPD-F AUGUST 1981

SECTION C

PROBLEMS AND NEEDS

SECTION C

PROBLEMS AND NEEDS

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SECTION C

PROBLEMS AND NEEDS

INTRODUCTION

From the time of study initiation an attempt has been made to identify the range of water resources problems in the study area. Extensive use has been made of various reports, both current and dated, in identifying existing and historical problems. In addition, information was obtained from formal and informal meetings from time to time over the eight years since study authorization, and particularly from local, county, and state officials in the recent past. Information has also been obtained from various service and lake organizations.

The problems in the study area have been divided into four broad categories: flooding, water quality, water-related recreation, and physical. These general problem areas have more definitive problem categories that are discussed in subsequent paragraphs. As will be seen, the water resource problems associated with the existing lake system have complex interrelationships that are difficult to quantify. While solutions to individual problems may seem apparent, it is difficult to find solutions to each of the problems which would not adversely affect other water resources uses and which are justified economically. Maps showing locations (or general areas) where water resource problems have been identified are shown on Plate C-1.

FLOOD PROBLEMS

Beaver Creek

Flooding has been reported for years, not only around Grand Lake, but also along Beaver Creek. The Federal Insurance Administration has prepared Flood Hazard Boundary Maps of Mercer and Auglaize Counties that identify areas that are potentially subject to flooding and flood damage in general. These maps show moderate flood hazard potential on the eastern and northern sides of the lake except for the area along State Highway 703 near Four Turkey Road and Harris Road, where the flood plain reaches a width of 1,000 feet in places. Flooding on Beaver Creek is most often reported in conjunction with uncontrolled releases from Grand Lake and high flows on the Wabash River. The Beaver Creek flood hazard area is only a few hundred feet wide from Grand Lake to Township Line Road, but reaches a width of over 3,000 feet as it approaches the Wabash River.

Periodic high rates of rainfall and runoff below the lake have caused high water condition and agricultural field flooding. The field flooding problems are due in part to restricted channel conditions and the limited flood control capability of Grand Lake, poor surface drainage, low creek gradient (1.5 foot per mile), and high creek stages that prevent adequate outlet for numerous artificial agricultural drains to Beaver Creek. Farmers along Beaver Creek have excess water problems such as drainage difficulties, destruction of crops, and late plantings as a result of flooding.

Information available includes rating curves, area and capacity data for the lake and pool elevations from 1927 to date. Surveyed cross sections and locations and outlet elevations of some field tiles along Beaver Creek are also known (Plate C-2).

The soil type along Beaver Creek is Defiance-Wabasha association. The dominant Defiance soil is somewhat poorly drained and has a depth of approximately 8 inches. The Wabasha soils are very poorly drained. Adequate artificial drainage is commonly difficult to establish because of the nearly flat topography and low grade to tile outlet. Additionally, extensive spoil banks along the creek tend to further confine surface runoff. Preliminary field inspection of the area indicated that the few tile drains observed may not be functioning properly.

Data are limited in regard to frequency of flooding along Beaver Creek. The only available information are pool hydrographs for Grand Lake. As such, it was necessary to develop a frequency curve by relation to other stream gages in the region. The reasonableness of the curve was checked by relating a few flood peaks computed from the changes in reservoir pool elevations, to the curve, determining their frequency, and comparing to the floods' frequency at other gages. The discharge frequency curve was then converted to an elevation-frequency curve, Plate C-3, by utilizing a rating curve determined from backwater computations.

Stream profiles without Grand Lake St. Marys (Plate C-2) were computed and plotted to reflect present conditions along Beaver Creek. These profiles indicate an impediment to drainage. It is not known at this time the complete extent of field tiles in the Beaver Creek basin. However, it is clear from studying Plate C-2 that any flooding will inhibit the drainage tiles from functioning properly. On 26-30 November 1979 a field survey of the flooding, drainage, and related water management problems along Beaver Creek and its major tributaries was conducted in Auglaize and Mercer Counties, Ohio. Beaver Creek is a natural tributary in Mercer County west of Grand Lake St. Marys.

A number of farmers/landowners along Beaver Creek were contacted and most were interviewed at length to record flooding and drainage problems, dates and magnitudes of major floods, and conditions believed to have caused or contributed to such damages and losses. From these interviews and through observations of inundated flood plain lands, which in some places obscured the locations of the stream channel, it was noted that, in addition to flooding, the lack of adequate drainage outlets throughout the lower portion of Beaver Creek constitutes a major obstacle to successful farming in this area. At that time, releases from Grand Lake were filling the stream's channel about three-fourths full immediately below the lake and the Wabash River was at or near flood elevation near its confluence with Beaver Creek.

Reductions of water levels maintained for recreational purposes in Grand Lake are made each year by releases into Beaver Creek. Efforts are said to be made to routinely slowly and steadily release water from the lake during the winter and early spring months when recreation demands are lowest. This is also the time of year when farming activities are normally at a minimum. However, most of the farmers interviewed along Beaver Creek stated that major releases from the lake were "automatically dumped" on them at excessive rates and volumes after very lengthy rainy periods, most notably in April and May, and also following such rainy periods that sometime occur in summer and fall, resulting in compounding the extent and severity of flood damages to their growing crops and farming operations in general. Numerous formal complaints, even litigation steps, have reportedly been made in recent years by a Beaver Creek farming interest in an effort to get the state to remedy this problem.

Through research of local newspaper accountings, it was learned that a formally organized Beaver Creek Improvement Association, no longer in existence, did in 1950-51 promote the widening, deepening, and straightening of Beaver Creek with the assistance of matching state funds. Some 13 miles of stream channel were improved at a total cost of $92,000, varying from 14-foot bottom width at Grand Lake increasing to 40-foot bottom width along a two-mile stretch of the Wabash River. This improvement reportedly proved to be somewhat effective in reducing flood problems for several years along Beaver Creek, but these have since been determined to be dry years. According to some interviewees who were members of that asociation, no additional local funding was provided for maintenance of the improved channel after the 1950's. As a result, uncontrolled vegetative growth along the banks, and filling of the stream with sediment and other obstructions have gradually diminished the capacity and effectiveness of much of Beaver Creek as a drainage outlet.

Some farmers, mainly in the upper segments of Beaver Creek, have managed to maintain the creek and banks which somewhat effectively minimize local flooding on their farms. Currently, however, according to local observers the lower 4 to 5 miles of Beaver Creek floods more frequently for several days duration. While these flooding problems do occur most frequently during the non-cropping winter and early spring seasons, such farming practices as late fall and winter plowing, early spring plantings, winter grain crops and cover crops, and late crop harvestings are usually not possible. Many other options necessary for diversified farming, such as pasture and hay crops, double cropping, and dairy/livestock production, operations that would significantly enhance farming incomes, are not available to the majority of farmers along Beaver Creek.

Although there has been no formally organized group since the 1950's representing the farmers and landowners, there is considerable concern expressed publicly about their flooding problems from time to time. It is generally recognized in this area that he Beaver Creek Valley has the fertility potential of being one of the most productive farming areas in the State of Ohio. An article appearing in the 29 November 1979 issue of The Daily Standard, a Celina, Ohio, local daily newspaper, states that the Ohio Senate, as an economy measure, had cut a $250,000 capital bill for improvements of Beaver Creek, along with numerous other funding items in a package proposal, from the state budget for the biennium, 1980-81. However, in a subsequent edition, the same newspaper quotes the local representatives in the State's legislature as having "considerable optimism" that another package bill containing the funding for improvement of Beaver Creek will be reintroduced and is "highly likely" to receive favorable committee action. There is considerable local interest in the passage of this bill.

The Mercer County engineering staff completed design of a plan for improvement of Beaver Creek, based on 1978 values, which was considered in the funding proposal in the Ohio legislature. It is believed that the County improvement proposal is based on matching funds from the state and that equal or some proportional share of local funding would have to be arranged.

Concensus of the persons interviewed, primarily residents and farmers in the Beaver Creek area, ranging in tenure from 4 years to 38 years, was that the largest floods observed occurred during January 1949, December and January 1957-58, March and April 1964, May 1972 and March 1975. Several other lesser floods were said to have occurred, some during June through November months of the year when crop losses were much greater. Assessment of actual damage values by specific floods were difficult to ascertain and confirm through interviews and were not incorporated in this survey effort.

For purposes of assessing the values of flood damages and losses, zero damage elevation points were established at 855 feet and 850 feet NGVD for the upper and lower evaluation reaches, respectively, of Beaver Creek. Representative gaging locations for these zero damage elevations within the upper and lower reaches were selected at stream miles 7.50 and 2.67, respectively. It was observed that in some low-lying fields, where higher water levels from within the stream's channel back up through tile systems causing saturation damages, the lowest elevations were below the 855-foot and 850-foot elevations. Actual elevations in these fields could not be seen, located, or quantified in terms of acreages, due to the extensiveness of standing water at the time of survey. However, it was also observed and recognized that both surface ditching systems and levee ponding and pumping operations served to raise the otherwise natural zero damage elevation points in other flood plain locations, in some instances two or more feet above the 855-foot and 850-foot elevations. These two man-made factors, lowering and raising zero damage elevations in given locations, were considered to be offsetting in establishing the representative average zero damage elevations.

Information obtained from landowners and local county agricultural officials indicated that presently about 60 percent of the flood plain fields along Beaver Creek are equipped with some form of tile drainage.

fields along Beaver Creek are equipped with some form of tile drainage. The ages and underground configurations of some of the tile systems in place are unknown, dating back to installations in the 1930's and perhaps beyond, and the effectiveness, if any, of these older systems is described as being suspect by the present landowners. However, most of the tile systems estimated by local agricultural officials to comprise over 30 pecrent of the total acreage tiled have been installed in the late 1950's, 1960's and 1970's. It is these more recently installed tile systems that are said by the farmers to not function effectively when Beaver Creek is flowing at or above one-half to three-fourths bankfull. Such flows are said to submerge the tile system outlets, backing the water up through the systems and saturating the lower lying areas in fields served by the systems.

Some of the farmers interviewed are presently maintaining surface ditched systems in addition to, or in lieu of, tile drainage in attempts to combat standing water problems in affected fields. Within more recent years, an increasing number of farm owners are utilizing leveed ponding basins with rather large pumps to remove the excess water off their fields during the crop growing season.

Considering the current installation costs of around $600 per acre for tile, plastic or ceramic, $200 to $400 for just moderate surface ditching of an average acre, and upward to over $800 per acre for installing a leveed pumping system, such initial costs and subsequent maintenance expenses for water management are significant to the financial success of many of the farming operations located largely along Beaver Creek. Farm ownership turnover is said by some interviewees to be at a relatively high rate in this particular area of Mercer County.

Other information obtained by interviews included agricultural cropping patterns, acreages and yields, planting, cultivation and harvesting practices and dates, and other pertinent farm operation data. Agricultural non-crop damage data were found to consist mostly of costs of clean-out, repair, and maintenance of surface ditches, tile outlets, on-farm roads and levees. Farm buildings, feed lots and fencing are virtually nonexistent along Beaver Creek.

Representatives of county and state highway departments, telephone, gas, electric, water, and other public utility services were contacted about flood damages/costs experiences along Beaver Creek. In most cases, such flood problems were described as minimal and were considered to be little more than costs of normal maintenance. Disruptions of public traffic due to floods were described as very infrequent, involving only some few isolated cases and of short durations.

Two established local real estate contacts were made concerning property values along Beaver Creek. Generalizations were discussed about the different on-farm buildings and other improvements made in evaluating farms, the relationships of farm size and exact location to market value, the effects of flooding property values generally, etc. The real etate agents' views were that Beaver Creek farms having mostly, or a majority of, flood plain land to farm are currently marketing up to $1,200 less per acre on the average than comparable farms in the county removed from flooding problems. The farms with less than one-third or no flood plain land are marketing at values fairly close to values of comparable upland farms in the area. A conservative overall estimate of market value of farm land, per se, was considered to be $800 less per acre in the Beaver Creek flood plain. The going market price for medium size farms with improvements was estimated to average $2,700 per acre in the general farming areas of Mercer County.

Lake Shore Flooding

In addition to Beaver Creek, periodic flooding also occurs along the south side of the lake where the shore topography and the developments are generally at a low elevation. The recreation-oriented developments around the lake tend to make any lowering of the water surface undesirable. Soils of the upland watershed are considered poorly drained. Poor natural drainage plus a high water table has caused most of these soils to be seasonally wet. Even though there is considerable agricultural tile, this poor drainage is aggravated by fluctuating lake water levels which cause localized and widespread flooding along the south shore and in depression areas. In addition, wave runup along the south shore occurs from frequent wind-induced wave action. During severe storms waves overtop existing riprap and walled reaches of the shoreline causing ponding and erosion behind them on occupied property. There is evidence of damage to buildings or homes due to flooding on the south shore.

During the week of 11-15 February 1980 a field survey was conducted of the flooding, erosion, and other lake-related shoreline problems along Grand Lake St. Marys. Principal emphasis was put on surveying those problems along the lake's south shoreline area, where the greatest incidence and magnitude of damages are reported to exist, although all accessible shoreline was investigated for potential and existing problems during the visit.

A number of residents, property owners, and business operators were contacted and most were interviewed to record their accounts of lake-related shoreline problems. Local government officials and realtors were also contacted for information relating to property ownerships, taxes and assessments, recent sales and real estate values. Since the lake was solidly frozen across, winter-time recreation activities were observed including ice fishing, skating, sledding and skimobiling.

Beginning at the state owned/operated St. Marys Wildlife Area at the southwest "corner" of the lake and traveling eastward, approximately two miles of unprotected shoreline was observed which has been eroding.

In Montezuma Bay, just to the east of St. Marys Wildlife Area, the Grand Lake State Park and residential developments in the city of Montezuma comprise about 1.8 miles of the lake's shoreline. Interviews and observations made in this area indicated relatively minor problems of flooding and erosion of mostly private properties. Some upland run-off flooding along Beaver Creek and Stafford Ditch adds to the problems of maintaining private property residences and businesses adjacent to this reach of the lake's shoreline.

Windy Point, just to the east of Montezuma Bay, provides a year-round outdoor recreation facility for the public, including a 2,000-foot riprapped jetty out into the lake. This state park facility is riprapped in several vital areas, unprotected in most other shoreline areas, but does provide some degree of protection from erosion by breaking wave action in the adjacent shoreline areas to the east.

Survey interviews in the Grand Haven Court development, immediately to the east of Windy Point, indicated that private property shoreline protection is generally effective through individual efforts of riprapping, concreting, and boarding of the lakeward area of boat docks and yards. These efforts are renewed practically every year and are costly to the property owners. However, as in most shoreline development areas, there are a number of private properties in Grand Haven Court being flooded and severely eroded by wave action from the lake.

For a distance of about six road miles east of Montezuma Bay and Windy Point there are over a dozen separate developments including multi-unit marinas, trailer courts, boat landings, recreation sales enterprises, and year-round residential communities. These complexes represent the major flooding and erosion problem areas along the entire shoreline of Grand Lake St. Marys. Each development is clustered around an individual spur road extension northward off U.S. Highway 703 leading into the lake, has at least one business office and some degree of recreation commercialization. Although most activities are minimal and almost dormant during the winter, it is obvious that the hundreds of boats, housetrailers and cabins, the beaches and ramps, and the many vacant residences are fully occupied during the recreation season.

There are at least 400 parcels of property strung out along this six-mile reach of the lake's south shoreline. From Windy Point east, these organized and named developments include Grand Haven Court, Bass Landing, The Maples, Wright Resort, Bayview Marina, Doss Landing, Bekins Landing, Hechts Landing, South Shore Acres, and Harmon's Landing. No attempt was made during this visit to inventory the obviously numerous shoreline problems in all of these developments. However, through some interviews and general observations, where snow and ice conditions of internal roads permitted, an identification of each complex was made in terms of approximate size, kinds of development and major shoreline exposure problems. Some of these developments have been in existence over 20 years, others were built in the 1960's and 1970's; some are obviously well maintained and managed, more so than others. Just to the east of Harmon's Landing, a recent development known as Southmoor Shores consists of some 20 to 30 rather expensive new residences located in the southeast "corner" of the lake. This is the only shoreline area observed that is presently undergoing new development, including new roads and streets, utilities, and developable lots.

The north shoreline of Grand Lake St. Marys is relatively much less developed, with four multiunit clusters of residential, recreational and commercial developments. This entire shoreline is largely stabilized, except for a few very small areas, by vegetation, riprapping, and natural rock outcrops. The west shoreline lies primarily along the edge of the city of Celina, Ohio, and U.S. Highway 703 where concrete walls and riprapping stabilize practically this entire length of shoreline. The east shoreline adjoins U.S. Highway 364 and a large State-owned park and fish hatchery development which is riprapped over a two-mile distance. In general, the shorelines on the east, west, and north borders of the lake are lacking the severe and widespread erosion and flooding problems that are prevalent along the south shoreline.

Erosion occurs along the five to six miles of raw exposed banks of the southern shoreline, much of which is owned by the State of Ohio, and from the thousands of acres of intensively cultivated private farm lands having natural drainage directly into the lake from the south. Aside from the individual efforts of private property owners along the south shoreline, there were no observations nor known plans to control erosion and sedimentation from these sources. The concensus of all individuals interviewed during this field survey was that the lake is filling up with sediment each year, and the lake's pool elevations are being raised each year to maintain adequate depths for recreation purposes. Dredging operations within the lake in recent years are said by locals to have been relatively ineffective in remedying this continuing sediment problem.

Flooding of private properties, access roads, and public recreation developments is an annual problem along the south shoreline area. It is much more visible than the erosion and sedimentation problems in that it disrupts the day-to-day activities of the people in the area. The observations of those individuals interviewed varied as to the personal costs and inconveniences experienced. However, all were in agreement that their flooding and erosion problems are getting worse over time.

Wave Runup and Wind Setup

The current and projected uses of the flood-prone areas adjacent to Grand Lake are seasonal residential, recreational and vacation types of uses. There are, however, permanent type residential structures of considerable value as well as business and commercial establishments catering to the lake community and its use of the lake.

The primary objective is to provide relief from flooding and flood damages while preserving the lake and the aesthetic nature of the residential, recreational and vacation type uses.

The problems of flooding from the lake occurs partially from lake level fluctuations. This, however, is not seen as the major determinant of damages. A major factor causing lakeshore flooding is the wind. Due to the rectangular shape of the 13,500-acre lake, moderate to high velocity winds produce damaging wave action and wind setup or higher lake levels at the leeward shore areas of the lake. Studies performed by a consultant firm working for the Louisville District point out that wind-produced wave action and wind setup are significant factors causing shore and beach erosion and structural flooding.

A check of lake level fluctuations above elevation 870.75 indicated that annual peak elevations averaged about 1 foot above the seasonal level. Single peaks for years that the lake level exceeded the rule curve were averaged and amounted to 0.85 foot, ranging from 0.1 foot to over 2 feet which is the maximum. In many years when the lake level exceeded the rule curve, it did so on more than one occasion. Therefore, 1.0 foot was used as the average lake level fluctuation above the rule curve.

Both wind setup and wave action are functions of wind velocity and fetch or open water distance. At Grand Lake the open water length or fetch along the west-east axis is about 8 miles. The significant wave height produced by a 60-mile-per-hour wind along the west-east axis of the lake would be about 2.7 feet. While the fetch along the north-south axis is considerably shorter, it is sufficient for wind-produced wave action to reach 2.6 feet at the same wind velocity. Wind setup produced by a 60-mile-per-hour wind is expected to be about 2 feet, 2.05 at the east end of the lake, while wind set up along the south shore would be about one-third that experienced at the east end of the lake. The design elevation for evaluation purposes is developed as follows:

<u>Development of Design Elevation</u>

Rule curve elevation =		El. 870.75 NGVD
plus:		
Average increase over rule curve	= 1.0 ft.	
Wind setup at 60 mph	= 2.0 ft.	
Wind-driven wave action at 60 mph	= 2.6 ft	5.6
Design level		El. 876.35 ft NGVD

The analysis addresses flood problems generated by the combination of higher than normal lake levels and wind setup - wave action. Therefore, the specific elevation for protection would be approximately 876.35, as noted above.

Since a great majority of the structural units are located in close proximity to the lake shoreline, the potential exists for flooding and flood damges.

Lake Regulation

Observed lake pool elevations, provided by the Ohio Department of Natural Resources, Division of Parks and Recreation, for a 51-year period (1928-1978) indicate that a regulation schedule or plan of operation was apparently nonexistent during the early years. However, an increasing emphasis on lake regulation was noted during the last 15-20 years with the corresponding emphasis for recreation and agricultural considerations. The existing operation schedule includes a 1-foot drawdown from the west bank spillway elevation 870.75 beginning 1 November. However, after the 1-foot drawdown for flood storage is attained, no significant regulation is exercised to maintain elevation 869.75 throughout the winter months. A practice of impounding some excess runoff early in the year to aid in attaining recreation pool by late March or early April appears to prevail.

Through discussion with the Grand Lake St. Marys Park management, an estimated maximum west bank conduit release of 200 cfs combined with Beaver Creek base flows is considered a near bankfull flow condition at low bank locations along Beaver Creek. During flood periods producing pool elevations in excess of elevation 870.75, uncontrolled outflows pass over the west bank spillway (200 cfs at elevation 872.45). During these periods, the conduit discharge must be reduced in order to maintain a maximum 200 cfs total outflow.

Lake pool elevation 871.75 was identified as the water surface elevation, together with wind wave action, "where lake shore flooding begins." Table C-1 presents 11 of the 12 observed annual events which exceeded elevation 871.75 for the period of record. Note that 7 of the 12 events occurred during the recreation season, thereby minimizing the beneficial effects of winter pool drawdown. These peak pool elevations

TABLE C-1

HISTORICAL LAKE POOL ELEVATIONS
ABOVE ELEVATION 870.75

Date	Observed Data		
	Peak Pool Elevation (feet)	Days Above Elevation 871.75	Peak Mean Daily Outflow (cfs)
January 1930	872.83	18	300
May 1943	872.67	24	330
April 1972	872.67	32	310
April 1938	872.42	19	550
February 1950	872.42	24	520
April 1978	872.17	37	380
January 1949	872.08	19	260
April 1957	872.08	23	550
June 1958	871.92	11	380
May 1933	871.92	5	490
November 1972	871.92	9	510

resulted from a wide variety of initial pool elevations, inflows and outflow conditions. Outflows ranged from spillway flow only (January 1930) to an estimated total west bank outflow (conduit plus spillway) of 550 cfs in April 1938. A pool elevation-frequency curve (Plate C-4) was developed from observed annual peak pool elevations derived from the 51-year period of record (Curve A). Also shown for this same period of record is a "paper routing" which reflects the current regulation of the lake (Curve B).

During initial field investigations and interviews with local interests, doubts have been expressed as to the effectiveness of the lake in reducing flood damage. In order to identify the effectiveness of the lake in reducing flooding, a comparison was made between existing operating methods and the hypothetical "no-lake" condition. For all cases evaluated (1-, 10-, and 100-year events) the existing operation reduced the area inundated substantially. For example, the existing lake operations reduce the area of cropland which would be inundated along Beaver Creek by a 10-year flood event from 2,720 acres to 2,000 acres.

The existing lake regulation plan includes a 10-inch drawdown from recreation pool, elevation 870.75 (west spillway crest), beginning the first of November. This drawdown provides approximately 1-3/4 inches of storage potential during the "flood prone months" (December through March). The 1-3/4 inches of runoff storage is available only at the start of the flood prone season in December and once filled it is maintained near west spillway crest to insure obtaining recreation pool by the first of April. Additionally, approximately 2-1/4 inches of storage is realized by surcharging to 1 foot above west spillway crest. This 1 foot is the limit considered necessary to minimize flooding of homes surrounding the lake.

It should be understood that references to inches of storage means the amount of runoff occurring from the total contributing drainage area of 112.1 square miles including the lake. One inch of runoff would then be equal to 5,980 acre-feet of storage in the lake. Therefore, a 1-foot rise above west spillway crest is equivalent to 13,600 acre-feet or 2-1/4 inches of runoff from the drainage area. Since a number of storms produce this amount or greater, the west embankment gates are opened to release excessive runoff.

Current regulation practices for the Grand Lake St. Marys western outlet will reduce natural peak discharges from excessive runoff to a modified condition. Attempts are being made to reduce natural Beaver Creek flows to a maximum bankfull flow condition while limiting lake storage to a maximum 1 foot above west spillway crest. Prolonged discharges, spillway plus gates, are reduced to optimize lake and downstream considerations. To deplete stored waters at an outlet rate of 150 cfs (which is considered the maximum feasible) will require approximately 46 days for the 2-1/4 inches of runoff. Therefore, the flood control capability of Grand Lake is considered limited.

FLOOD DAMAGES

Extent and Character of the Study Area

Flood problems in the Grand Lake study are located in agricultural areas along Beaver Creek and to some extend along developed suburban areas along the lake's south shore. Beaver Creek extends 10.6 miles from the western end of Grand Lake to its confluence with the Wabash River. For study purposes, Beaver Creek is divided into two reaches (Plate C-5). Reach BC-1 extends from the confluence of Beaver Creek with the Wabash River stream mile 0.0, to stream mile 4.75; and Reach BC-2 extends from stream mile 4.75 to Grand Lake, stream mile 10.6. Selected representative gaging locations within the upper and lower reaches were selected at stream miles 2.67 and 7.50, respectively. Development of damage curves, tables, and other supportive data are presented for these reaches. The total affected area in reaches BC-1 and BC-2 are shown on stage-area inundated curves, Figures C-1 and C-2, respectively.

With the exception of those areas immediately adjacent to the lake, the land surrounding Grand Lake is primarily agricultural and open land, 60 percent of which is equipped with some form of tile drainage system. Per field survey efforts in conjunction with relevant office data, it was determined that the majority of land in the Beaver Creek flood plain is for corn, soybeans, and hay production, with average per acre yields of 101 bushels, 38 bushels, and 1.5 tons, respectively, under flood-free conditions.

Two local real estate agents were contacted during a December 1979 field survey effort concerning the valuation of property within the estimated 3,216-acre flood plain of Beaver Creek. A conservative overall estimate of the value of the farmland was $800 less per acre for farms in the Beaver Creek flood plain than for comparable farms in the county removed from flooding problems. The prevailing price for medium size farms, with improvements, was estimated to average $2,700 per acre

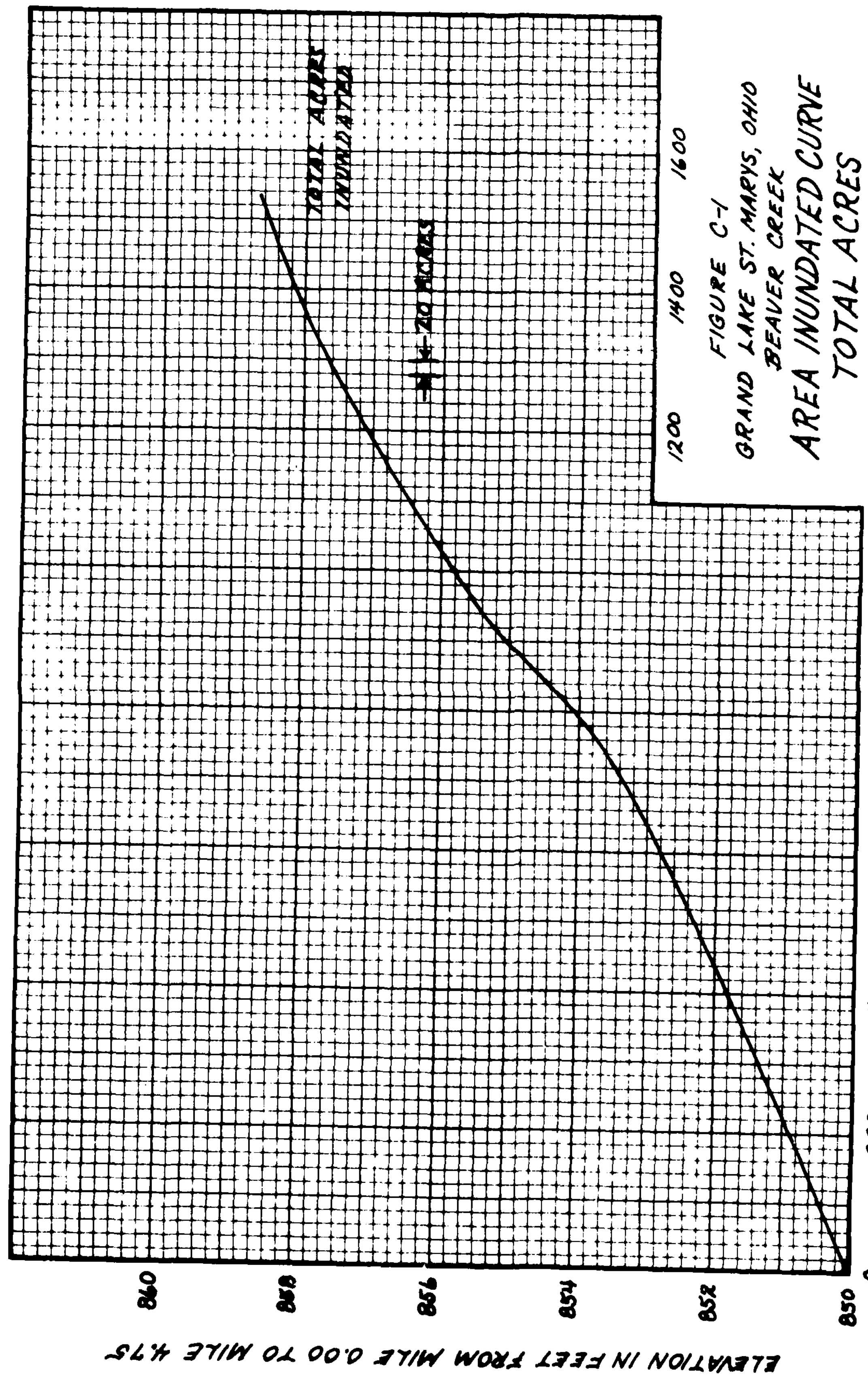

FIGURE C-1
GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK
AREA INUNDATED CURVE
TOTAL ACRES
REACH BC-1 MILE 2.67
ORLPD-E AUGUST 1981

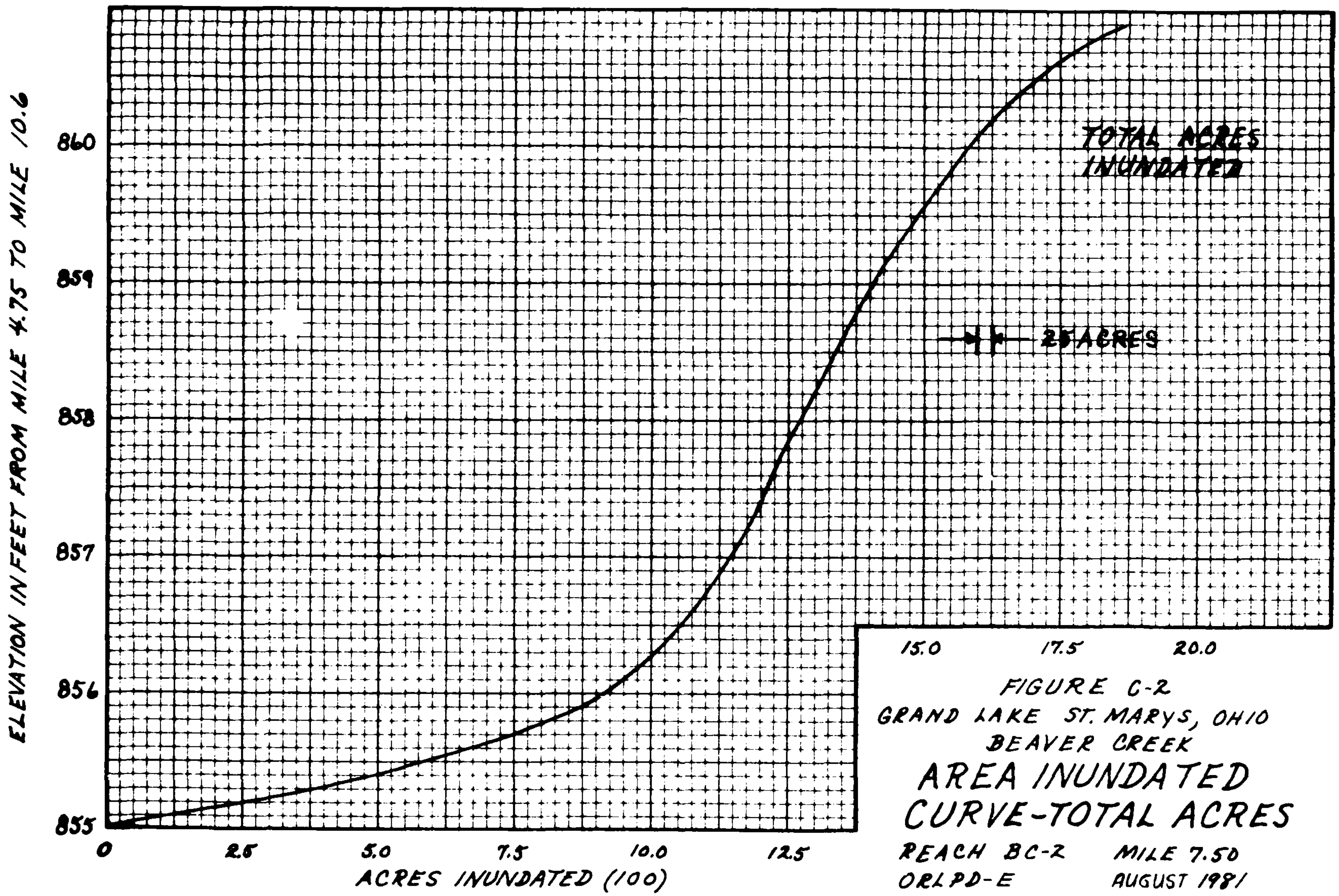

FIGURE C-2
GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK
AREA INUNDATED
CURVE-TOTAL ACRES
REACH BC-2 MILE 7.50
ORLPD-E AUGUST 1981

in the general farming areas of Mercer County, as compared to approximately $1,900 an acre for properties located in the Beaver Creek flood plain. The total value of land and improvements on Beaver Creek below Grand Lake is about $6.5 million. The number of acres potentially affected and estimated value are presented by reach in Table C-2.

TABLE C-2

ESTIMATED NUMBER OF ACRES AND VALUE OF
LAND AND IMPROVEMENTS
BEAVER CREEK, MERCER COUNTY, OHIO
1979 CONDITIONS AND PRICE LEVELS

Reach	Upper Limits of Reach Geographic	Mile	Acres	Value ($1,000)
BC-1	Gause Road Bridge	4.75	1,520	$2,888
BC-2	Grand Lake Western Embankment	10.60	1,875	3,562
Total			3,395	$6,450

The land adjacent to the lake, particularly along the south shore, consists of many private and commercial establishments used primarily for recreational purposes, along with several residential subdivisions. Much of the land to the north of the lake remains undeveloped. To the surrounding towns of St. Marys, Celina, Montezuma, Coldwater and Wapokoneta, there are sizable revenues to be earned each year from the commercial base directly dependent upon recreational uses of the lake.

Damages

Present (1979) flood damages were determined for crop, non-crop, transportation facilities, and public utility categories along Beaver Creek. Residential damages were evaluated for the lake shore properties. Estimation of said damges was based on field survey data gathered during the periods of May 1979, November 1979, and February 1980, and subsequent office studies.

Crop

The analyses of crop damages involved relating flooding along Beaver Creek to gross crop valuation data. The gross crop damage per acre values for reaches BC-1 and BC-2 were determined for the major crops produced in the study area, corn, soybeans, and hay, based on estimated current average flood-free yields and normalized prices, provided by the U.S. Water Resources Council dated September 1979. Stage-crop area inundated curves for Reaches BC-1 and BC-2 are presented as Figures C-3 and C-4, respectively. Crop damage curves, developed by relating crop area inundation data and gross crop valuation data, are shown on Figures C-5 and C-6 for Reaches BC-1 and BC-2.

Non-Crop

This category consists of damage to agricultural properties other than crop, i.e., siltation of tile, debris removal, land erosion and repair, and maintenance of surface ditches and on farm roads and levees. Damage to personal property such as farm buildings, feed lots, and fencing is virtually nonexistent and thus will not be considered here. Figures C-7 and C-8 show estimated non-crop curves for Reaches BC-1 and BC-2.

Transportation

This category includes estimates of physical damages to roads, road fills, bridges and culverts based on interviews with county and state highway departments and supplemented by pertinent in-office data. Disruptions of public traffic due to floods were described as very infrequent, involving isolated cases of short duration. Estimated transportation damages curves for Reaches BC-1 and BC-2 appear as Figures C-9 and C-10.

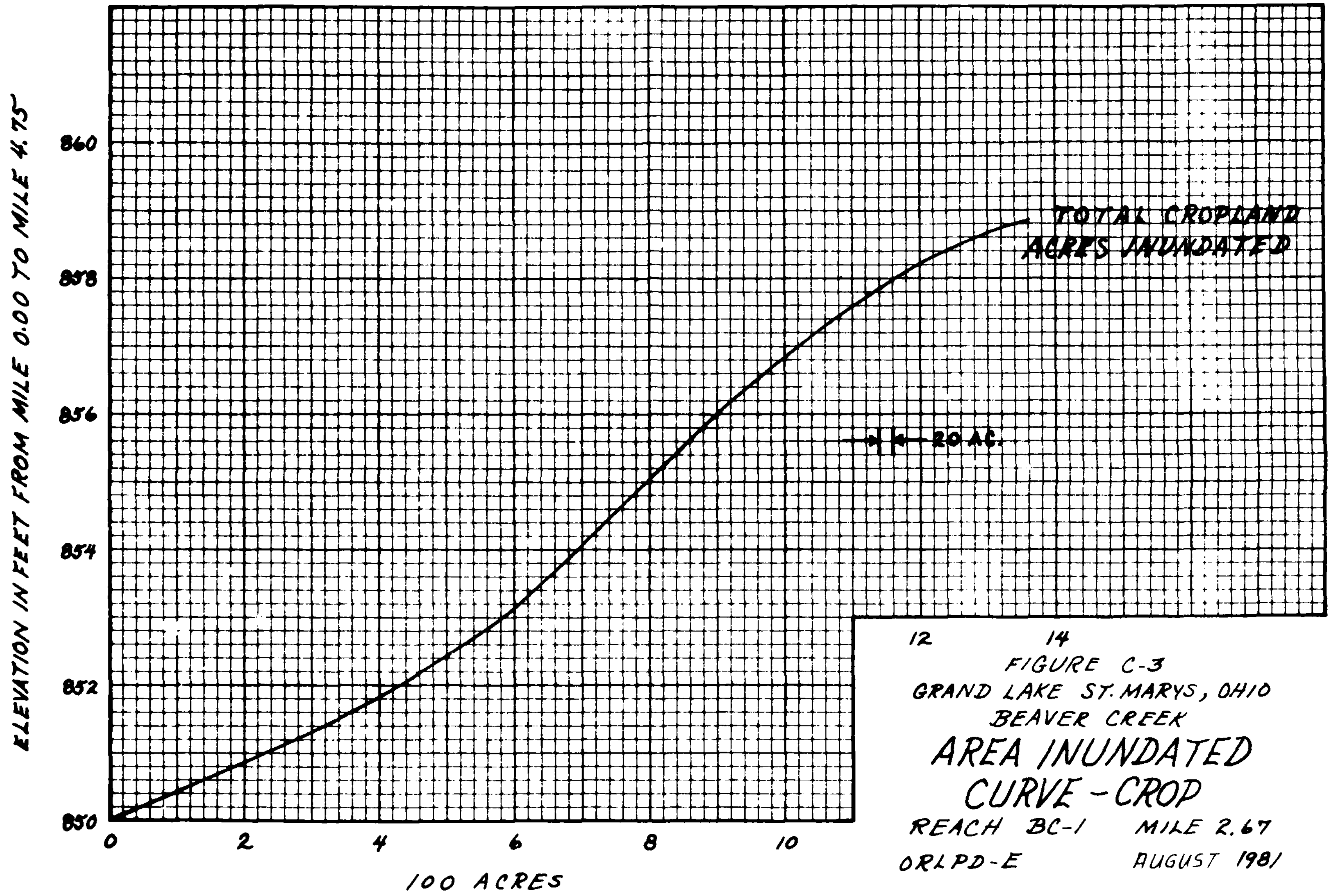

FIGURE C-3
GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK
AREA INUNDATED
CURVE - CROP
REACH BC-1 MILE 2.67
ORLPD-E AUGUST 1981

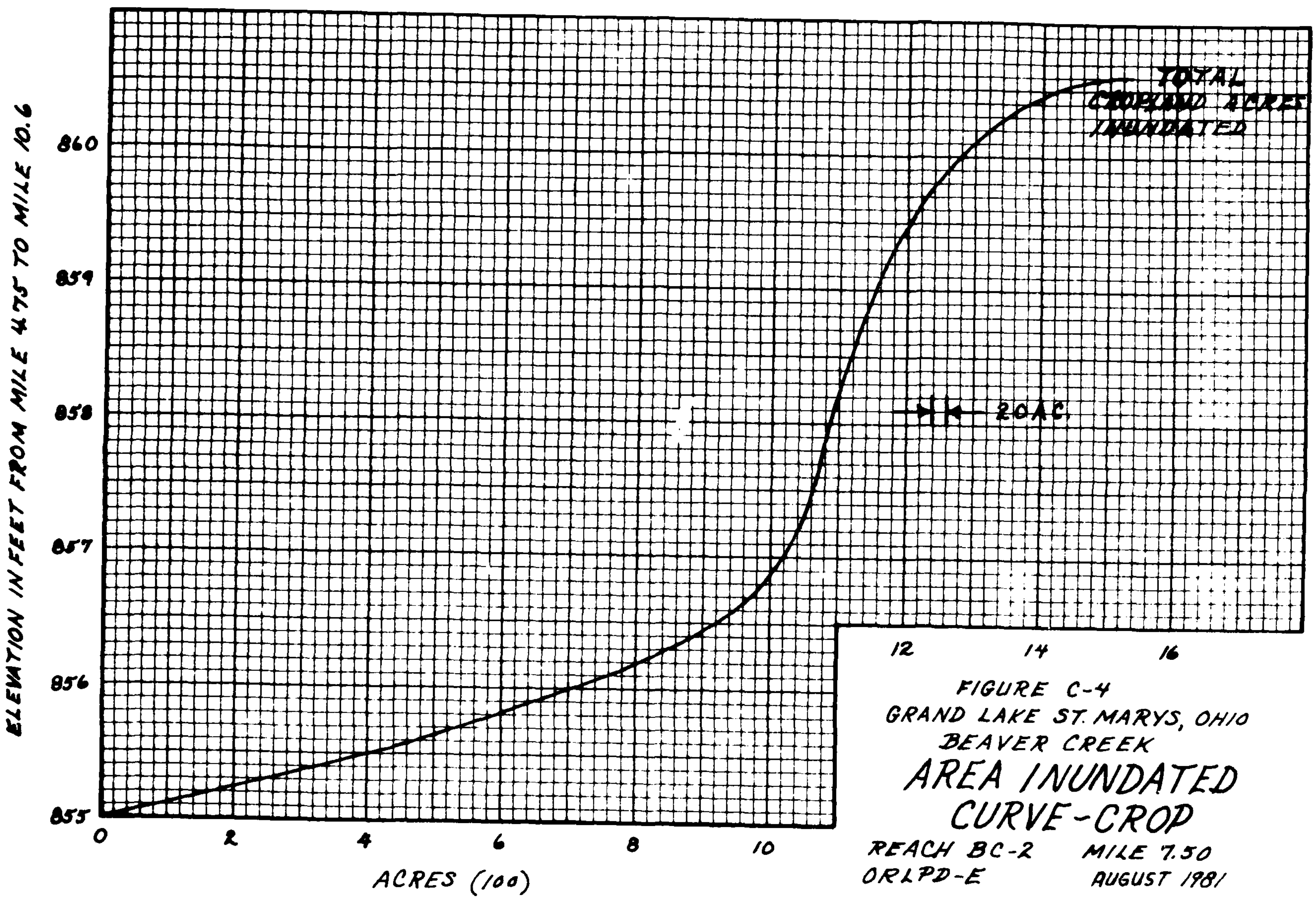

FIGURE C-4
GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK
AREA INUNDATED
CURVE-CROP
REACH BC-2 MILE 7.50
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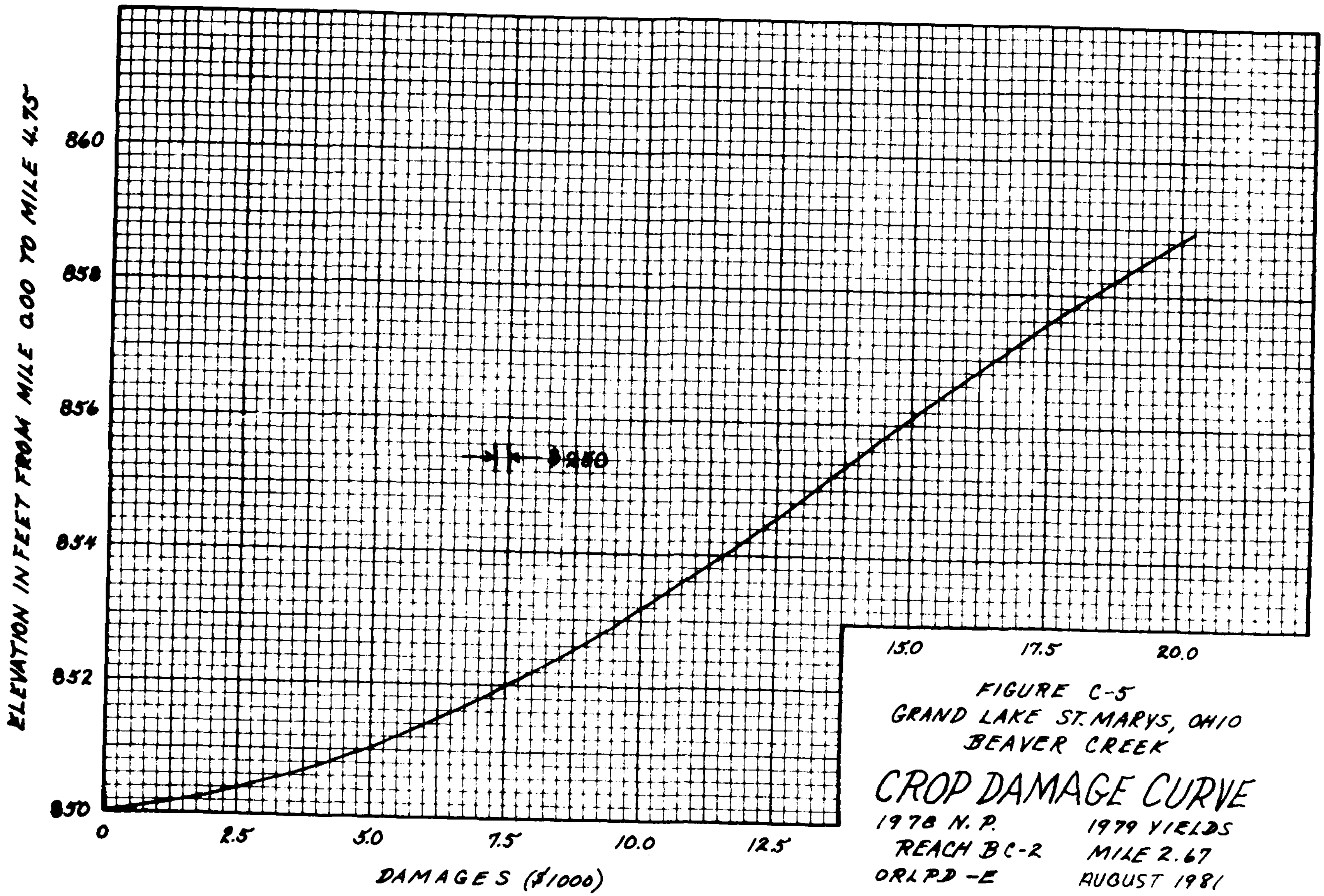

FIGURE C-5
GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK

CROP DAMAGE CURVE

1978 N.P. 1979 YIELDS
REACH BC-2 MILE 2.67
ORLPD-E AUGUST 1981

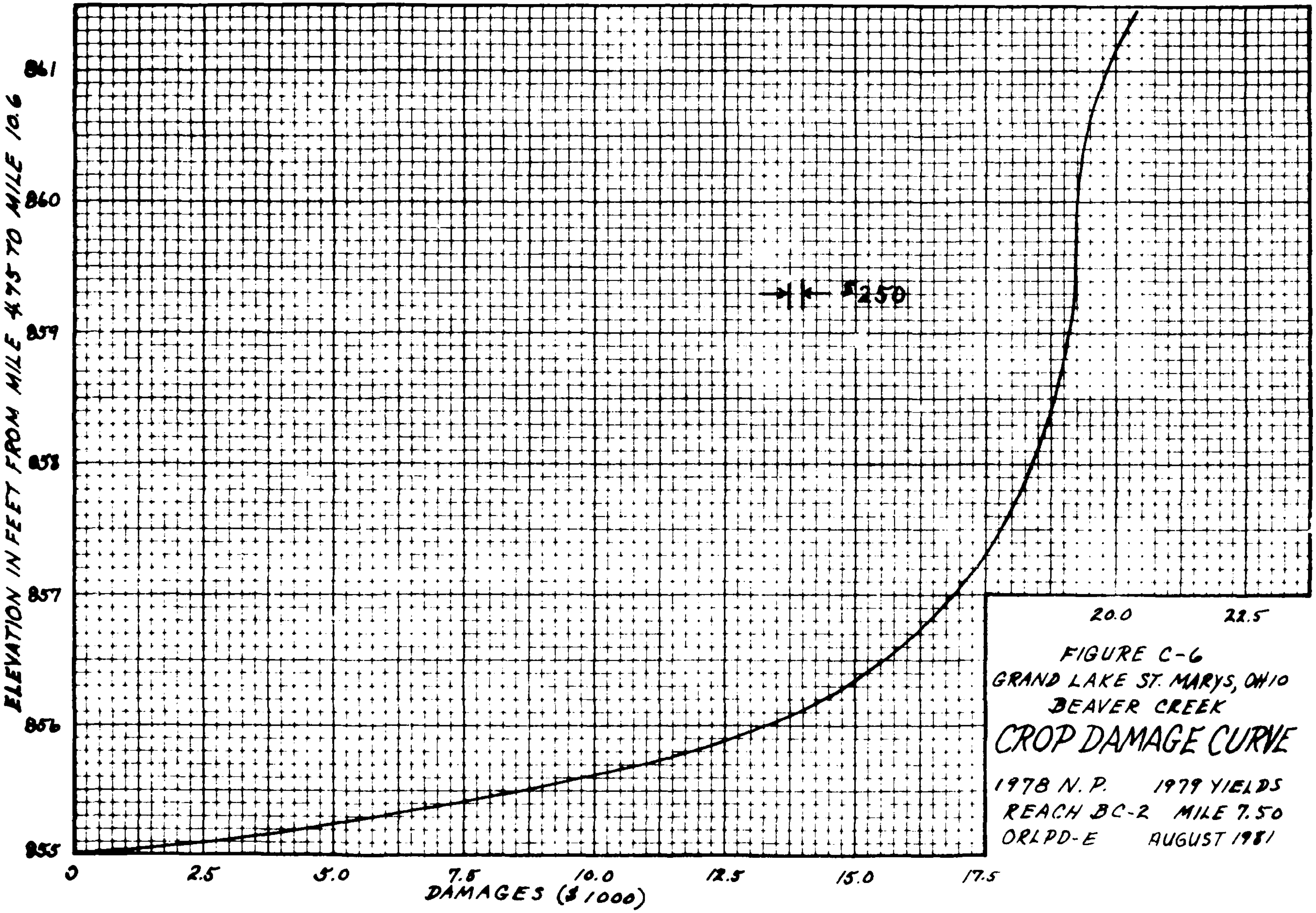

FIGURE C-6
GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK
CROP DAMAGE CURVE

1978 N.P. 1979 YIELDS
REACH BC-2 MILE 7.50
ORLPD-E AUGUST 1981

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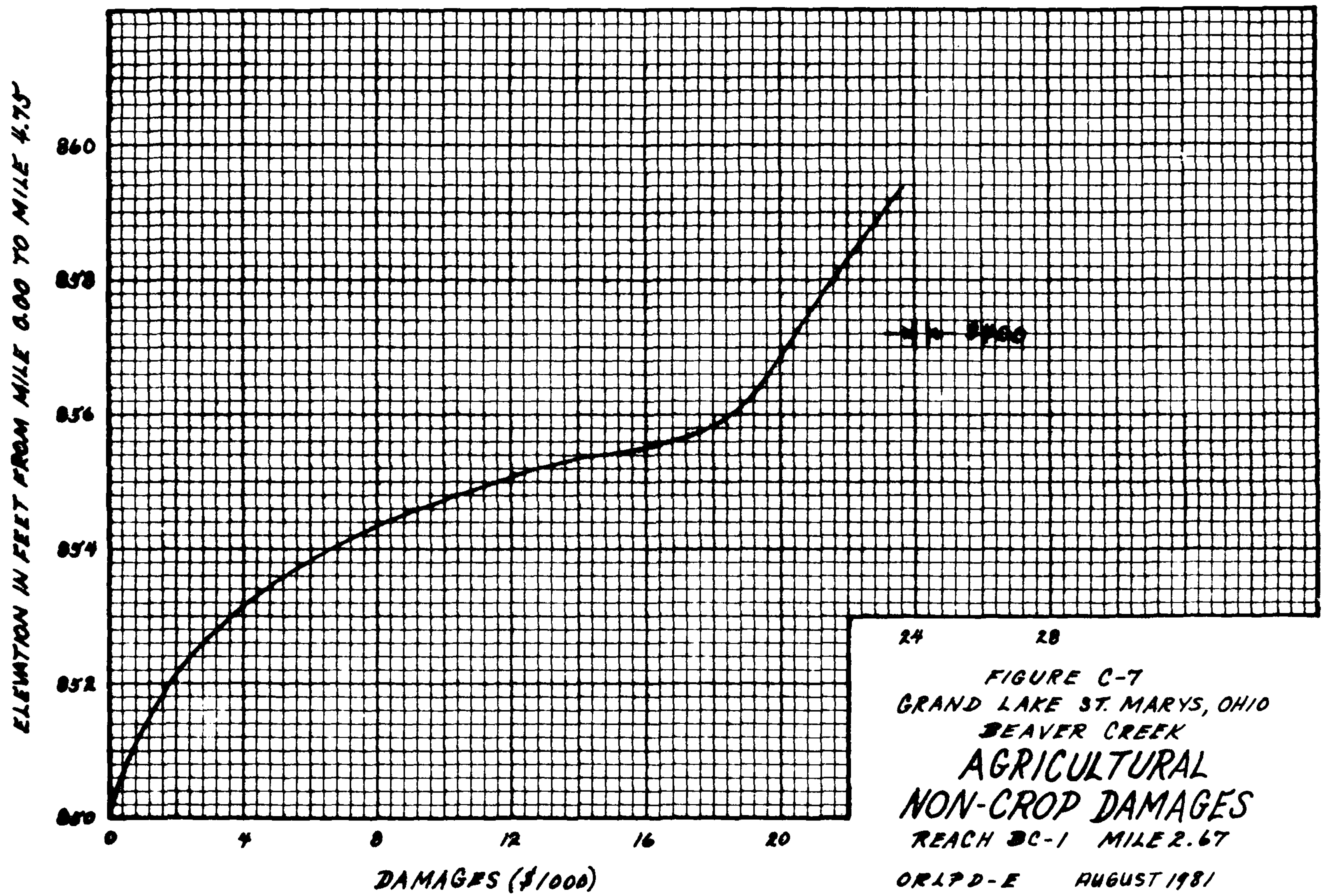

FIGURE C-7
GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK
AGRICULTURAL
NON-CROP DAMAGES
REACH BC-1 MILE 2.67
ORLPD-E AUGUST 1981

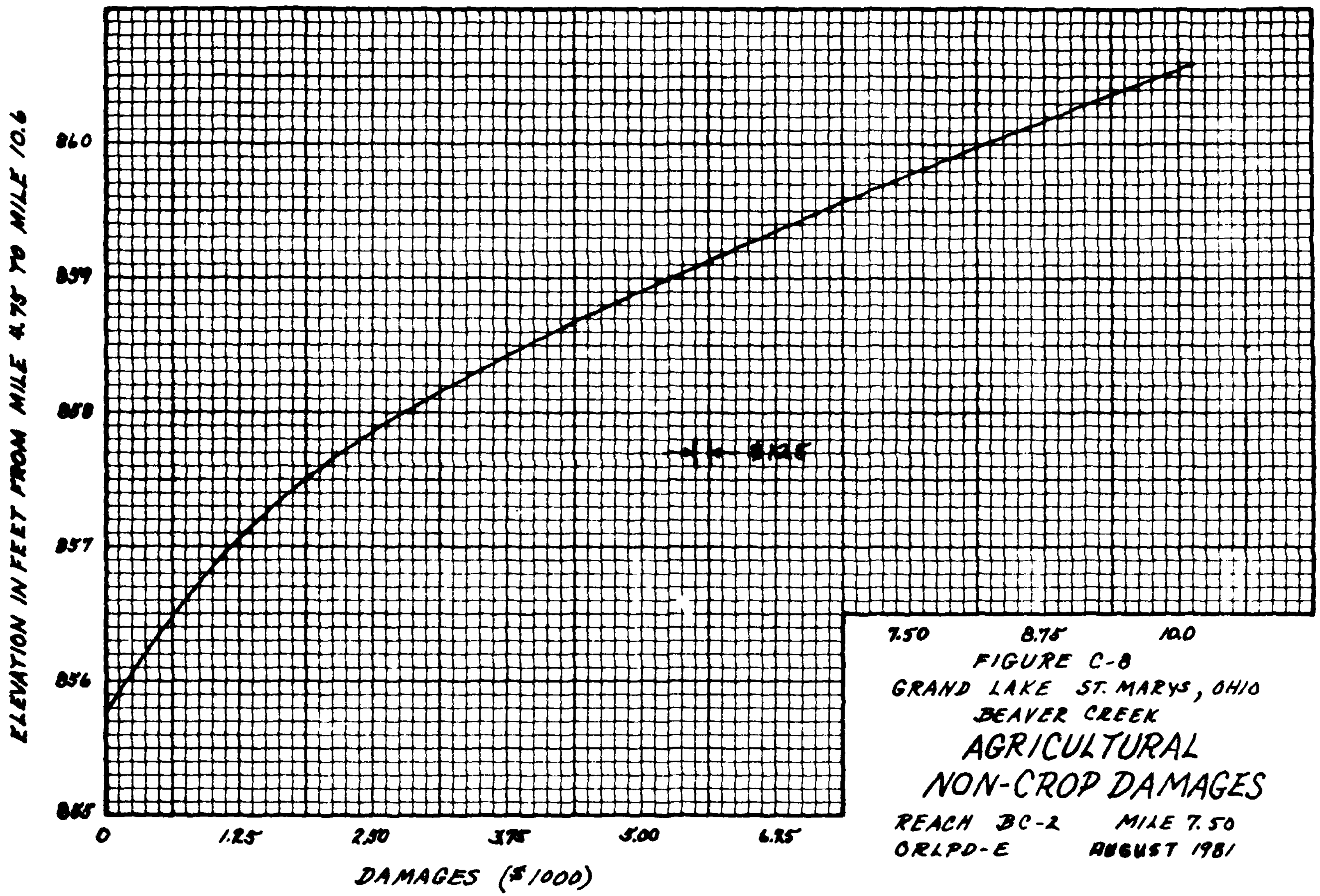

FIGURE C-8
GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK
AGRICULTURAL
NON-CROP DAMAGES
REACH BC-2 MILE 7.50
ORLPD-E AUGUST 1981

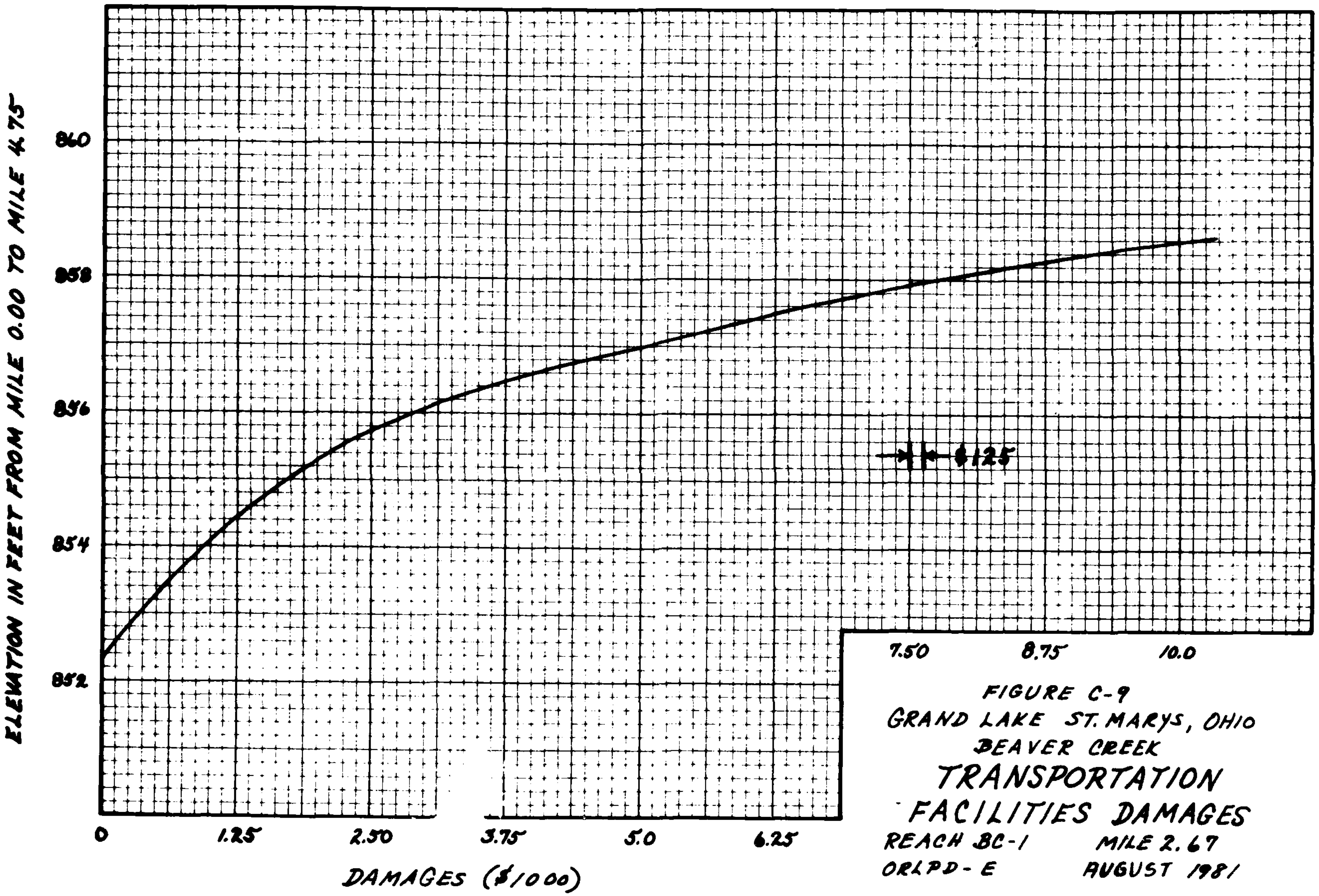

FIGURE C-9
GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK
TRANSPORTATION FACILITIES DAMAGES
REACH BC-1 MILE 2.67
ORLPD-E AUGUST 1981

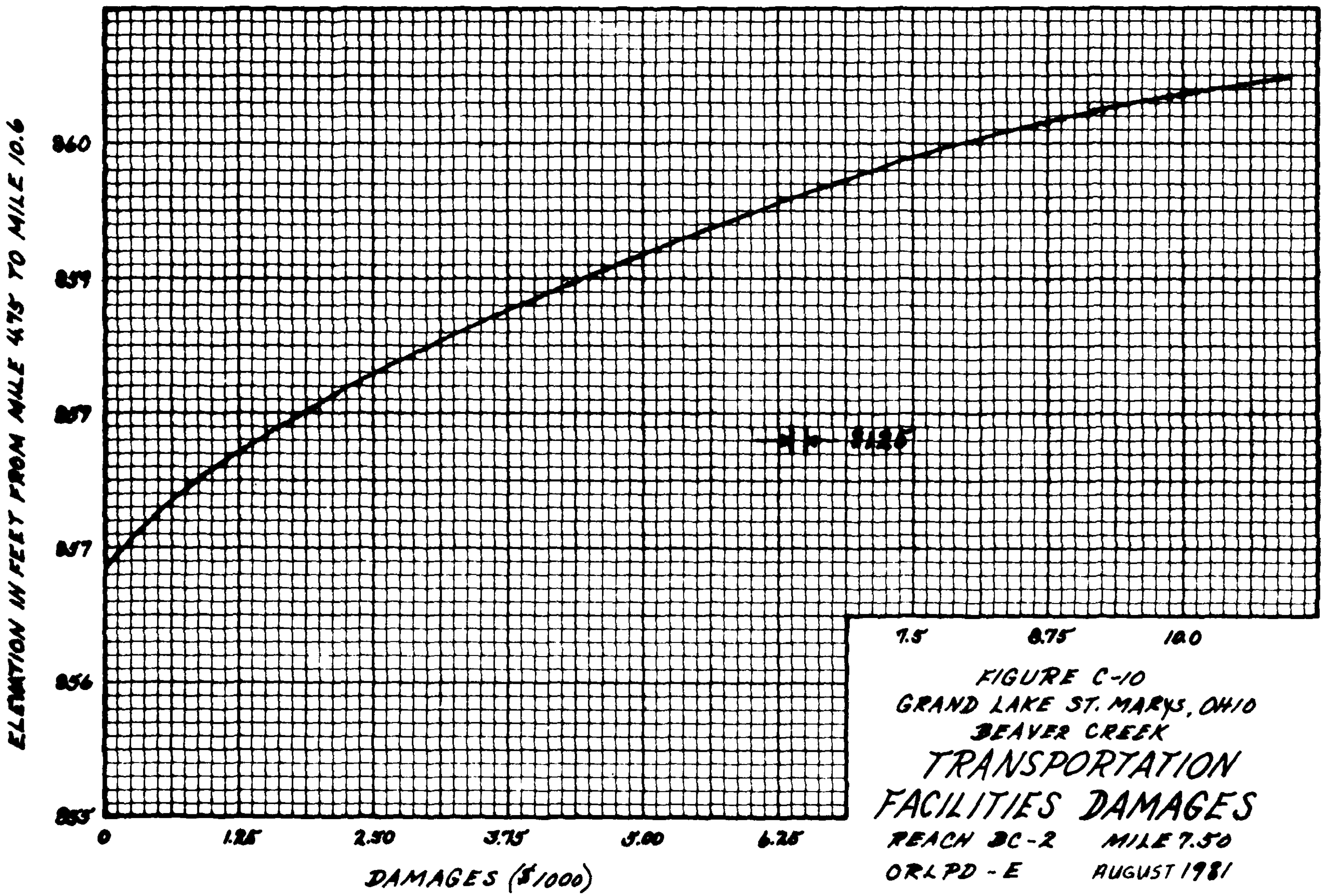

FIGURE C-10
GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK
TRANSPORTATION
FACILITIES DAMAGES
REACH BC-2 MILE 7.50
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Public Utilities

Representatives of telephone, gas and electric, water, and other public utility services were contacted about flood damage costs along Beaver Creek. In most cases, problems resulting from flooding were described as minimal and were considered to be little more than costs of normal maintenance. Damages to public utilities, although not of great significance in the study area, were evaluated, and are illustrated by the elevation-damage curves presented as Figures C-11 and C-12.

Urban

Flood damage surveys were made for selected residences along the Grand Lake shoreline area. Because commercial establishments in the area were located either at elevations out of reach of flooding, or sufficiently removed from the lake shoreline, damages were virtually nonexistent, and therefore not evaluated here. During these surveys, a fairly representative sampling of dwellings was surveyed as to dollar amounts of residential damages, debris removal, content damages, and other areas in which costs were incurred as a result of flooding. The total value of residences along the south shore of Grand Lake was estimated to be approximately $6.0 million. The residential damage curve for the south shore of Grand Lake is shown as Figure C-13.

Average Annual Damages

Present average annual flood damages were computed by relating damage curve data to that provided by all-season flood frequency curves for Reaches BC-1 and BC-2. These damages are summarized in Table C-3. Table C-4 is an estimate of flood damage that would result from occurrence of the 5-, 10-, and 100-year frequency flood events. Flood damages for the lake shoreline area are attributed to a high lake level, combined with wave action. Present average annual damages for the south shore of Grand Lake are estimated to be $150,000 for some 142 private shoreline properties as given in Table C-5.

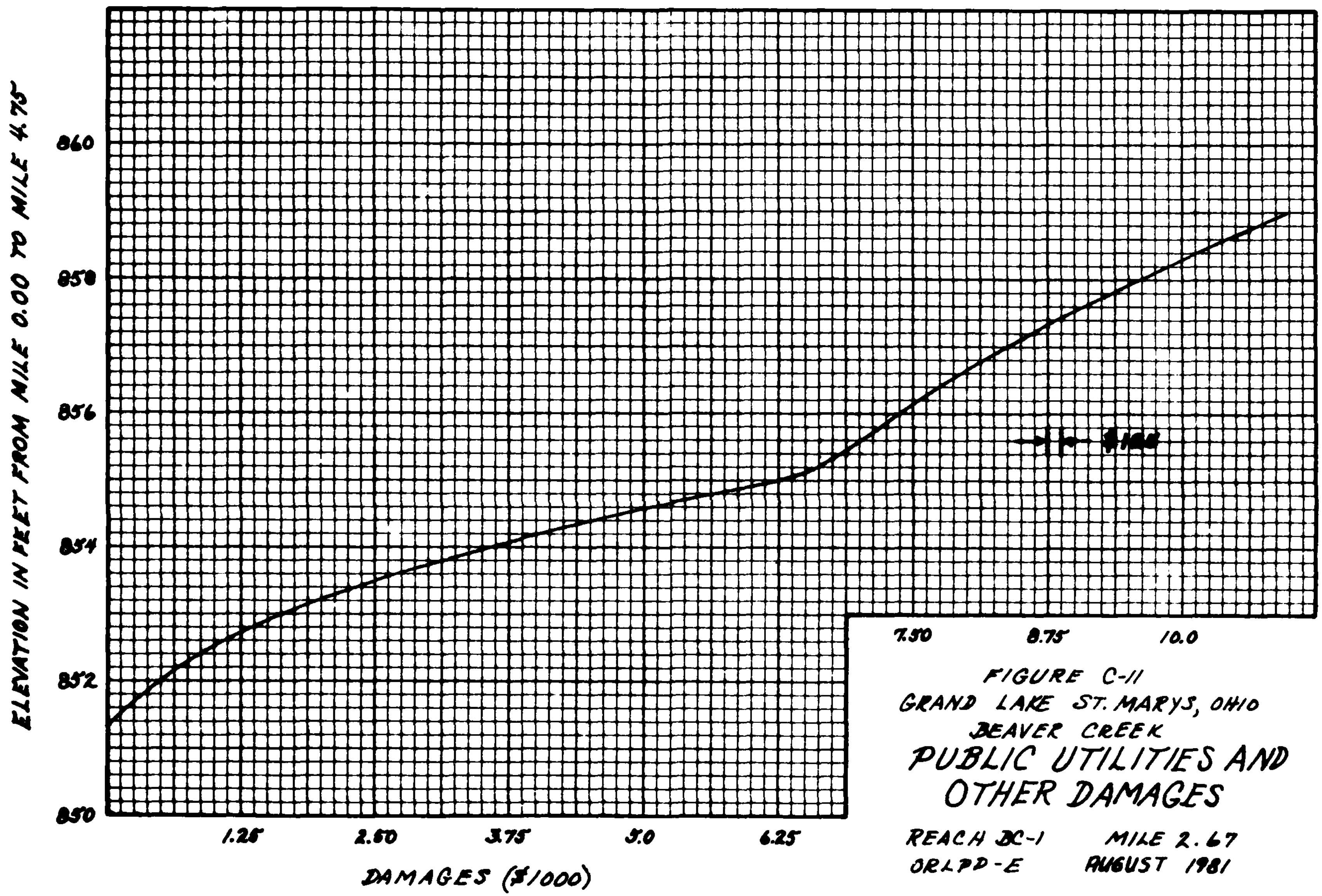

FIGURE C-11
GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK
PUBLIC UTILITIES AND
OTHER DAMAGES

REACH BC-1 MILE 2.67
ORLPD-E AUGUST 1981

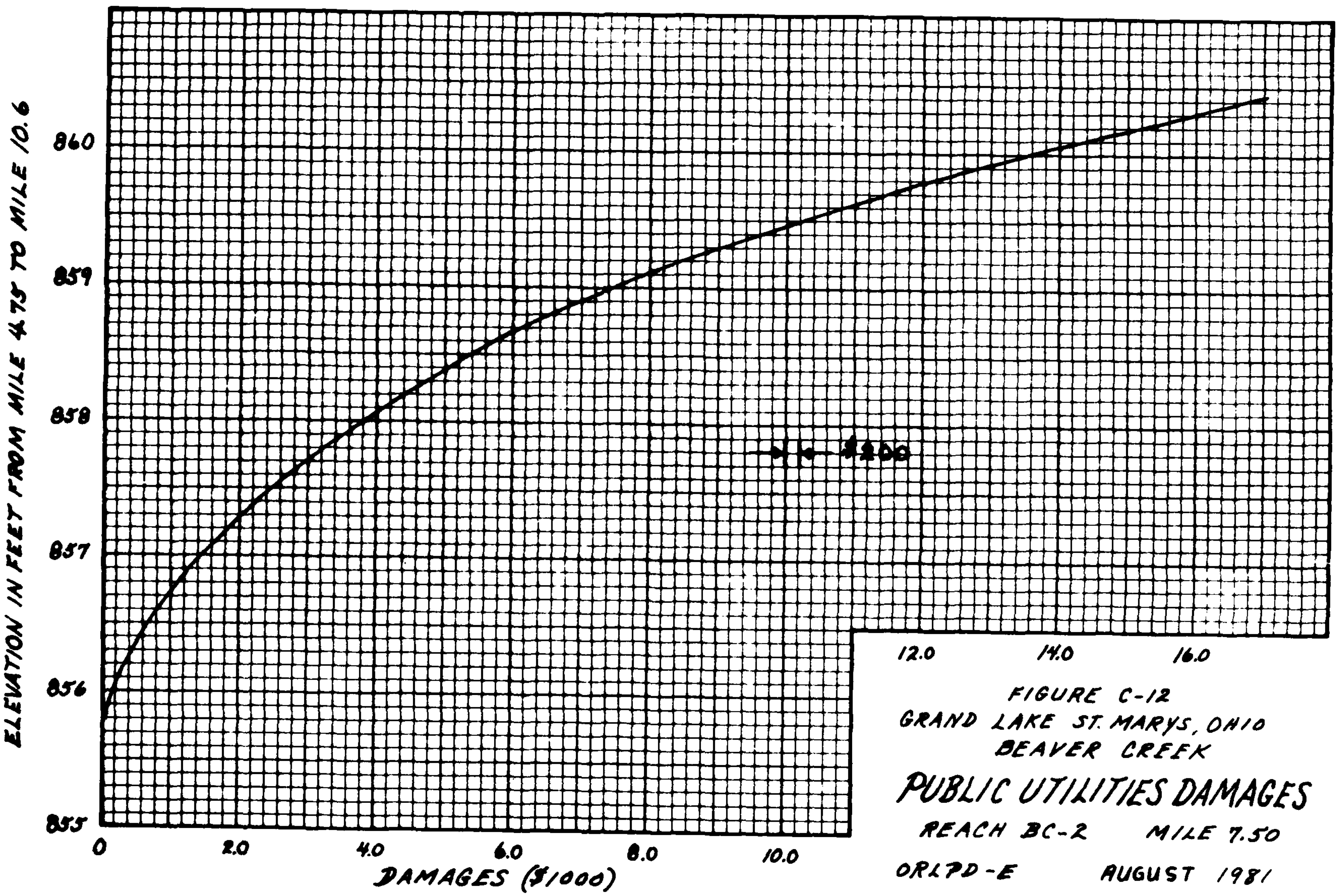

FIGURE C-12
GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK

PUBLIC UTILITIES DAMAGES

REACH BC-2 MILE 7.50

ORLPD-E AUGUST 1981

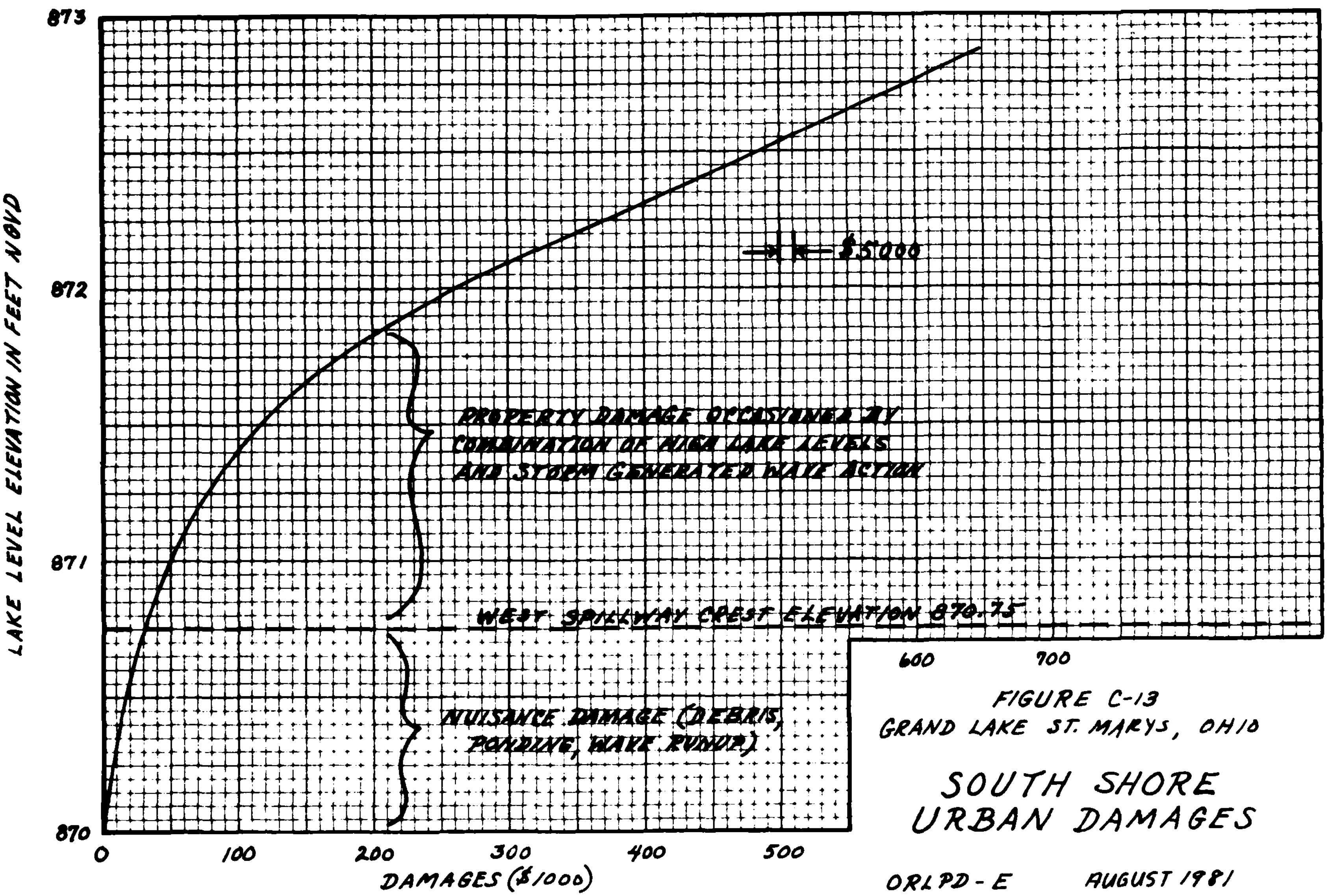

FIGURE C-13
GRAND LAKE ST. MARYS, OHIO

SOUTH SHORE
URBAN DAMAGES

ORLPD-E AUGUST 1981

TABLE C-3

AVERAGE ANNUAL DAMAGES
BEAVER CREEK
(Present 1979 Conditions)

Damage Category	Reach BC-1	Reach BC-2	Damage Totals
Crop	$30,850	$32,350	$63,200
Non-Crop	9,700	3,200	12,900
Transportation Facilities	1,400	1,310	2,710
Public Utilities	3,950	$ 2,240	$ 6,190
Totals	$45,900	$39,100	$85,000

TABLE C-4

DAMAGE FOR OCCURRENCE OF SELECTED FLOOD HEIGHTS
BEAVER CREEK, MERCER COUNTY, OHIO
(1980 Conditions and Price Levels)

Reach	Upper Limits of Reach: Geographic	Upper Limits of Reach: Stream Mile	Item	Damage for Specific Flood Height ($1,000): 5-Year	10-Year	100-Year
BC-1	Gause Road Bridge	4.75	Acres	865	985	1,401
			Crop	12.7	14.4	18.3
			Noncrop	9.9	17.6	21.6
			Transportation Facilities	1.5	2.5	8.1
			Public Utilities	5 5	7.1	9.7
			Subtotal Damages	29.6	41.6	57.7
BC-2	Grand Lake Western Embankment	10.6	Acres	1,250	1,338	1,833
			Crop	18.3	18.9	21.6
			Noncrop	2.4	4.0	10.6
			Transportation Facilities	1.4	3.1	11.9
			Public Utilities	2.3	4.3	15.4
			Subtotal Damages	24.4	30.3	59.5
TOTAL ALL REACHES			Acres	2,115	2,323	3,234
			Crop	30.9	33.2	40.0
			Noncrop	12.3	21.6	32.2
			Transportation Facilities	2.9	5.6	20.0
			Public Utilities	7.8	11.4	25.1
			TOTAL	53.9	71.8	117.3

TABLE C-5

AVERAGE ANNUAL DAMAGES
SOUTH SHORE OF
GRAND LAKE ST. MARYS

Location 1/	Estimated Number of Properties Subject to Damage	Estimated Annual Damages 2/
1	10	$ 10,680
2	31	32,500
3	39	42,610
4	14	14,940
5	6	6,900
6	18	15,750
7	12	15,000
8	7	7,480
9	5	5,340
	142	$150,200

1/ See Plate C-6.
2/ Structure and contents damage.

WATER QUALITY PROBLEMS

Grand Lake St. Marys

Grand Lake St. Marys has a significant water quality problem caused by excessive algal growths. Grand Lake St. Marys is an eutrophic lake in that its rich nutrient content allows for massive algal blooms during certain times of the year. This interferes with one of its beneficial uses which is recreation. The other major beneficial use of the lake, that of a raw water supply for the city of Celina, is adversely affected by the lake water quality because of severe taste and odor problems in both the raw and finished water.

Nitrogen and phosphorus, the nutrients of major concern for algal growth in any water body, enter Grand Lake St. Marys from streamflows and overland runoff. Nutrients already in the lake play an important role in the seasonal algal growth cycles, since these nutrients are recycled when death and biological oxidation release them from their organic bonds.

The algal blooms of Grand Lake St. Marys cause a "pea soup" appearance. When wind-swept to the shoreline, the algae die, producing an unsightly appearance and an unpleasant odor which detrimentally affect recreation. The blue-green algae in the lake are the most obnoxious of all the algae species, since in addition to the above, they also release by-products which are toxic in the higher concentrations. Certain blue-green algal species maintain their dominant position in the lake because they possess gas vacuoles which allow them to remain in the lighted zone of the lake waters. Thus, they get the light needed for their growth, while shading other genera of algae such as the greens and diatoms.

The Grand Lake St. Marys area has been the object of several water quality related studies in the past few years. The lake is used primarily as a recreational facility and is administered by the Ohio

Department of Natural Resources. Its recreational uses include boating, fishing, and body contact water activities such as skiing and swimming. Another important use is as a water supply for the City of Celina.

Water Quality Criteria

The water quality criteria for the lake and its tributaries are found in the Ohio Administrative Code, Regulations 3745-1 through 3745-1-14, which became effective 14 February 1978. The lake is classified as an exceptional warm water habitat, a public water supply, and as bathing waters. Its tributaries are classified as warm water habitats. In general, all waters of the State of Ohio are required to be free of floating oil or debris and substances attributable to discharges that would form sludge deposits, produce disagreeable taste and odor, or exhibit toxic effects on people, animals, or plant life.

Because the lake has three designated uses, no one set of State water quality criteria is exclusively applicable to it. In the case where several sets of criteria exist for the same body of water, the most stringent criteria apply. The most stringent of the criteria applicable to Grand Lake for its three classifications (exceptional warmwater habitat, bathing waters, and public water supply) are identified below. The criteria are presented as: (a) those applicable to both Grand Lake and its tributaries, (b) criteria applicable to Grand Lake alone, and (c) criteria applicable to tributary streams only.

a. Water quality criteria that are not to be exceeded for Grand Lake St. Marys and its tributaries - these criteria apply to all waters of all classifications within the Grand Lake watershed.

Beryllium	- 1,100 mg/l
Chlorine (total residue)	- 0.002 mg/l
Cyanide	- 0.025 mg/l
Lead	- 0.03 mg/l
MBAS	- 0.500 mg/l
Oil and grease	- none
Pesticides	- see Table C-6
pH	- 6.5 - 9.0

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a. Water quality criteria that are not to be exceeded for Grand Lake St. Marys and its tributaries - these criteria apply to all waters of all classifications within the Grand Lake watershed.

Beryllium	- 1,100 mg/1
Chlorine (total residue)	- 0.002 mg/1
Cyanide	- 0.025 mg/1
Lead	- 0.03 mg/1
MBAS (Foaming Agents)	- 0.500 mg/1
Oil and grease	- none
Pesticides	- see Table C-6
pH	- 6.5 - 9.0

Ammonia	- 6.5 mg/1
Arsenic	- 0.05 mg/1
Barium	- 1.0 mg/1
Cadmium	- 0.0012 mg/1
Chloride	- 250 mg/1
Chromium	- 0.05 mg/1
Copper	- 0.005 mg/1
Cyanide (amenable to chlorination)	- 0.005 mg/1
Dissolved oxygen	- 6 mg/1
Dissolved solids	- may exceed one but not both of the following: (a) 750 mg/1 (b) 150 mg/1 attributable to human activities
Fecal coliform	- geometric mean shall not exceed 200 per 100 ml
Fluoride	- 1.8 mg/1
Iron	- 0.3 mg/1
Mercury	- 0.002 mg/1
Nickel	- 0.025 mg/1
Nitrates	- 10.0 mg/1
Phenolic compounds	- 0.001 mg/1
Polychlorinated biphenyls	- none
Silver	- 0.01 x 96 hour LC_{50} of any representative aquatic species
Sulfates	- 250. mg/1
Temperature	- at no time shall the water temperature exceed the temperature which would occur if there were no temperature change attributable to man's activities
Zinc	- 0.03 mg/1

c. Additional water quality criteria applicable to the tributaries to Grand Lake St. Marys -

Ammonia	- 13 mg/1
Cadmium	- 0.012 mg/1
Chromium	- 0.100 mg/1
Copper	- 0.145 mg/1
Dissolved oxygen	- 4.0 mg/1
Dissolved solids	- may exceed one but not both of the following: (a) 1500 mg/1 (b) 150 mg/1 attributable to human activities

Iron	- 1.0 mg/l
Mercury	- 0.002 mg/l
Nickel	- 0.01 x 96 hour LC_{50} of any representative aquatic species
Phenolic compounds	- 0.01 mg/l
Polychlorinated biphenyls	- 0.00001 mg/l
Temperature	- 82° F. (27.8° C.)
Zinc	- 0.365 mg/l

Existing Water Quality

The water quality of Grand Lake St. Marys has been most thoroughly examined in connection with its eutrophication problems. The lake experiences massive algal blooms several times each year, and taste, odor, and fish-tainting problems with the water have been reported frequently. In the National Eutrophication Survey[(1)] report on Grand Lake St. Marys, algal productivity was found to be phosphorus-limited during the spring and summer and nitrogen-limited in the fall. The estimated phosphorus loading of the lake (0.49 $g/m^2/yr$) was 1.8 times greater than the eutrophic loading limit of 0.28 $g/m^2/yr$ proposed by Vollenweider and Dillon, 1974 in (1). Nutrient samples taken in 1973-1974 from each of the six main tributaries (Table C-7) were used in conjunction with estimates of nutrient loadings from small tributaries and direct drainage areas to produce a nutrient "budget" for the lake. According to this survey, 92 percent of the nutrient loading to the lake is from non-point sources, and 8 percent is due to point sources (sewage treatment plant effluents) as listed in Table C-8. The non-point nutrient export rates for each of the drainage area are shown in Table C-9.

TABLE C-6

PERMISSIBLE CONCENTRATIONS OF PESTICIDES
FOR VARIOUS WATER QUALITY CLASSIFICATIONS

Pesticide	Public Water Supply (μg/l)	Warmwater Habitat (μg/l)
Aldrin 1/	1.0	0.01
Benzene hexachloride		0.1
Chlordane	3.0	0.01
Chlorophenoxy herbicides		
2,4-D 1/	100.0	
2,4,5,-TP (Silvex) 1/	10.0	
Ciodrin		0.1
Coumaphos		0.001
Dalapon		110.0
DDT 1/	50.0	0.001
Demeton		0.1
Diazinon		0.009
Dicamba		200.0
Dichlorvos		0.001
Dieldrin[a]	1.0	0.005
Diquat		0.5
Dursban		0.001
Endosulfan		0.003
Endrin	0.2	0.002
Guthion		0.005
Heptachlor 1/	0.1	0.001
Heptachlor expoxide	0.1	
Lindane	4.0	0.01
Malathion		0.1
Methoxychlor	100.0	0.005
Mirex		0.001
Naled		0.004
Parathion		0.008
Phosphamidon		0.03
Simazine		10.0
TEPP		0.4
Toxaphene	5.0	0.005

1/ Banned

TABLE C-7

AVERAGE NUTRIENT CONCENTRATIONS (mg/L) IN THE TRIBUTARIES TO AND DISCHARGES FROM GRAND LAKE, 1973-1974

Station	NH_3-N			NO_2-N			NO_3-N			Total Kjeldahl N			Total N			Total Phos			Ortho-Phos.		
	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min
Prairie Creek (Montezuma)	0.89	9.6	0.48	0.08	0.22	0.00	3.07	6.35	0.01	1.54	3.70	0.80	3.15	6.45	0.01	0.43	1.05	0.20	0.36	1.47	0.02
Little Chickasaw Creek (New Bremen)	0.13	0.44	0.04	.047	0.16	0.00	3.00	5.80	0.10	1.41	3.90	0.70	3.06	6.00	0.01	0.22	1.05	0.05	0.90	0.40	0.19
Chickasaw Creek (New Bremen)	0.21	0.69	0.02	0.04	0.97	0.00	2.20	3.90	0.02	1.64	9.10	0.07	2.25	3.96	0.02	0.31	1.33	0.12	0.15	0.46	0.02
Barnes Creek (St. Marys)	0.09	0.32	0.01	0.04	0.09	0.00	2.84	6.70	0.01	1.63	3.57	0.60	2.87	6.70	0.01	0.23	0.70	0.11	0.07	0.35	0.01
Miami Erie Canal (St. Marys)	0.05	0.14	0.01							1.84	2.6	0.90	0.41	1.50	0.01	0.15	0.28	0.09	0.03	0.08	0.01
Beaver Creek (Celina)	0.16	0.52	0.02							2.00	3.0	0.80	0.56	0.86	0.01	0.19	0.38	0.08	0.03	0.05	0.01
Beaver Creek (Montezuma)	0.20	0.70	0.04							1.50	5.1	0.35	2.41	5.50	0.01	0.28	1.45	0.07	0.13	0.22	0.05
Coldwater Creek (Celina)	0.26	0.65	0.04							1.81	4.60	0.80	2.61	6.70	0.07	0.57	1.6	0.21	0.36	1.44	0.04

SOURCE: USEPA. 1975. (1)

TABLE C-8

ANNUAL TOTAL PHOSPHORUS LOADING - AVERAGE YEAR

Source	Loading (kg/yr)	Percent of Total
Inputs		
Tributaries (non-point load)		
Little Chickasaw Creek	825	3.8
Chickasaw Creek	3,450	15.9
Beaver Creek	2,960	13.7
Coldwater Creek	6,430	29.7
Barnes Creek	635	2.9
Prairie Creek	1,785	8.5
Minor tributaries including Monroe Creek, Grassy Creek, several unnamed creeks, and immediate drainage	3,085	14.2
Known municipal STP's		
St. Henry	1,445	6.7
Septic tanks1/	275	1.3
Known industrial - Avco New Idea	?	?
Direct precipitation2/	780	3.6
Total	21,670	100.0
Outputs		
Lake outlet - Beaver Creek	9,695	
Lake outlet - Miami and Erie Canal	5,325	
	15,020	
Total		
Net annual P accumulation	6,650 kg	

1/ Estimate based on 500 permanent and 169 seasonal shoreline dwellings and one state park; see Working Paper No. 175.

2/ See Working Paper No. 175.

Source: (1)

TABLE C-9

MEAN ANNUAL NON-POINT NUTRIENT EXPORT
BY SUBDRAINAGE AREA

Tributary	Phosphorus ($kg/km^2/yr$)	Nitrogen ($kg/km^2/yr$)
Little Chickasaw Creek	45	1,502
Chickasaw Creek	72	1,281
Beaver Creek	56	1,305
Coldwater Creek	129	1,340
Barnes Creek	68	1,537
Prairie Creek	131	1,656
Minor Tributaries including Monroe Creek, Grassy Creek, Several Unnamed Creeks, and Immediate Drainage	57	1,520

Source: (1)

Of the total annual non-point phosphorus (19,950 Kg), Chickasaw Creek contributed 15.9 percent; Beaver Creek, 13.7 percent; Coldwater Creek, 29.7 percent; Prairie Creek, 8.2 percent; Little Chickasaw Creek, 3.8 percent; Barnes Creek, 2.9 percent; and unsampled tributaries, 14.2 percent. The report postulated, however, that because the export rates for Coldwater and Prairie Creeks were much higher than for the others, there may have been point source loadings that were not accounted for in the survey.

In addition to the USEPA study, the Mercer-Auglaize Environmental Research Association monitored water quality in the Grand Lake St. Marys area from 1973 to 1975 at locations shown in Plate C-7. A summary of this data is presented in Table C-10. In general, the data support the high nutrient loadings found during the USEPA study, but it also indicates significant bacterial pollution of the lake. The average fecal coliform concentrations from 1972 to 1975 exceeded the state water quality criteria for bathing waters (200 coliform/100 ml) at all 10 sites sampled. The bacterial contamination of the lake has been attributed to the Mercer Wildlife Refuge on Montezuma Bay. Considering the large number of persons that visit the lake annually and the extensive use of septic tanks in many unsuitable areas along the south shore, it is probable that a large part of the lake's microbiological contamination is due to human waste.[2] Contamination from boat waste is also suspected although the extent is unknown.

Severe taste and odor problems have been reported with the water of Grand Lake St. Marys. People living around the lake complain of a musty odor in the air at times, and the City of Celina experiences taste and odor problems both with the raw water it withdraws from the lake for its public water supply and with finished water. A threshold odor level of 3-4 is detectable to the customer and the city has experienced threshold odor levels as high as 17 in its finished water (by interview, Lowell

TABLE C-10

GRAND LAKE WATER QUALITY, 1972-1975 AVERAGES

Test Site	Temp. °C	pH	Turbidity Formazin Units	D.O. mg/1	BOD mg/1	Phos.-ORTHO ppm-PO_4	Phos.-TOTAL ppm PO_4	NO_3-N ppm	NH_3 ppm	Fecal Coliform # 100 ml
#1	17.3	7.36	19.2	8.34	10.2	0.223	0.540	7.24	0.91	747
#2	16.8	7.38	31.1	7.80	9.9	0.350	0.546	11.43	0.97	1870+
#3	16.3	7.39	32.3	7.93	9.1	0.258	0.665	10.93	1.05	1795+
#4	17.0	7.44	31.6	8.04	9.0	0.171	0.745	10.07	0.91	2078+
#5	17.4	7.52	36.3	7.54	10.1	0.286	1.145	10.00	1.15	1877+
#6	17.4	7.68	39.4	9.29	9.2	0.193	0.975	7.58	1.05	2483+
#7	18.3	7.62	30.7	9.06	9.6	0.180	0.884	8.38	1.01	2009+
#8	17.6	7.68	27.3	9.00	10.8	0.144	0.552	7.21	1.21	3231+
#9	18.0	7.74	15.8	9.41	8.9	0.160	0.425	6.64	0.82	278
#10	16.9	7.47	37.7	7.52	9.7	0.124	0.731	9.92	1.02	1791+

SOURCE: (2)

Dock of the City of Celina, 8 May 1979). These threshold values indicate that a definite odor problem exists. The threshold odor number is the dilution ratio at which odor is just detectable. A threshold number is not a precise value. In the case of a single observer, it represents a judgment at the time of testing. Panel results are more meaningful because individual differences have less influence on the result.

The State has no specific water quality standard for taste and odor, but general water quality criteria recommend that public water supplies be free from objectionable odor for aesthetic reasons.(3) Odor-producing substances found in raw water supplies include organic compounds produced by microorganisms as well as tainting substances from human and industrial wastes.(3) Phenolic compounds are typically associated with taste and odor problems, and other hydrocarbons in waste and oils are suspected as well. Odorous compounds of biological origin known to taint water supplies were found in Grand Lake during a study of its odor problems.(4) These compounds included geosmin and 2-methylisoborneol, which are produced by certain strains of actinomycetes. Although geosmin is characteristically associated with the musty odor of heavy algae blooms in reservoirs (NAS, 1972), data indicated that 2-methylisoborneol constituted 68 percent of the odor from Grand Lake and 75 percent of the odor from nearby Indian Lake, Ohio.(4) In 1964, a taste and odor study of Celina's water supply (Grand Lake) was conducted by Finkbeiner, Pettis & Strout, Ltd. The study indicated that algae, either directly or indirectly, were responsible for the majority of the taste and odor problems. The study also indicated that by applying copper sulfate to the water the quality could be improved to a point where conventional treatment processes could produce palatable water.

The municipal water supply of the City of Celina is drawn from the northwest corner of Grand Lake in conjunction with the municipal power plant intake. While the water supply is more than ample in quantity to satisfy needs, the quality of the finished water has generally deteriorated in regard to flavors, tastes and odors. Previous reports conducted in the early 60's identified many different taste and odor algae, three of which were found in abundant numbers in the raw water from Grand Lake. It is suspected that high phosphorus levels in the lake provide a food source for higher forms of aquatic life such as algae which have been blamed, at least in part, for the taste and odor problems that currently plague the lake resource. Past studies indicate that: (1) algae are the prime source of Celina's taste and odor problem; (2) chemical costs for treatment of the raw lake water are high as compared to other cities and will continue to rise; (3) the limited quantity and objectionable mineral content of Celina's available well water is such that using groundwater as a supplemental source is not practical; and (4) the daily per capita water consumption is increasing at an increasing rate.

Recent reviews of previous reports indicate that most of the extended future predictions have been realized. The cost of chemical treatment has risen sharply, the gallons per capita is over 100 gpd, and the finished water still has taste and odor problems even though many alternative treatment techniques have been applied. The cost and technical feasibility of removing tastes and odors, sometime without great success, is a major reason for improving the raw water quality.

The primary water pollution problem in the Grand Lake St. Marys study area is the eutrophication of the lake as described above. The main water quality problems are associated with nuisance algae blooms and inadequate sewage treatment. Taste and odor problems in the Lake have been linked to the algae blooms, which also interfere with recreation and water supply uses. Other information indicates significant bacterial pollution of the lake. Presently, the lake receives effluent discharges from 22 small wastewater treatment plants as well as runoff from surrounding agricultural areas.[2] These small plants discharge high biochemical oxygen-demanding pollutants, suspended solids, as well as nutrients, but the phosphorus from all of the point sources combined amounts to only 8 percent of the total phosphorus load to the lake.(1) It was concluded in the USEPA study of Grand Lake that even complete removal of phosphorus from the point source discharges would not reduce the lake loading to a subeutrophic level because non-point sources contribute 92 percent of the phosphorus load to Grand Lake, most of which is from agricultural runoff.

Bacterial pollution of Grand Lake has been reported by two sources. Samples taken by the Mercer-Auglaize Environmental Research Association show numerous instances of fecal coliform contamination on the south side of the Lake. A Master's thesis by James P. Loughran (1973) entitled, "The Analysis of Tributary Outfalls as Possible Sources of Micro-biological Contamination of Grand Lake-St. Marys" concluded that the bacterial pollution of the lake was severe enough to warrant action discouraging its use for primary body contact recreation. Data presented in this thesis indicated that bacterial contamination of the lake was from both human and animal sources, although the relative magnitude of each of these sources was not identified.(2) A possible source of animal waste contamination of the lake was identified as the Mercer County Waterfowl Refuge on Montezuma Bay, but no attempt was made to determine the magnitude of this source.

Sources of Nutrients

Phosphorus input sources have been reassessed in this study and categorized as either "point" or "non-point" sources for purposes of estimating annual phosphorus loadings to the lake.

Point Sources. Point sources are those which discharge effluent at known locations and include one municipal sewage treatment plant (St. Henry) and 17 small pre-manufactured (package) treatment plants surrounding the lake, each of which discharge effluent with varying degrees of treatment directly or indirectly to the lake.

Non-point Sources. Non-point sources include phosphorus from such diverse sources as precipitation, agricultural and livestock areas, waterfowl, septic-tank-soil absorption systems, and direct urban and suburban runoff.

Phosphorus contained in rainwater falling directly on the lakesurface is generally uncontrollable and the ability of algae to utilize the phosphorus is still in question with researchers. Cropland and animal concentration areas (feedlots) both contribute nutrients and sediment through runoff and erosion. The high concentration and number of waterfowl at Grand Lake St. Marys has been suspected of contributing phosphorus and bacterial contamination of the lake. Although the concentration of septic tank-soil absorption systems around the lake is generally known, they are considerd non-point sources because pollution from them seeps into the lake over a dispersed area. Urban and suburban runoff contributes pollutants after rainfall events from residential areas and streets. Finally, erosion of watershed lands, streambanks, and shoreline contribute sediments which cause turbidity and phosphorus-bound particulate matter which causes the proliferation of algae throughout the lake.

It is estimated that approximately 33,000 kilograms of total phosphorus are currently contributed to the lake on an annual basis. The estimated phosphorus loading rate is greater than the commonly accepted loading limit. This means that Grand Lake St. Marys can be considered eutrophic. The excess nutrient concentration results in increased biological activity and culminates in nuisance algal growths, reduced dissolved oxygen content at times, and noxious tastes and odors.

Of the total phosphorus loading, it is estimated that on the average, approximately 15,000 kilograms are removed from the lake annually via Beaver Creek and the St. Marys Feeder Canal. At the current estimated rate of phosphorus input and output, approximately 18,000 kilograms of total phosphorus accumulates annually in the lake.

Several sources of phosphorus which were thought to be significant, specifically septic tank systems and waterfowl, are contributing only small quantities of phosphorus to the lake.

The estimated percentage contributed by each source is identified in Table C-11. The most significant contribution of phosphorus to the lake appears to be from non-point sources or rural, primarily agricultural land. **Phosphorus load calculations are shown in Attachment 3 to Section C.**

TABLE C-11

ESTIMATED ANNUAL
TOTAL PHOSPHORUS LOAD FROM SPECIFIC SOURCES
GRAND LAKE ST. MARYS

Source	Annual P Load Kilograms	Percentage of Total
Precipitation	780	2.3
Waterfowl (geese)	216	.6
Animal Concentration Areas (Feedlots)	7,500	22.6
Agricultural/Rural Land	21,000	62.9
Municipal Point Sources (St. Henrys)	1,449	4.3
Domestic Point Sources (small plants)	746	2.2
Septic Tank-Soil Absorption Systems	610	1.8
Direct Urban and Suburban Runoff	1,088	3.3
Totals	33,389	100.0

Beaver Creek

Other than in Grand Lake, the major water pollution problem in the study area involves Beaver Creek. During dry periods, the flows in the upper reaches of Beaver Creek essentially cease[2], and the only flow in Beaver Creek is the effluent from the Celina wastewater treatment plant.[5] This has resulted in serious water quality problems in the creek, including high levels of suspended solids and nutrient concentrations and low dissolved oxygen. Plans are presently being prepared for improvements to Celina's wastewater treatment plant that will alleviate this problem.

General Recreation Needs

The State of Ohio Comprehensive Outdoor Recreation Plan indicates significant deficiencies in realizing the recreational potential for boating, camping, canoeing, sailing, swimming, and picnicking in the Mercer and Auglaize County area. The plan, for example, states that the study area "has not developed its full potential because of (1) lake siltation and pollution problems, (2) lack of adequate lands to balance water area, and (3) unconsolidated land ownership surrounding the lake."

Table C-12 compares visitation at other lake facilities in a 60-mile radius region. A determination of average lake visitation to surface acres from this table shows the following:

Grand Lake	129 visitors/acre
Lake Loramie	457 visitors/acre
Indian Lake	221 visitors/acre
Huntington Lake	332 visitors/acre

TABLE C-12

REGIONAL LAKE VISITATION
(1,000's of Visitor Days)

Facility	Surface Acres	1970	1971	1972	1973	1974	1975	1976
Grand Lake	13,500	1,711.8	1,636.2	2,106.1	2,448.5	1,725.2	1,656.8	1,489.9
Lake Loramie	1,500	900.0	942.7	788.2	581.5	503.7	466.1	529.6
Indian Lake	5,800	1,698.0	1,989.3	1,566.6	926.8	1,062.5	1,255.1	531.7
Huntington Lake 1/	900	-	366.9	266.2	244.7	226.8	313.1	375.4

1/ Huntington Lake is outside the 60-mile region. It is used for comparison because of its regional significance.

The comparison of visitor numbers generally indicates that Grand Lake is underutilized. The reasons for this are many and varied since several water-related problems exist at the lake. These include extreme shallowness, siltation, submerged tree trunks and stickups which interfere with boating, water pollution, water odors, and wind and wave problems. In addition, lake freezing in winter combined with level fluctuations cause damage to launch ramps as well as to marinas and docks. All the above cited problems, when considered alone, create difficulties with existing and potential recreation; however, when considered simultaneously, the overall effect of these problems are massive. A smaller than usual amount of boating occurs for such a volume of water and this is attributed to problems associated with the lake.

Using approved forecasting methods, it was determined that, were the lake free of its problems (shallowness, pollution, wind and wave action, tree stumps, etc.), the 1980 visitation would approach 2,750,000 visitor days; the 2000 visitation would be 3,000,000, and the 2020 visitation would be 3,600,000. This anticipated attendance, however, would require additional recreation facilities (camp sites, picnic sites, boat ramps, etc.) and additional lands. It might also pose stress to the presently good fishery and existing waterfowl values.

Fish and Wildlife Needs

During the early years, the lake was used as a successful commercial fishery. Between 1890 and 1900, several droughts lowered the lake level considerably. Heavy fish kills occurred, stumps and snags were removed, and aquatic vegetation disappeared. Carp and white crappie became numerous. The lake changed from a clear body of water to a turbid lake. Fish population changed to less desirable species (from bass, bluegill, sunfish, perch, and bullhead to predominantly crappies, bullhead, channel catfish, and carp). Since the time the lake was turned over for recreational purposes, in the 1930's, many attempts have been made to improve fishing habitat, and in recent years fishing has improved greatly and has a good population of largemouth bass, gills, black and white crappie, channel catfish, bullhead, yellow perch, and occasionally northern pike and striped bass. Fishing is considered excellent the year round. However, fluctuating lake waters may affect fish habitats along the shoreline and areas set aside for this purpose. Low water in the winter has an adverse effect on the large gamefish. Low water in the spring also effectively eliminates some traditional fish spawning areas. A rigorous stocking program is required and followed by the State of Ohio to insure that adequate populations of the various species are maintained.

The State of Ohio maintains the 1,400-acre Mercer County Waterfowl Management Area in the southwest corner of the lake. This is a nesting refuge for Canadian geese, wood ducks, mallards, blackducks and teal. In addition, other wildlife forms exist in medium density within the planning area such as cottontail rabbit, fox squirrel, white-tailed deer, ruffed grouse, muskrat, and many others.

Lake problems such as widely fluctuating water levels may cause disruption of fish and wildlife habitats and wetlands. These fish and wildlife resources must be protected, if not enhanced.

The present fishery at Grand Lake provides fishing opportunity for many anglers, but apparently does not compare to the fishery which existed prior to 1900. The inevitable comparison between the fishing then and now and the question of whether or how the lake could be returned to its previous condition has been discussed for several years. Water quality has probably had a role in limiting the fishery.

EROSION AND SEDIMENTATION PROBLEMS

Erosion

Organizations representing lake users and lake-derived commerce have been persistent in citing the gradual steady erosion of the lake as the major concern. Erosion has been identified in six categories of concern to lake users: farm drainage erosion, streambank erosion, channel erosion, lake shoreline erosion, island erosion, and dredge spoil erosion.

Farm Drainage Erosion

Farm drainage erosion includes displacement and washoff of agricultural soils and farm chemicals dissolved in the runoff. Normally, soil erosion creates economic and environmental problems because fertile soil components are depleted or massive areas of topsoil and subsoil are lost when gullying takes place, and because of the effects of suspended and dissolved solids on water quality and of sedimentation on water column and bottom-dwelling flora and fauna. In this case, much of the erosion within the general study area creates further complications as a potential cause of sedimentation and shallowing of Grand Lake, with attendant effects on lake circulation, aeration, water quality concentrations, and navigation. In addition, bare soils produce rapid runoff, accelerated flooding, and scour erosion of the channels of receiving streams and the lake. Erosion of cultivated soil has been taking place since the native forests of the area were extensively stripped in the late 1800's and early 1900's for farming. Erosion of the soils in the lake's drainage area consists of slight to moderate sheet erosion. Nearly all waters observed entering the lake have considerable amounts of suspended silt.

Streambank Erosion

Streambank erosion occurs in the study area although the erosion is considered moderate. Soils notable for erosion problems - Blount and Glynwood (or Morley) - occur throughout the drainage areas feeding into Grand Lake from the south and southwest. These streams include Coldwater, Burntwood, and Chickasaw Creeks and several streams entering along the south shore. Coldwater Creek banks have developed serious erosion problems due to runoff scour, increasing sediment load delivered to Grand Lake. Beaver Creek is also affected by stream channel and bank erosion.

Channel Erosion

Channel erosion problems result from a combination of factors and affects boat channels, boat basins, and natural inlets which are subject to severe bank undercutting from natural flows and boat wash. The shallow depth makes channel banks susceptible to wave scour. Rapid surface runoff erodes and silts in natural inlets. Prop wash and boat wakes, not a problem during the first 100 years of lake processes, have become a major and growing factor with conversion of lake use to recreational boating. Lack of coarse gravels and rocks or bottom vegetation contributes to the erodibility of channels and other bottom features. Periodic dredging of these channels are required to allow boater access to open water.

Lake Shoreline Erosion

Lake shoreline erosion is caused by a number of factors, including wind-driven waves, boat wake attack, high water, winter ice, and, along the north shore and east and west ends of the lake, lack of onshore or along-shore sediment sources for shore building and the absence of natural-type wave action for beach replenishment. In the latter areas, revetments, walls, and riprap have been constructed over an estimated 80 percent of the shoreline to protect the backshore from erosion. The condition and effectiveness of these protective measures is a matter of concern. Many miles of shoreline have been protected with rock riprap or concrete walls, but unusual wave and ice action tear loose the installations or break over and cut behind them. In addition, many areas, both public and private, are unprotected.

Along the south shore, a trend toward marsh formation and shoreline encroachment into the lake continued into the 1940's and 1950's. Habitat improvement projects in the 1940's were carried out by the Ohio Department of Public Works and included clear-cutting of coves into the cattail vegetation mass. Whether these or other forces were the cause is not known, but recent reconnaissance of the south shore indicates that shoreline erosion is now prevalent in many locations there.

Islands

Islands are especially susceptible to ice and wind erosion because of their small size and exposure from any side. During extremely high water several years ago, Safety Island lost large areas of shoreline above the riprap protection. According to the Lake Development Corporation (1977), "two islands created by dredging and not riprapped have lost one-fourth of their original size to erosion."

Dredge Spoil Material

Dredge spoil material placed in unprotected rows and left unprotected erodes quickly back into channels and into other parts of the lake. Contained dredge spoil areas for dredging is warranted in a water body subject to high wind and wave activity. Currently, dredge spoils are being deposited in unprotected disposal areas along portions of the exteme east and west ends of the lake. Dredged rows are suspected of contributing sediment back into the lake and channels where turbidity is increased for long periods of time.

Sedimentation

The patterns, extent, sources, and distribution of sediment in Grand Lake are not well documented and there are conflicting viewpoints in the absence of good data. On the one hand, although historical mapping of the lake does not exist, it is considered that the lake, because of its location on a major drainage divide, has always been extremely shallow. It has been generally assumed that tremendous silt loads are carried into the lake by tributary streams from the 93 square mile contributing watershed. The State of Ohio operates a continuous dredging program at the lake to keep access channels open for boat traffic, and the operation suggests that the lake receives a high sediment load from its drainage area. The turbid nature of the lake also would seem to confirm this conclusion. This contributing watershed is predominantly agricultural, with an average of 67 percent under cultivation.

The only sedimentation survey on Grand Lake was made in 1948. The survey estimated that in the 96 years of operation between 1844 and 1940, approximately 23,570 acre-feet of sediment, representing approximately 18.1 percent or 0.2 percent annually, of the storage capacity was deposited. The sedimentation rate from that survey of 2.64 acre-feet/square mile/year corresponds to about 3,200 tons/square mile/year or 5 tons per acre per year. For comparison purposes this very high production rate is almost 2.5 times the average of lakes measured in the Great Lakes and Maumee River Basins.

Unofficial reports indicated that sediment deposits were heaviest along the north and south offshore areas, but that sediments were virtually absent in the central part of the lake, in the area of former oil derricks. According to the only controlled sedimentation survey on record for Grand Lake (Brune, 1948)[6], the greatest depth of sediment (7.2 feet) was found in the northwest corner near the Beaver Creek outlet, and the greatest average depths of 2.7 and 2.3 feet, respectively, were found at the extreme west and east ends. This information may reflect a general absence of currents in the lake except in the immediate vicinity of the outlets, especially during flood stages. If sediment accumulations are otherwise concentrated along the north and south shores, as has been reported, this may indicate the priority of downslope surface creep, or gravity flow, in transporting of heavier constituents, while clay and silt may be kept in suspension for some time by the water turbulence that is characteristic throughout much of the year.

On the other hand, there are other factors which suggest that the lake does not receive a high sediment input from its basin as previously thought. A recent reconnaissance survey of the basin indicates that relief is almost non-existent, stream gradients are extremely low, and there is no visible evidence of "excessive" erosion. The lake is located in an area designated by the U.S.G.S. as "moderately low" in sediment yield (100 to 200 tons/square mile/year) as compared to the reported 3,200 tons/square mile/year in the 1948 survey report. The soils of the basin are mostly clays and silts and are not particularly susceptible to high erosion. The results of the original survey, therefore, appear to be unrealistic and are not yet consistent with known characteristics of the basin. The fact that the 1940's survey was used in conjunction with information collected in 1844 makes the results even more questionable.

The great reduction in storage capacity estimated in the 40's was probably the result of encroaching marshes more than sediment input from the basin. The ODNR report, "Lake St. Marys and Its Management,"(7) indicates that "the accumulation of years of partially decomposed plants and silt and debris soon fill in the shallow areas of the lake." The report also notes that the cattail marsh may have advanced as much as 20 to 50 feet in one year. The sedimentation report describes heavy organic deposits of three or four feet in thickness in the marshy areas of the lake. Thus it appears that most of the material measured by the survey was due to formation of marshes or to erosion of the shoreline rather than input from the drainage basin.

Sedimentation does not appear to be seriously depleting lake storage. The main problem is that the material accumulates in places where it is especially noticeable and troublesome.

There are numerous access channels entering the lake and its tributaries, mostly on the south shore. These channels serve many private homes, rental cottages, and recreation and camping areas, providing easy access to the main lake by boat. Deposition near the mouths of these channels and tributaries is the main reason for the state dredging program.

Dredged material is disposed of on land and at sites within the lake itself. The in-lake sites are located along the shoreline, where the material is used to build additional recreation lands.

The sediment removed by the dredging is mostly silt and clay. It apparently deposits at the mouths of the channels because of the slack water there. Material carried in by streamflow on the one hand and by wave wash on the other would all tend to be deposited there.

The source of the deposited material appears to be the main question. If the main source is material eroded by wave action, then additional bank protection measures would be helpful in reducing the problem. If the main source is inflow from the drainage basin, then soil conservation practices would be more beneficial. It is almost certain that wind and wave action distribute the silt loads over the lake since the shallowness of the lake permits the entire area to be stirred up from top to bottom. Evidence exists that the lake bottom is in a continuous flux with changes in wind and wave action and results in dispersal of sediment. Numerous areas that were once deep are now only 2 to 3 feet deep. A 25-foot channel dredged several years ago in a north-south direction on the east side of the lake has completely filled in.

The most important statistic, however, for net sedimentation in Grand Lake is the estimated 99 percent trap efficiency of the reservoir. Trap efficiency is a measure of the ability of a basin to catch and hold the sediment load of the inflowing water. The small contributing drainage area and large surface area of Grand Lake make it a nearly ideal sedimentation basin. Any plans to improve the conditions in Grand Lake cannot be considered completely reliable or quantifiable until more current sedimentation data are available.

The material which causes the deposition problems also contribute to the turbid condition of the lake. While the warmwater habitat standards do not have a criterion for turbidity or suspended solids, particulates in large concentration do limit the quality of an aquatic habitat. Persons familiar with Grand Lake have generally described the water as turbid or "muddy" and the data verifies this; Secchi disc readings for the EPA ranged only between 12 and 20 inches. There is no exact correlation between Secchi inches, turbidity units, percent light transmission, or suspended solids concentrations, so it is difficult to judge the actual effect of suspended solids on the aquatic community. Potentially suspended material can have several effects on the habitat, some of which depend on the materials' light scattering effect and others on the actual bulk or weight of sediment that might settle out or accumulate. The material in suspension in Grand Lake is most likely a clay originating from the soils of the area. As such, it could limit the ability of the water to transmit light without causing an extremely high suspended solids concentration.

The Water Quality Criteria published in 1972 by EPA[8] suggests that turbidity can impact a lake fishery by: (1) acting directly on fish swimming in water in which solids are suspended; (2) preventing the successful development of fish eggs and larvae; (3) modifying natural movements and migrations of fish; (4) reducing the food available to fish; and (5) affecting efficiency in catching the fish.

These effects are important at Grand Lake because the character and quality of its fishery began to deteriorate (at least in the opinion of many) concurrently with the increases in turbidity. The increase in turbidity apparently resulted from the clearing of the lake bed and shore of trees and stumps and the loss of rooted aquatic vegetation in the period 1890-1900. The clearing increased the effect of wind in producing wave action, resulting in bank erosion and constant resuspension of sediment particles.

Turbidity also produces other impacts which would indirectly affect the fishery. Because suspended particles inhibit the penetration of sunlight, water temperatures are increased. Photosynthetic activity is also affected; the populations of algae and fixed aquatic plants have apparently changed drastically at Grand Lake, partly because of higher turbidities.

In an effort to relate sedimentation and lake depths, a hydrographic survey was conducted by the Corps of Engineers in October 1979. Results of the data in the form of depth contours are shown on Plate C-8. The great portion of the lake (80 percent) averages 8 feet in depth while the remaining 20 percent portion is littoral based on the 6-foot depth contour. This suggests that, except for isolated concentration areas within the main body of the lake, most of the sediment accumulations occur at the mouths of tributaries, in bays, and along the littoral zone.

PROBLEM SUMMARY

Water and related land resources problems in the study area are varied, complex, and interrelated. Problems of downstream and lake shore flooding can be expected to continue. Problems with lake water quality, sedimentation and erosion, are expected to continue and in most instances produce negative impacts on the lake resource. Recreation use on the lake could continue to decline if problems of lake depth, water quality, physical obstructions, and wave action, to name a few, are not resolved.

IMPROVEMENTS DESIRED

State and local officials and organizations have from time to time since 1970 expressed, through meetings, correspondence, and minor reporting efforts, their desires for improvements to problems in the areas of flood control, drainage, water quality, erosion and water-related recreation. Local lake interests cite lake water quality problems including adverse odor and taste caused by frequent widespread blue-algae blooms, severe wave action, shallow lake water depths, and erosion as problem areas of primary concern. The State of Ohio, Department of Natural Resources, has indicated that erosion control, pool level control, and nutrient-algae control are the State's primary concerns as related to the lake's primary purpose which is water-related recreation.

Local concerns would like to have the water quality improved and the lake level stabilized to enhance recreation potential and control flooding of portions of the lake perimeter. Downstream farmers along the lake's western outlet channel, Beaver Creek, seek relief from periodic flooding caused by restrictive channel conditions, low stream gradient, inadequate outlets, and releases from the lake.

PLANNING OBJECTIVES

The primary objectives of this survey investigation were to report to Congress an inventory of the publicly identified water and related resources problems and needs in the study area and to investigate a range of feasible alternatives for resolving water-related problems that may be implemented individually or collectively by local, state, and Federal agencies. The general overall objective is to determine what, if any, feasible, economic measures could be undertaken to restore and enhance Grand Lake St. Marys and its environs as a viable water resource.

For the Beaver Creek and lake shore area, specifically, planning objectives were established to provide for problems and needs which were identified. The authorization for this investigation made particular reference to the flood problems at Grand Lake St. Marys. Therefore, flood control for the south side of the lake and for Beaver Creek was established as a primary planning objective.

Review of other study area problems and needs indicated that there was a need to include opportunities for improvement, restoration, or enhancement of overall water quality of the lake as a planning objective as well as erosion control and sedimentation control. All of these objectives are oriented toward enhancing and increasing the potential of water-oriented outdoor recreation opportunities.

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4. Rosen, A.A., C. I. Mashni, and R. S. Safferman. 1970. Recent developments in the chemistry of odor in water: the cause of earthy/musty odor in water treatment and examination. Water Treat. Exam. 19: 106-119.

5. Ohio Department of Natural Resources. 1976. Southwest Ohio Water Plan. 744 p.

6. Brune, G. M. 1948. Rates of Sedimentation Production in Midwestern United States. U. S. Department of Agriculture - Soil Conservation Service. Miscellaneous publication.

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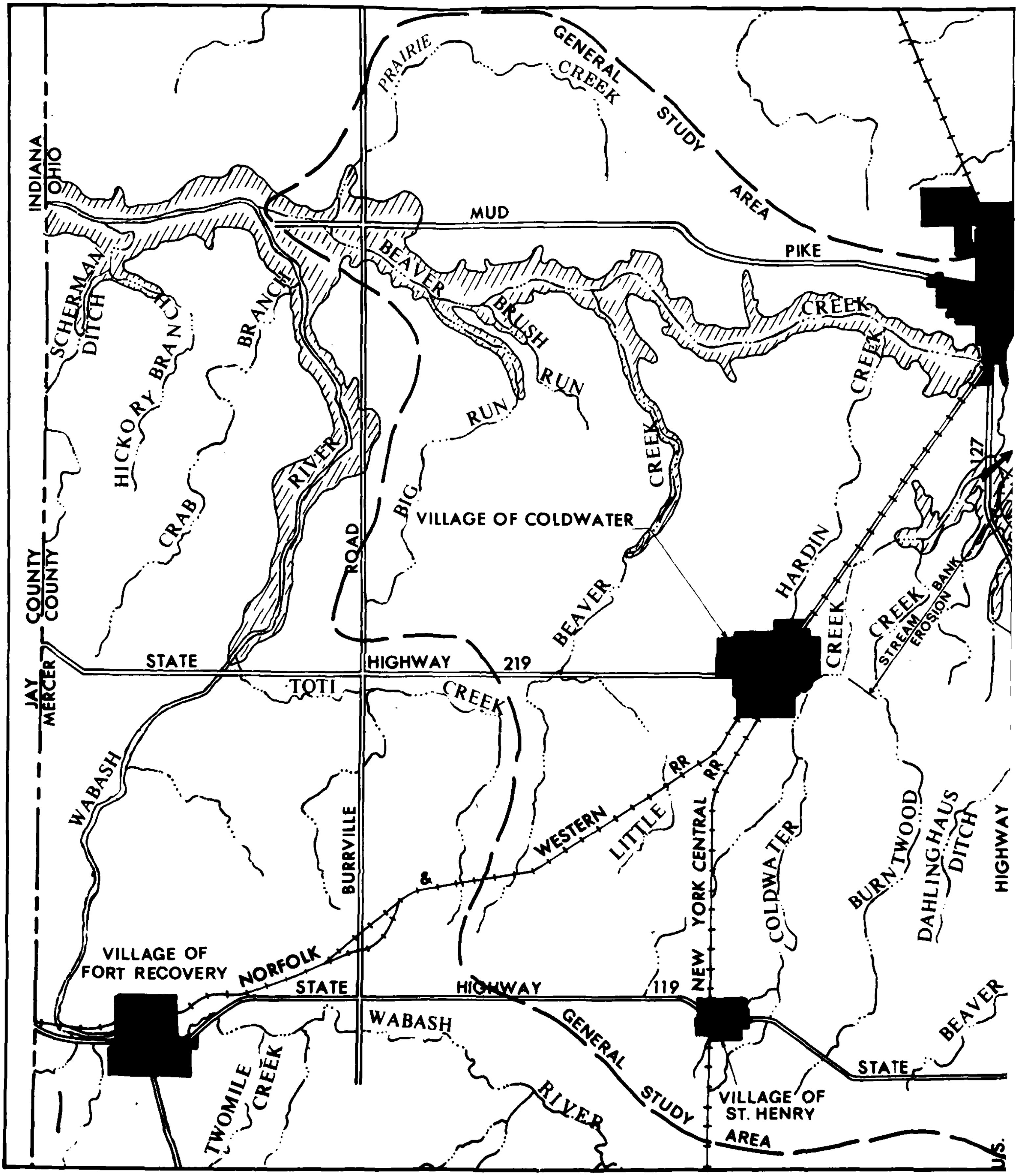
SECTION C

PLATES


INDIANA
OHIO
JAY COUNTY
MERCER COUNTY
GENERAL STUDY AREA
PRAIRIE CREEK
MUD PIKE
BEAVER CREEK
SCHERMAN DITCH
HICKORY BRANCH
BRANCH
BRUSH RUN
BIG RUN
RIVER
CRAB
ROAD
VILLAGE OF COLDWATER
HARDIN CREEK
CREEK
BEAVER
127
STREAM BANK EROSION
STATE HIGHWAY 219
TOTI CREEK
WABASH
BURRVILLE
NORFOLK & WESTERN RR
LITTLE
NEW YORK CENTRAL RR
COLDWATER
BURNTWOOD
DAHLINGHAUS DITCH
HIGHWAY
VILLAGE OF FORT RECOVERY
STATE HIGHWAY 119
WABASH RIVER
TWOMILE CREEK
VILLAGE OF ST. HENRY
STATE
U.S.

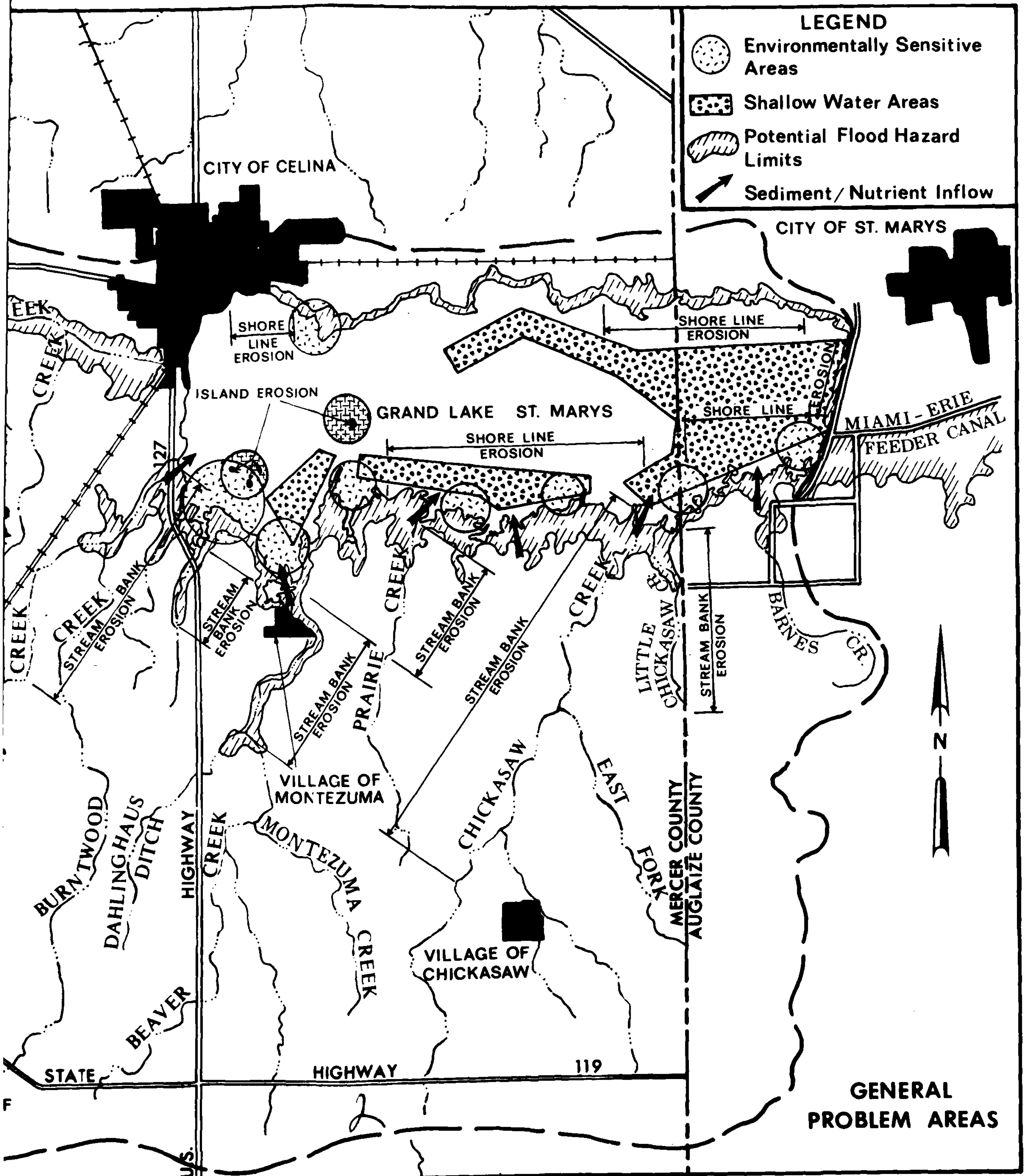
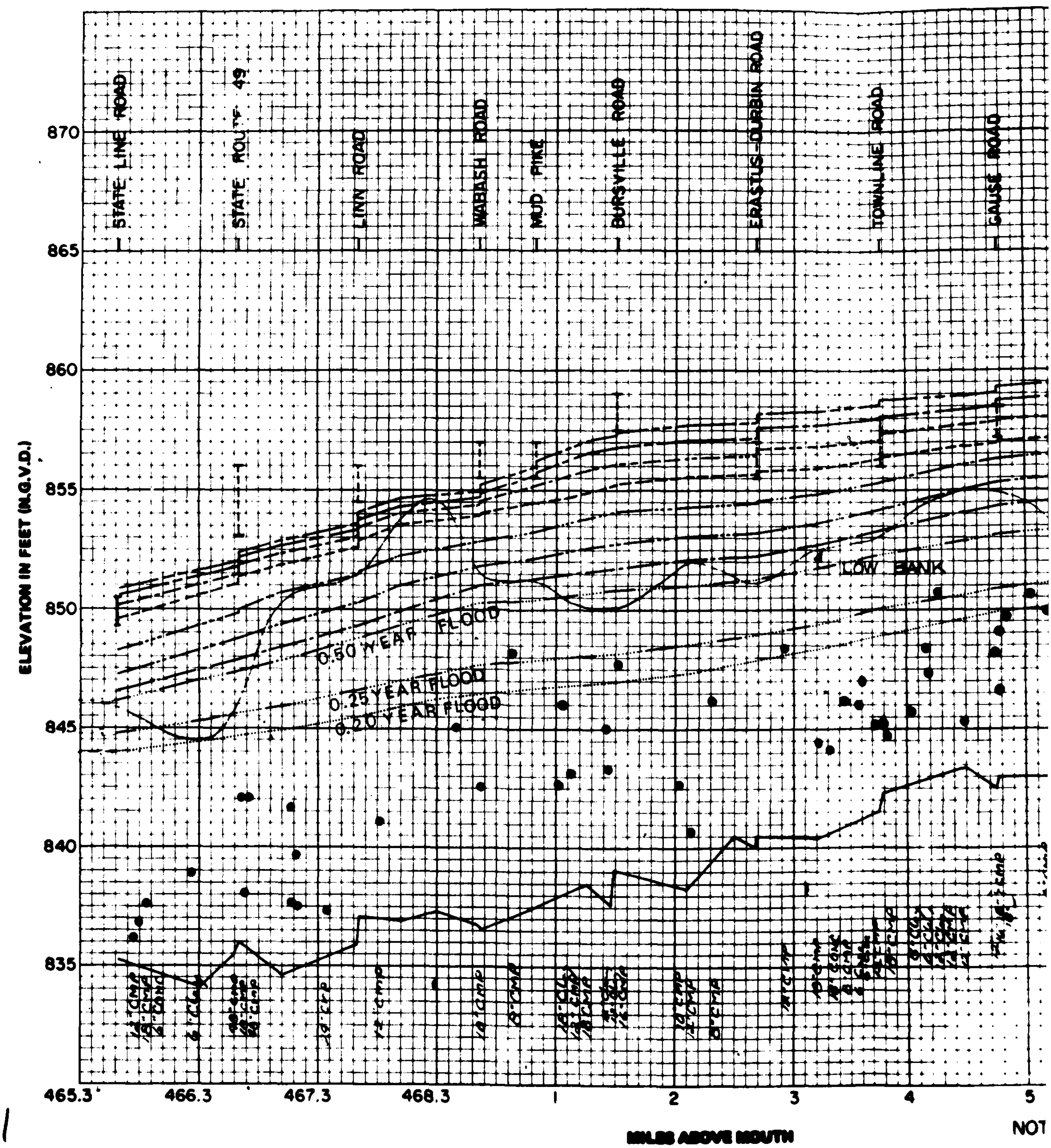
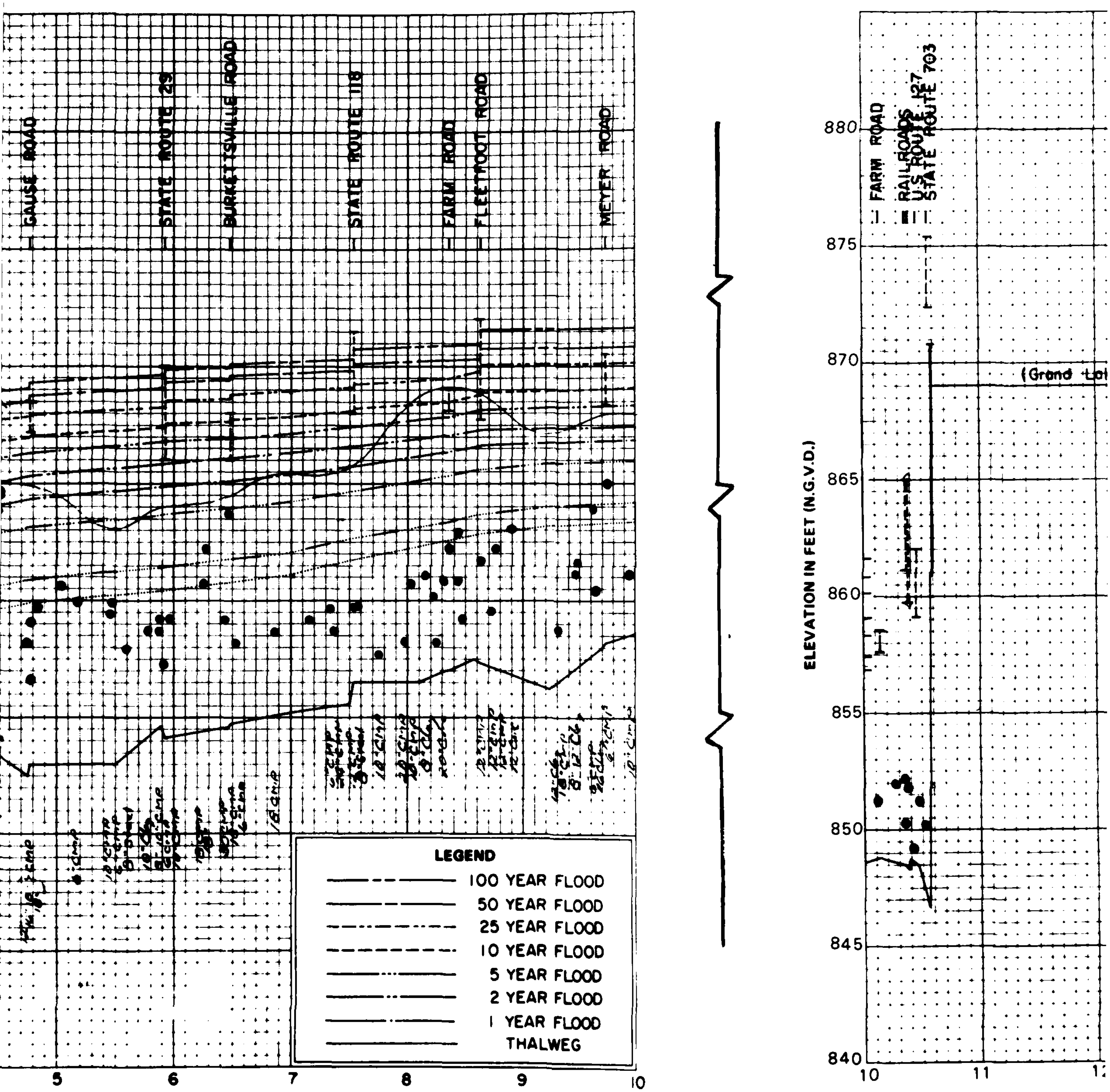

LEGEND
Environmentally Sensitive Areas
Shallow Water Areas
Potential Flood Hazard Limits
Sediment/Nutrient Inflow
CITY OF CELINA
CITY OF ST. MARYS
GRAND LAKE ST. MARYS
SHORE LINE EROSION
ISLAND EROSION
STREAM BANK EROSION
MIAMI-ERIE FEEDER CANAL
VILLAGE OF MONTEZUMA
VILLAGE OF CHICKASAW
PRAIRIE CREEK
CHICKASAW CREEK
LITTLE CHICKASAW CR.
BARNES CR.
EAST FORK
MONTEZUMA CREEK
BURNTWOOD CREEK
DAHLINGHAUS DITCH
BEAVER CREEK
HIGHWAY 127
STATE HIGHWAY 119
MERCER COUNTY
AUGLAIZE COUNTY
N
GENERAL PROBLEM AREAS

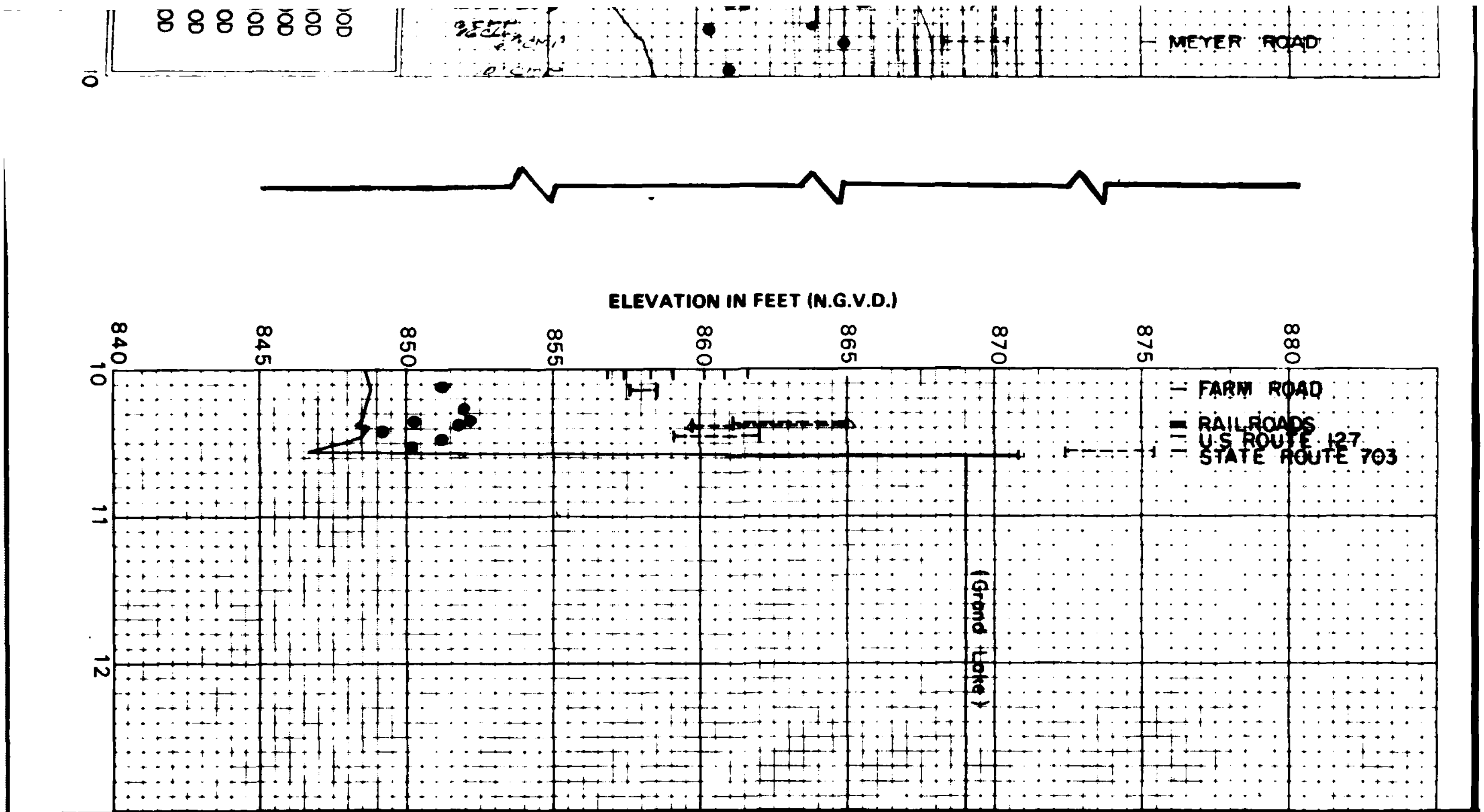
PLATE C-1



ELEVATION IN FEET (N.G.V.D.)
870
865
860
855
850
845
840
835
STATE LINE ROAD
STATE ROUTE 49
LINN ROAD
WABASH ROAD
MUD PIKE
BURSVILLE ROAD
ERASTUS-DURBIN ROAD
TOWNLINE ROAD
GAUSE ROAD
LOW BANK
0.50 YEAR FLOOD
0.25 YEAR FLOOD
0.20 YEAR FLOOD
465.3
466.3
467.3
468.3
1
2
3
4
5
MILES ABOVE MOUTH
NOT



NOTE: Natural All-Season



GRAND LAKE - ST. MARYS, OHIO

FLOOD PROFILES

PLATE

CORPS OF ENGINEERS U. S. ARMY

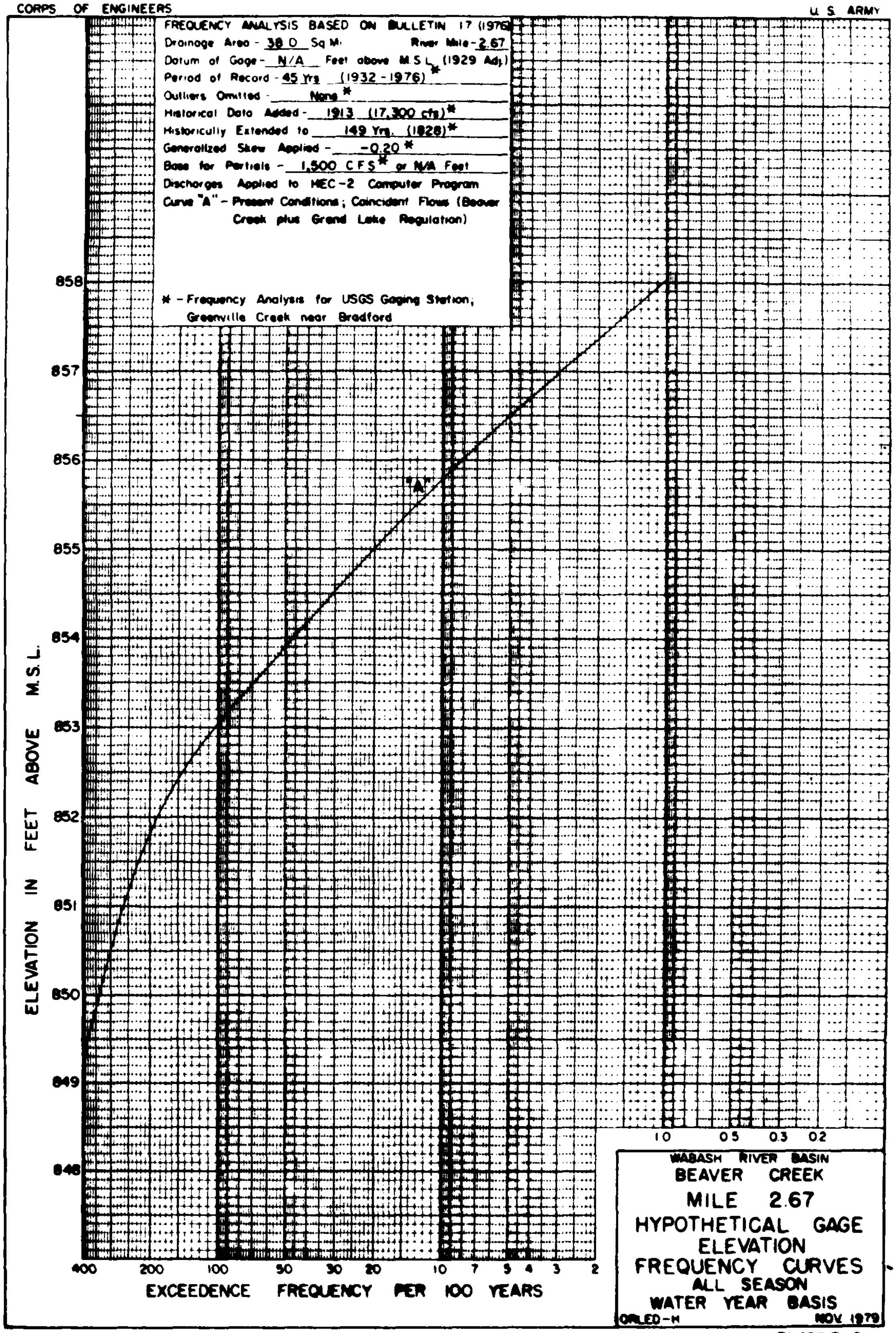


PLATE C-3a

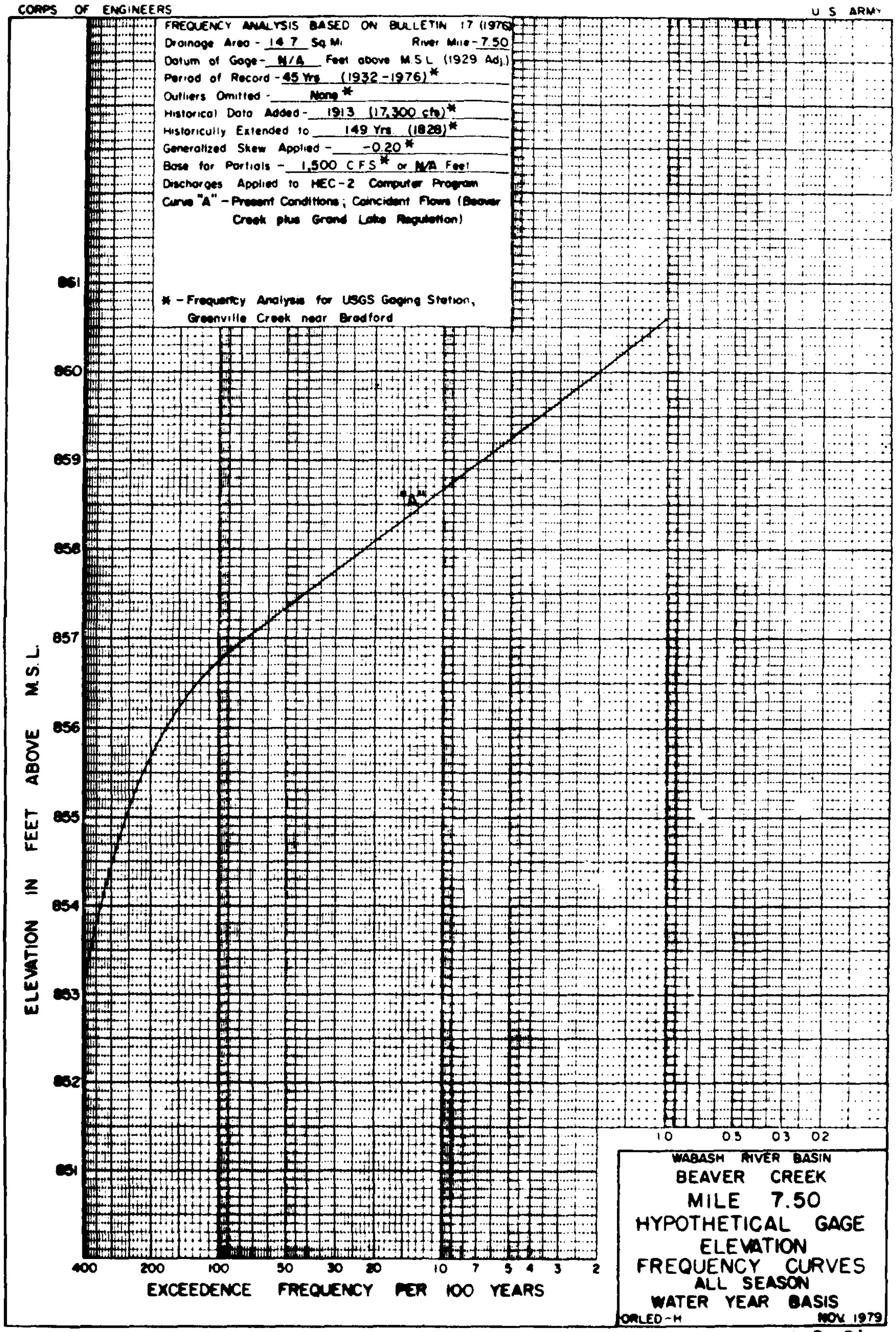
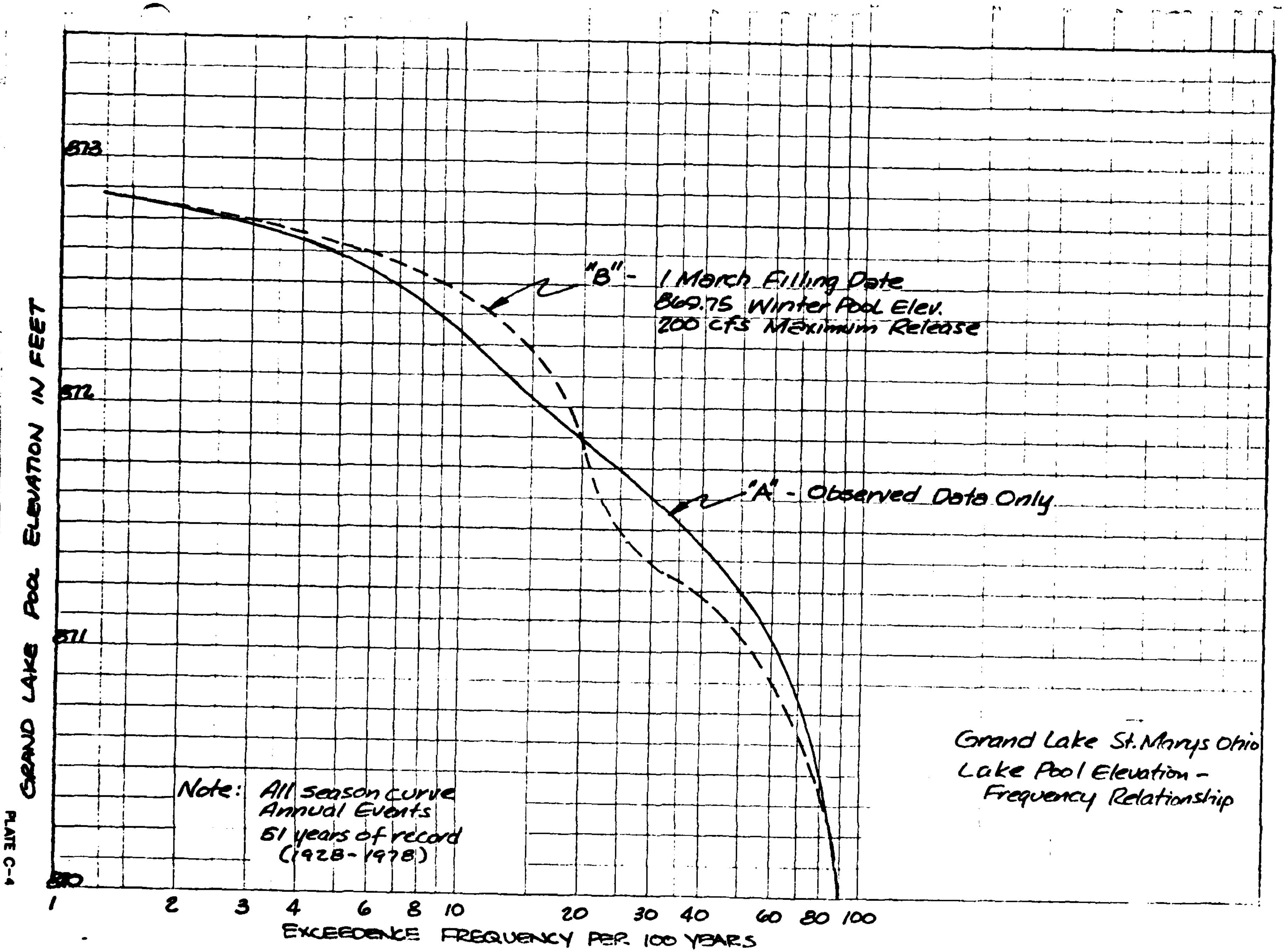
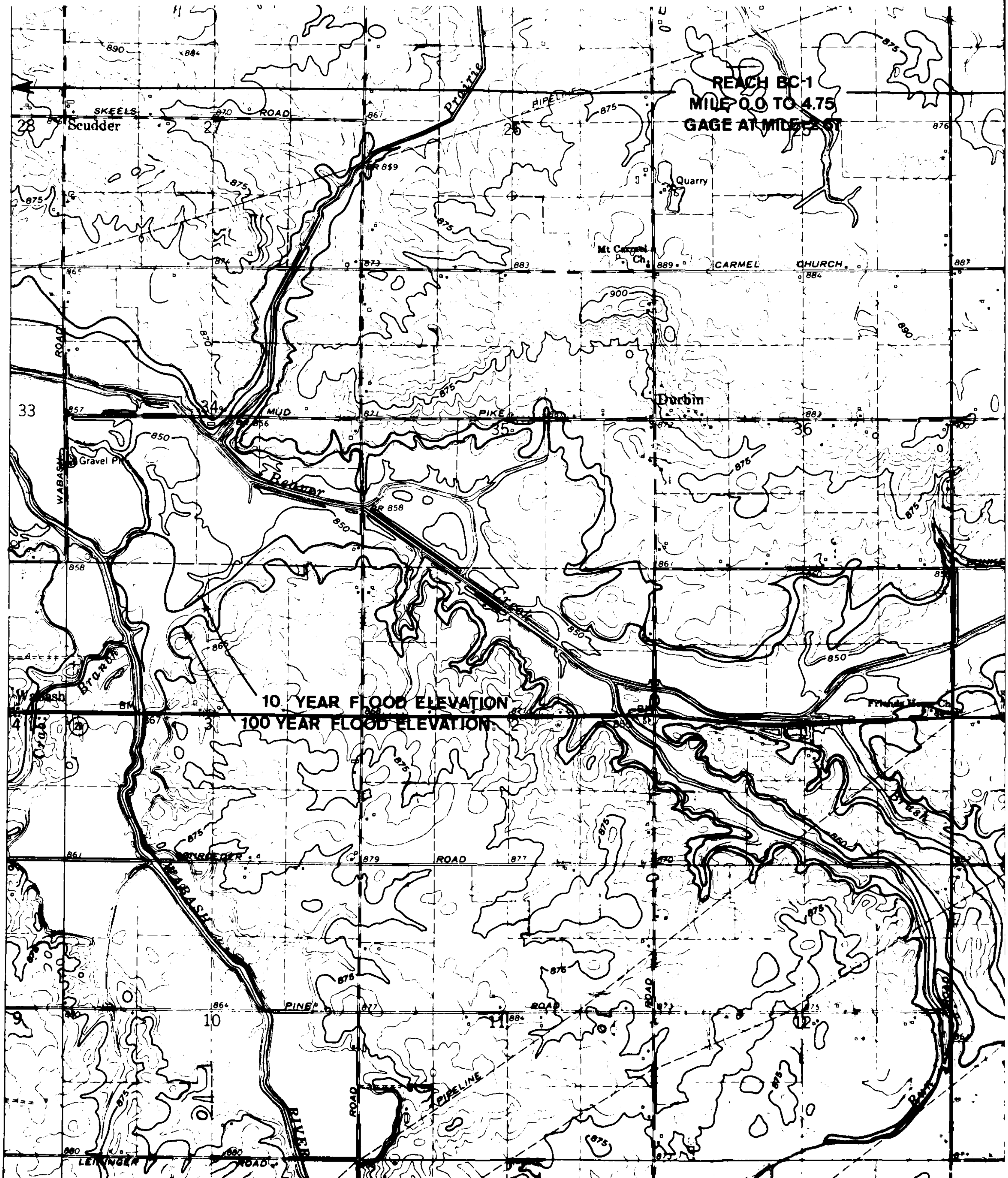

CORPS OF ENGINEERS
U S ARMY
FREQUENCY ANALYSIS BASED ON BULLETIN 17 (1976)
Drainage Area - 14.7 Sq Mi River Mile - 7.50
Datum of Gage - N/A Feet above M.S.L. (1929 Adj.)
Period of Record - 45 Yrs (1932-1976)*
Outliers Omitted - None*
Historical Data Added - 1913 (17,300 cfs)*
Historically Extended to 149 Yrs (1828)*
Generalized Skew Applied - -0.20*
Base for Partials - 1,500 C.F.S.* or N/A Feet
Discharges Applied to HEC-2 Computer Program
Curve "A" - Present Conditions; Coincident Flows (Beaver Creek plus Grand Lake Regulation)
* - Frequency Analysis for USGS Gaging Station, Greenville Creek near Bradford
"A"
ELEVATION IN FEET ABOVE M.S.L.
861
860
859
858
857
856
855
854
853
852
851
400
200
100
50
30
20
10
7
5
4
3
2
1.0
0.5
0.3
0.2
EXCEEDENCE FREQUENCY PER 100 YEARS
WABASH RIVER BASIN
BEAVER CREEK
MILE 7.50
HYPOTHETICAL GAGE
ELEVATION
FREQUENCY CURVES
ALL SEASON
WATER YEAR BASIS
ORLED-H
NOV. 1979

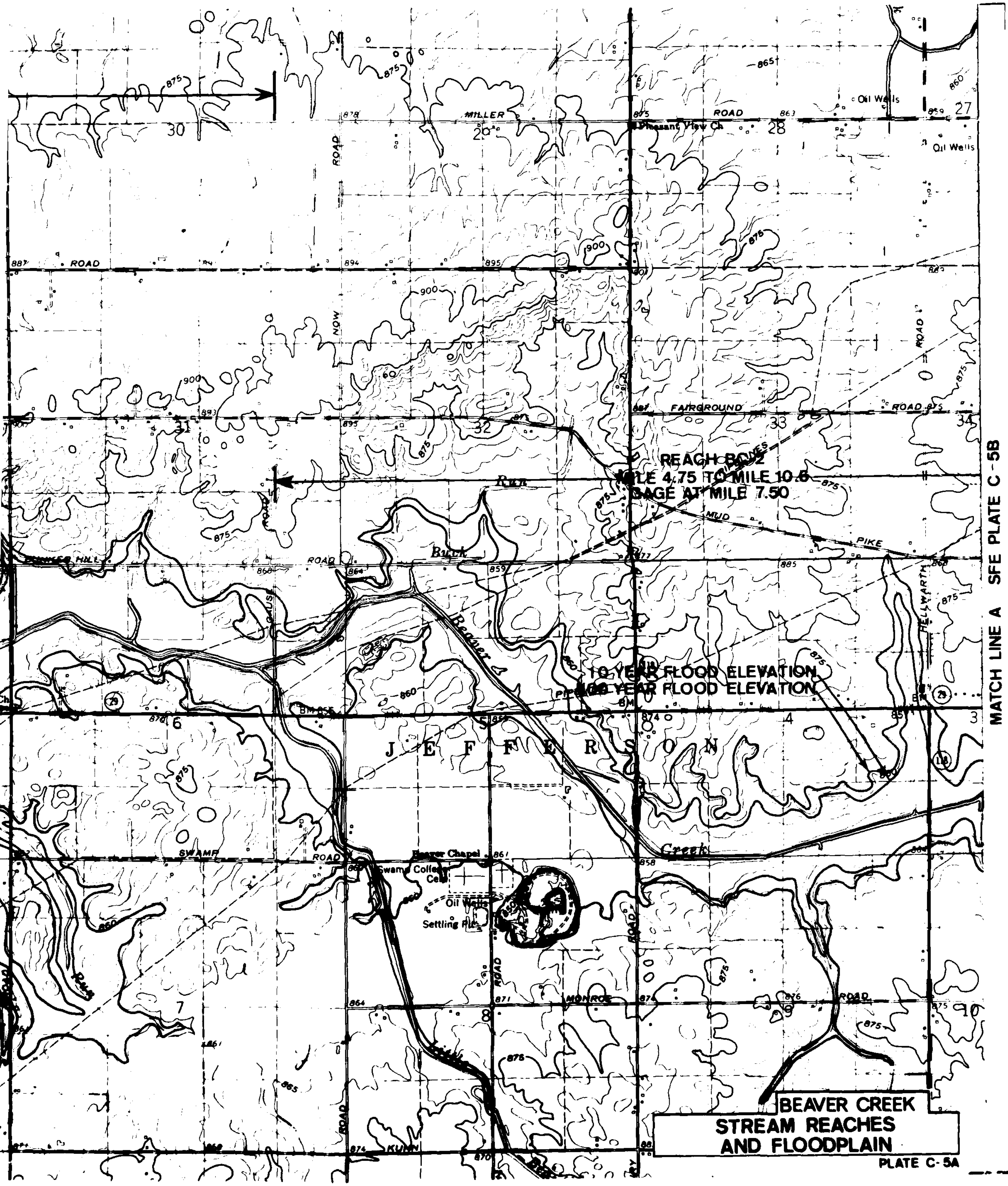
PLATE C - 3b



873
872
871
870
"B" - 1 March Filling Date
869.75 Winter Pool Elev.
200 cfs Maximum Release
"A" - Observed Data Only
Note: All season curve
Annual Events
51 years of record
(1928-1978)
Grand Lake St. Marys Ohio
Lake Pool Elevation -
Frequency Relationship
1 2 3 4 6 8 10 20 30 40 60 80 100
EXCEEDENCE FREQUENCY PER 100 YEARS
GRAND LAKE POOL ELEVATION IN FEET



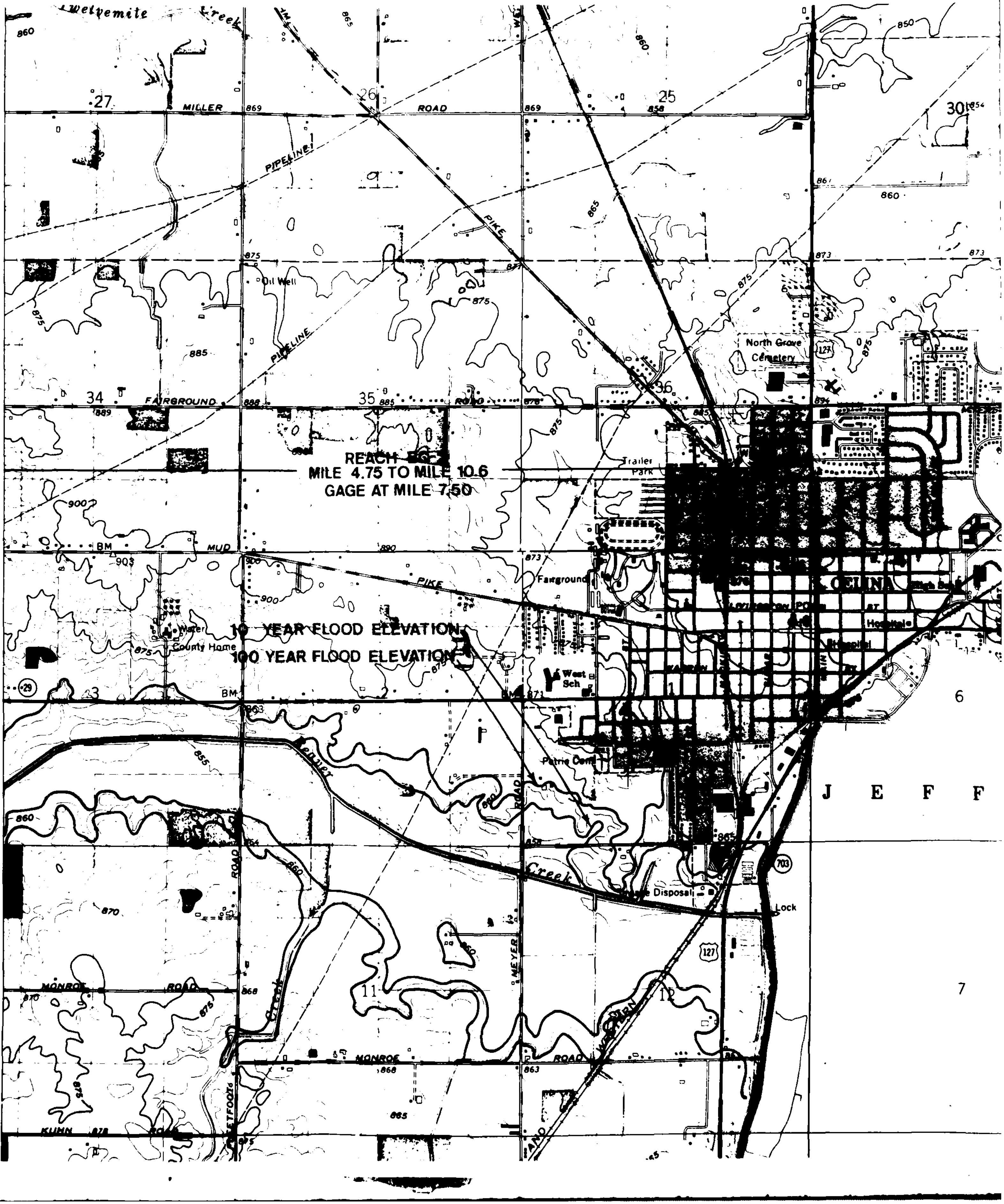
REACH BC-1
MILE 0.0 TO 4.75
10 YEAR FLOOD ELEVATION
100 YEAR FLOOD ELEVATION
Scudder
SKEELS
ROAD
Prairie
PIPELINE
Quarry
Mt Carmel Ch.
CARMEL
CHURCH
MUD
PIKE
Durbin
Gravel Pit
WABASH
ROAD
Creek
Wabash
SCHROEDER
ROAD
PINE
ROAD
LEININGER
ROAD
WABASH
RIVER

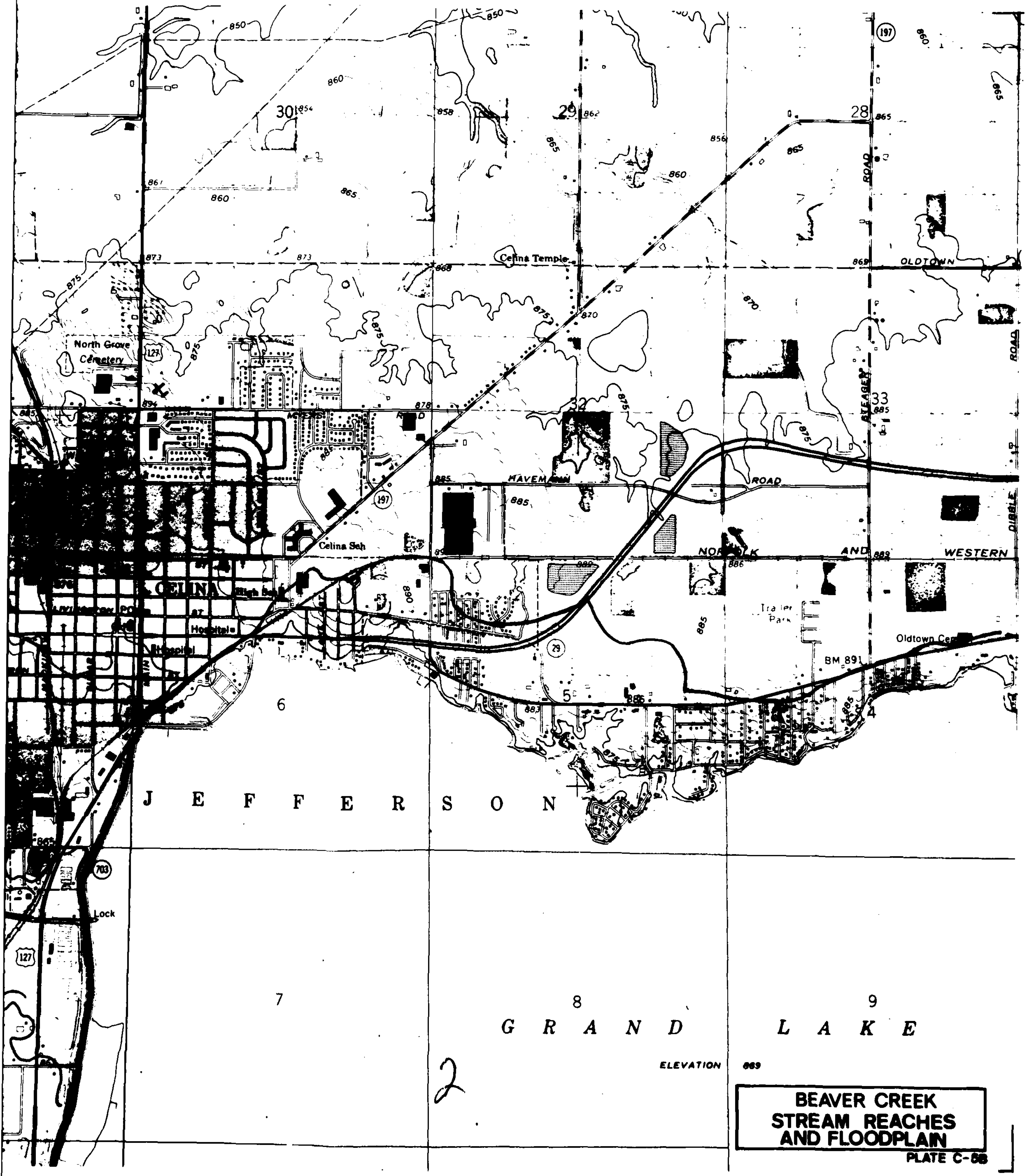


BEAVER CREEK
STREAM REACHES
AND FLOODPLAIN

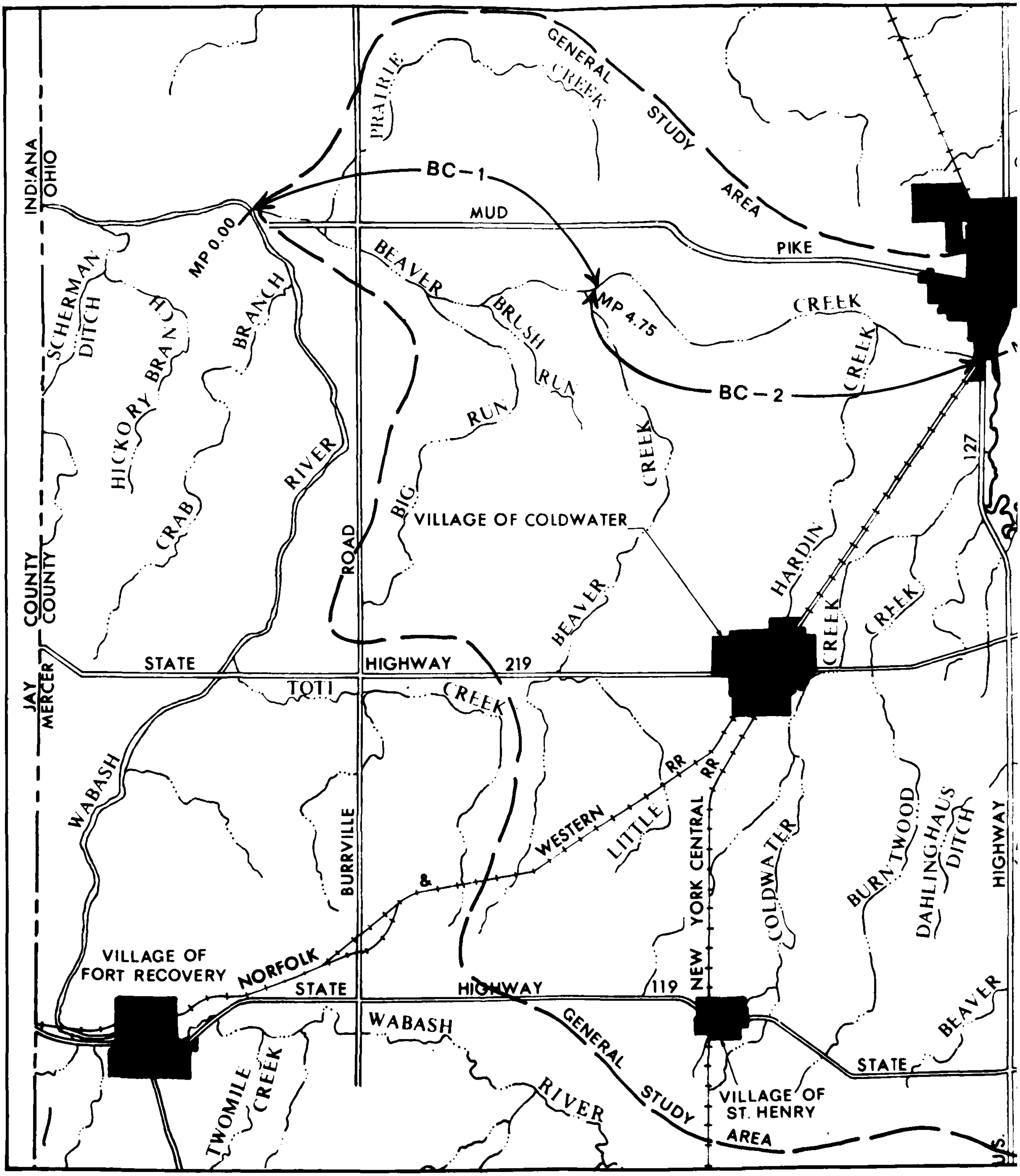
PLATE C-5A

MATCH LINE B SEE PLATE C-5A





BEAVER CREEK
STREAM REACHES
AND FLOODPLAIN
PLATE C-5B


GENERAL STUDY AREA
PRAIRIE CREEK
BC-1
BC-2
MP 0.00
MP 4.75
MUD PIKE
BEAVER CREEK
BRUSH RUN
INDIANA
OHIO
SCHERMAN DITCH
HICKORY BRANCH
BRANCH
CRAB
RIVER
BIG RUN
ROAD
VILLAGE OF COLDWATER
HARDIN CREEK
CREEK
127
JAY COUNTY
MERCER COUNTY
STATE HIGHWAY 219
TOTI CREEK
BEAVER
WABASH
BURRVILLE
NORFOLK & WESTERN RR
LITTLE
NEW YORK CENTRAL RR
COLDWATER
BURNTWOOD
DAHLINGHAUS DITCH
HIGHWAY
VILLAGE OF FORT RECOVERY
STATE HIGHWAY 119
WABASH RIVER
TWOMILE CREEK
VILLAGE OF ST. HENRY
STATE
BEAVER
GENERAL STUDY AREA

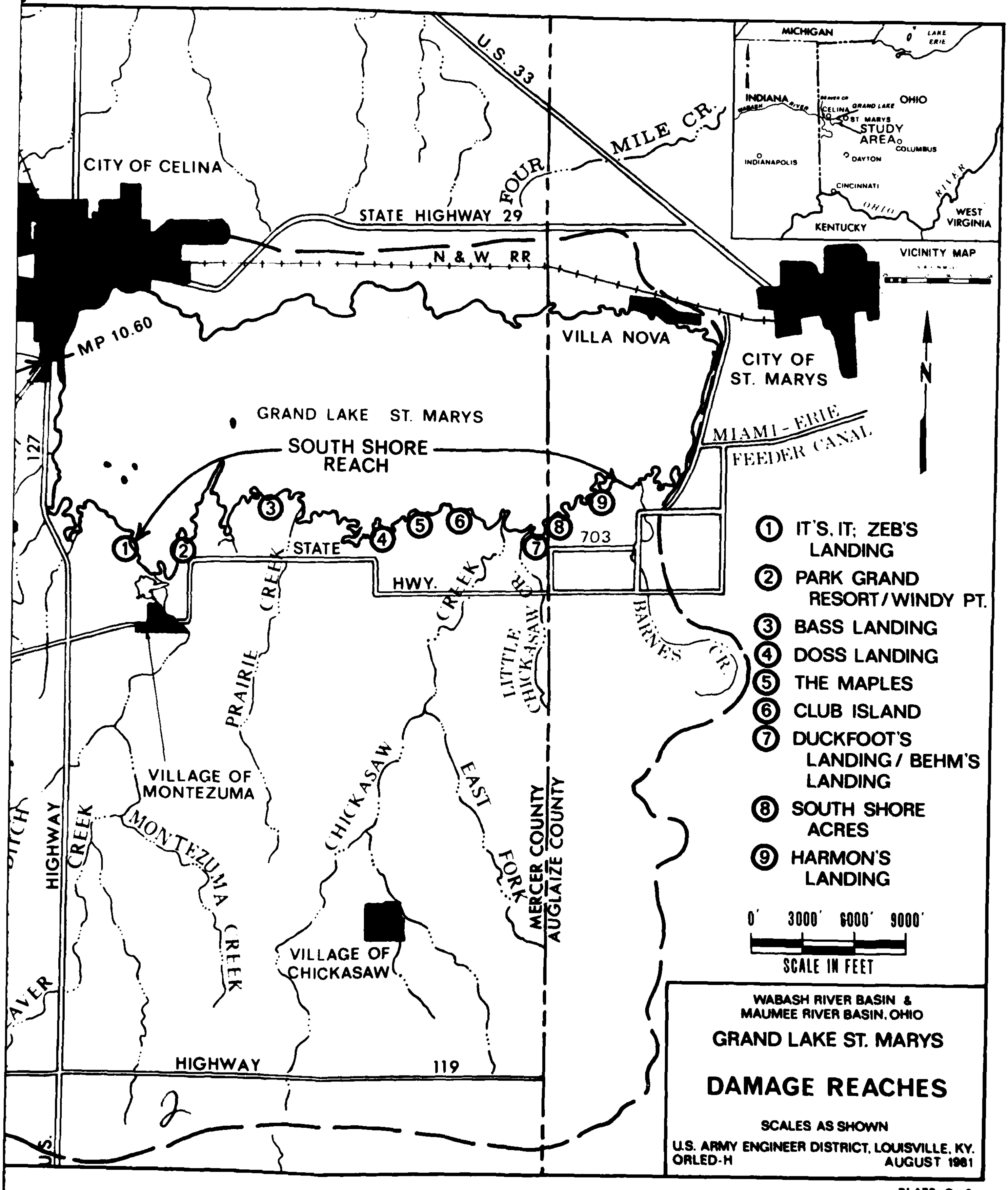
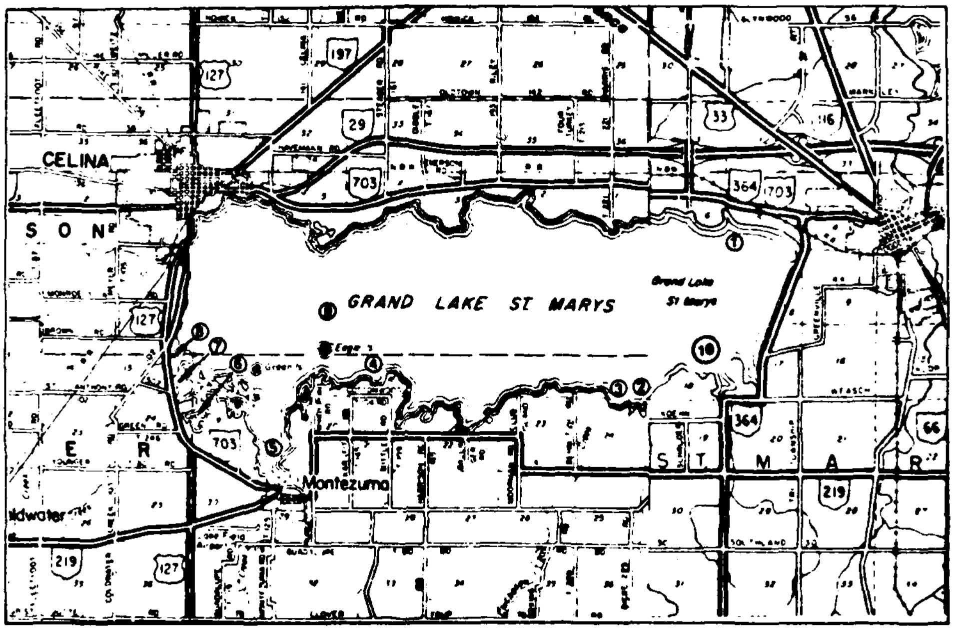

MICHIGAN
LAKE ERIE
INDIANA
OHIO
WABASH RIVER
CELINA
GRAND LAKE
ST MARYS
STUDY AREA
COLUMBUS
INDIANAPOLIS
DAYTON
CINCINNATI
OHIO
RIVER
KENTUCKY
WEST VIRGINIA
VICINITY MAP
U.S. 33
FOUR MILE CR.
CITY OF CELINA
STATE HIGHWAY 29
N & W RR
MP 10.60
VILLA NOVA
CITY OF ST. MARYS
N
GRAND LAKE ST. MARYS
SOUTH SHORE REACH
MIAMI - ERIE
FEEDER CANAL
127
STATE
HWY.
703
PRAIRIE CREEK
CREEK
LITTLE CHICKASAW CR.
BARNES CR.
VILLAGE OF MONTEZUMA
CHICKASAW
EAST FORK
MERCER COUNTY
AUGLAIZE COUNTY
HIGHWAY
CREEK
MONTEZUMA CREEK
VILLAGE OF CHICKASAW
HIGHWAY 119
1 IT'S, IT; ZEB'S LANDING
2 PARK GRAND RESORT / WINDY PT.
3 BASS LANDING
4 DOSS LANDING
5 THE MAPLES
6 CLUB ISLAND
7 DUCKFOOT'S LANDING / BEHM'S LANDING
8 SOUTH SHORE ACRES
9 HARMON'S LANDING
0' 3000' 6000' 9000'
SCALE IN FEET
WABASH RIVER BASIN & MAUMEE RIVER BASIN, OHIO
GRAND LAKE ST. MARYS
DAMAGE REACHES
SCALES AS SHOWN
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLED-H
AUGUST 1981

PLATE C-6

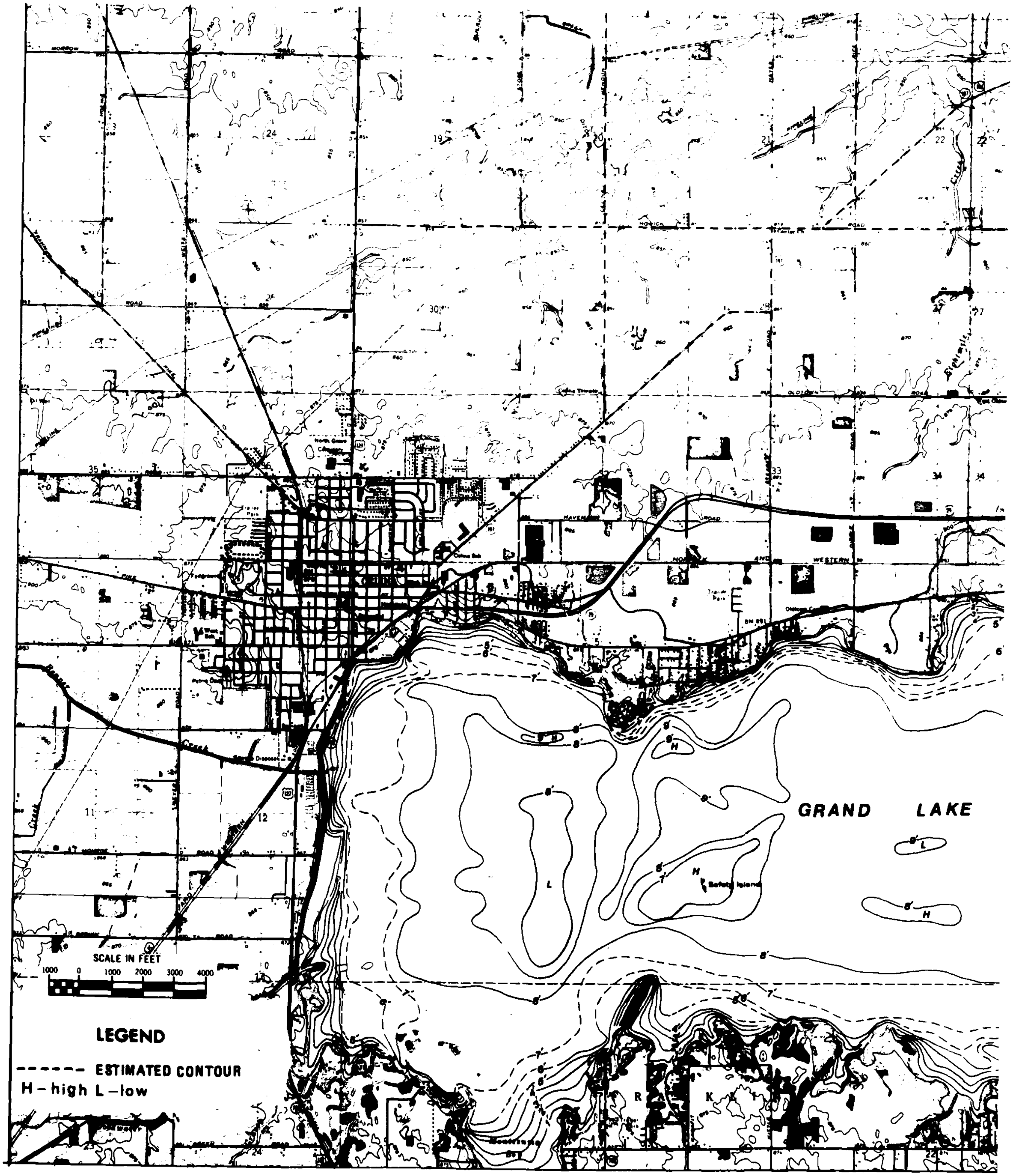


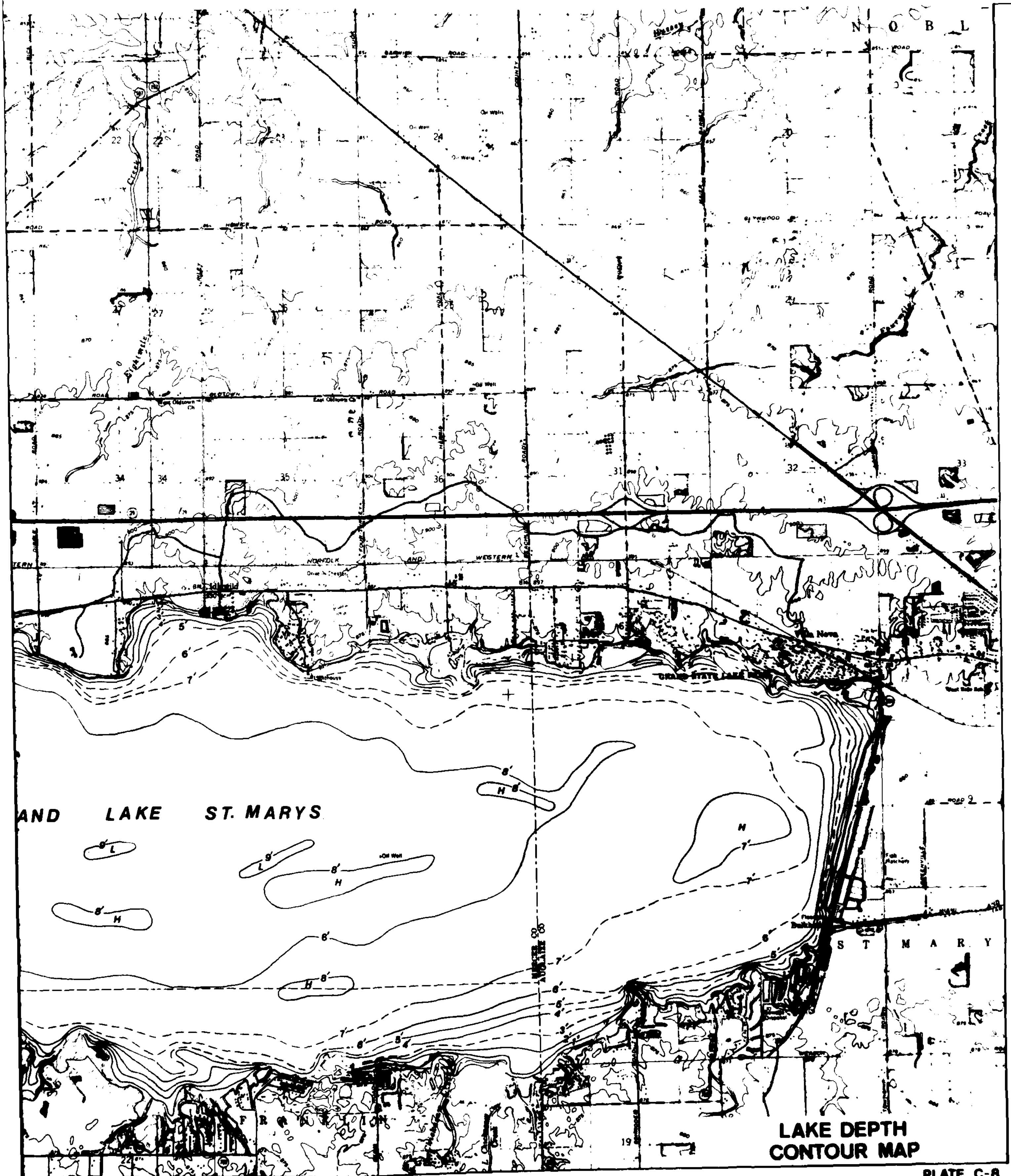
SOURCE: MERCER AUGLAIZE ENVIRONMENTAL RESEARCH ASSOCIATION 1975, IN FINKBEINER, PETTIS AND STROUT 1977

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS WATER QUALITY MONITORING STATIONS

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLED-H 1981


GRAND LAKE
SCALE IN FEET
1000 0 1000 2000 3000 4000
LEGEND
ESTIMATED CONTOUR
H-high L-low
Safety Island
NORFOLK AND WESTERN



LAKE DEPTH CONTOUR MAP

PLATE C-8

ATTACHMENT 1

WATER QUALITY REPORT

C

Introduction

The water quality of Grand Lake has undergone a number of changes since the impoundment of the lake in the 1840's. Some have been of natural origin, but others can be attributed to man's activities in the drainage basin and lake. The primary uses of the lake have changed also, and the water quality problems experienced there now are particularly troublesome for recreation and water supply uses.

The main water quality problems are associated with nuisance algae blooms and inadequate sewage treatment. Taste and odor problems in the lake have been linked to the algae blooms, which also interfere with recreation. High bacteria counts are apparently the result of inadequate sewage treatment.

The fishery of the lake is also considered in this water quality investigation. The present fishery at Grand Lake provides fishing opportunity for many anglers, but apparently does not compare to the fishery which existed prior to 1900. The inevitable comparison between the fishery then and now and the question of whether or how the lake could be returned to its previous condition has been discussed for several years. Water quality has probably had a role in limiting the fishery.

Water Quality Data

Data describing the water quality of Grand Lake are available from several sources. Extensive sampling was done from 1972 through 1975 by a volunteer group composed mainly of Wright State University faculty and students called the Grand Lake Environmental Research Associates (ERA). Their program included monitoring most of the common parameters, but also included sampling for plankton and macroinvertebrates. The United States Environmental Protection Agency (U.S.E.P.A.) sampled the lake and its tributaries during 1973 as part of the National Eutrophication Survey; parameters of interest in that study were confined mainly to nutrients and plankton concentrations. EPA has also sampled the Celina raw water intake and the treated water and did extensive analyses, including pesticides. In 1975 the United States Geological Survey (U.S.G.S.) and Ohio Environmental Protection Agency (O.E.P.A.) surveyed 17 Ohio lakes, including Grand Lake, to evaluate the status of Ohio's lakes and reservoirs. Extensive sampling, including profiles of the water column, was done once in spring and once in late summer. The data from these sources are summarized in Tables 1 through 16.

The sampling stations are indicated in Exhibits 1 and 2. It should be noted that the U.S.G.S. station is located in the main body of the lake, a considerable distance from the banks or any point of inflow. The ERA stations are mainly located at the mouths of tributaries; they are in the slack water of the lake, but each should show at least some of the characteristics of the respective tributary. Of the four EPA lake stations, three are near the bank and one is at midlake.

Water Quality of the Lake

In its 1975 report the U.S.G.S. characterized Grand Lake as a moderately hard, magnesium calcium sulfate bicarbonate type, a description which fits most Louisville District lakes. However, there are major differences in water quality between Grand Lake and the multipurpose lake projects operated by the Louisville District.

The primary reasons for the difference are the extreme shallowness of the lake, its high capacity to inflow ratio (C/I), and the relatively high degree of residential and commercial development on the lake shores. The U.S.G.S. reported a maximum depth of 10 feet, a mean depth of 6.8 feet, and a C/I of 1.3 years.

The shallow nature of the lake, along with its wide expanse of open water (which promotes mixing by wind action) prevents stratification. The lake is essentially well mixed throughout the summer, showing only slight decreases in temperature and dissolved oxygen near the bottom.

A comparison of existing data with criteria of the Ohio Water Quality Standards provides a basis for evaluating the relative quality of the lake. Grand Lake is classified for warmwater aquatic habitat, public water supply, and bathing and primary contact recreation. These are among the highest use of surface waters and generally impose the most stringent criteria in the Standards.

Dissolved oxygen (D.O.) has traditionally been used as the primary indicator of water quality and its effect on aquatic life is obvious. Ohio Standards for the warmwater habitat designation require a minimum of 5.0 mg/l for 16 hours of any 24-hour period and an absolute minimum of 4.0 mg/l. Available data indicate that Grand Lake exceeds those values by a wide margin; dissolved oxygen (or lack of it) does not limit the lake as aquatic habitat. The U.S.G.S. profile data indicate that during the summer the D.O. drops only slightly near the bottom. The heavy algae growth, extreme shallowness, and very effective mixing by wind and wave action are the most important factors in keeping the lake well oxygenated, in spite of abnormally high Biochemical Oxygen Demand (BOD).

There are no data to describe diurnal fluctuations in dissolved oxygen. The lake could be expected to experience a decrease in D.O. at night due to respiration of the large algae population. If such a depletion does occur, it does not produce significant adverse effects.

The BOD is usually in the range of 10-12 mg/l (ERA data); however, as noted above, the D.O. remains near saturation. Apparently the high BOD is not detrimental except during periods of prolonged ice cover. During such occurrences, the high BOD has caused enough depletion of D.O. to cause the death of fish, mainly shad and rough fish such as carp. The ice cover apparently prevents reoxygenation through wind action and photosynthesis. During most winters, wind and wave action is sufficient to prevent the formation of thick ice and snow cover, thus preventing D.O. depletion.

The only other parameters which would affect the warmwater habitat designation are iron and total phosphorus. The iron criteria of 1.0 mg/l has been exceeded several times in the data. At the Celina raw water intake, the average total iron concentration is 1.2 mg/l. The source of the iron is apparently natural and the lake has not suffered significant damage from it. Because the water is so well oxygenated, most of the iron is probably in the particulate form; the material which causes the lake's high turbidity would carry most of the iron.

The Ohio standards require that "total phosphorus shall be limited to the extent necessary to prevent nuisance growths of algae..." That requirement is not being met at Grand Lake where algae blooms are a nuisance throughout the summer and fall. The ERA data indicate that average ortho-phosphorus concentrations are above 124 µg/l at all stations. The U.S.E.P.A. in its National Eutrophication Survey has indicated that the majority of phosphorus entering the lake is from non-point sources and is therefore difficult to control. The role of phosphorus in the algae problem is discussed further in the section on productivity.

Other parameters for which criteria are listed in the warmwater habitat standards do not affect Grand Lake. No sources of potentially toxic materials are known to exist. Pesticide data are very limited, but the one sample taken at Celina's intake revealed no significant concentrations and none were detected in the U.S.G.S. study.

Celina uses Grand Lake as a source of raw water for its public water supply, and the lake around the intake (northwest corner) would be expected to meet the public water supply standards. The only parameters of concern there appear to be iron and nitrates. The nitrate criterion sets a limit of 10 mg/l as N; nitrates at higher concentrations are a potential health hazard. Dissolved iron is limited to 0.3 mg/l by the standards for aesthetic reasons (taste and staining), not for health reasons.

The ERA data indicate a potential nitrate problem with some concentrations in the 10-11 mg/l range. However, the ERA sampling points are near the south shore and the data from other sources indicate that no nitrate problem exists near the Celina intake. The EPA data (Tables 3 and 4) indicate that the raw water and finished water do not contain nearly enough nitrate to be a health hazard.

As mentioned before, most of the iron in Grand Lake is in the particulate form, which is readily removed in the common water treatment process. Celina has not experienced problems with dissolved iron and probably will not as long as the lake remains well oxygenated.

The bathing waters and primary contact recreation standards are based on fecal coliform content. Both standards require not less than five samples in a 30-day period to establish a geometric mean. Such extensive data are not available. However, the ERA data contains the results of monthly samples which indicate that the waters of Grand Lake would not meet the primary contact criterion (geometric mean less than 1,000 per 100 ml), much less the bathing waters criterion (geometric mean less than 200 per 100 ml). The proximity of these sampling stations to the south shore and tributary mouths is the probable reason for the consistently high readings for fecal coliform (as well as nitrates). While they may not be representative of the whole lake, they do illustrate the effect of septic tank discharges and other sewage sources on the south shore.

The U.S.G.S. samples were taken in the main body of the lake and do not indicate a violation of fecal coliform standards. The ERA station near Safety Island also shows lower readings. These reductions would be expected since the coliforms would not reproduce significantly and would not persist long in the open waters of the lake.

Fecal coliform are, of course, only indicator organisms and show only the potential for existence of pathogens. No known water-borne diseases have been attributed to the lake, which is heavily used for recreation.

Productivity and Fishery

The biological productivity of Grand Lake is quite different today than it was during the first 50-60 years of the lake's existence. Certainly the natural aging process accounts for part of the change, but a large part is also attributable to man's activities in the basin.

The lake has apparently gone through three "stages" of productivity. During its early years, up until around 1900, a very dense stand of rooted aquatic plants (locally known as moss) extended from the shore about one-half to one mile into the lake. The center of the lake was an open water area with little underwater vegetation. It was during this period that an extraordinary fishery existed; the fishery reportedly supported up to 100 commercial fishermen and attracted many sport fishermen. The dominant fish were black bass, sunfish, perch and catfish.

In the decade of 1890-1900, several changes occurred which apparently greatly affected the water quality, productivity, and the fishery of the lake. A drought exposed large areas of the uncleared lake bottom and much of the remaining standing timber and log jams were removed. As many as 200-300 oil wells were drilled in the lake during this period and undoubtedly produced leakages and spills. Thus, when the lake refilled after the drought, wave action was increased by the lack of vegetation and timber, and turbidity increased. In a very short time the lake was converted from a relatively clear, cool body of water to a turbid, warmwater area with much increased wave action (ODNR). The fishery became dominated by carp and white crappie at this same time. The relationship between the fishery, the rooted aquatic vegetation, the wave action, and turbidity levels of the lake has not been precisely defined or proven, but the fact that all changed at about the same time has been taken to indicate this relationship or interdependency.

The lake remained in this turbid, relatively unproductive condition for the next six or seven decades. Research conducted by the state during this period indicated a nutrient deficient lake with a relatively sparse plankton population. Crappie and carp remained the dominant fishes, although game fish were also caught. Much research on the fish populations was done during this period including attempts to enhance the habitat and spawning areas to increase the game fish population. Attempts also were made to reestablish the rooted aquatic vegetation of the previous period.

The productivity of the lake during this second stage was apparently limited by low levels of dissolved nutrients. Sampling in the 1930's revealed that nitrate concentrations were so low as to be undetectable. The plankton concentration was measured in the 1930's and was also found to be relatively low (average of 150,000 cells/liter); the population was dominated by diatoms and green algae, with a low percentage of blue-green algae (ODNR). Rooted aquatic vegetation was mainly limited to cattails in the shallow areas.

During the last two-three decades, another major change has occurred in the productivity of the lake. The nutrient concentrations have increased dramatically and the lake has become a classic example of a culturally eutrophic impoundment. The increase in nutrients and subsequent eutrophication were concurrent with the increased development of the south shore and increased use of fertilizer in farming practices. The contributions of the various nutrient sources are summarized in the section on sources of pollutants.

The term "eutrophic" covers a wide range of water quality conditions from very desirable lakes which support excellent warmwater fisheries (and which may also experience occasional nuisance algal blooms) to the lakes which are in essence comparable to pea soup and are of no value except, perhaps, as sources of irrigation water.

Grand Lake has remained a valuable resource in spite of its algae problems, which are certainly more than occasional. Starting in May, the lake experiences an almost continual algae bloom throughout the summer. Later in the summer an odor problem develops from decaying algae; fish are tainted by the products of the decomposition. The Celina public water supply also develops taste and odor problems. The algae adversely affects the aesthetic appeal of the lake and reduces recreation potential. Several factors appear to contribute to the eutrophic condition of Grand Lake. The most important is the high concentration of nutrients (nitrogen and phosphorus).

Ambient nutrient levels are shown in the data from each source. All indicate phosphorus and nitrogen concentrations in excess of those required to support nuisance algae blooms. As noted in the U.S.G.S. report, relatively low concentrations of inorganic nitrogen and ortho-phosphorus may exist at times because so much of these nutrients are incorporated into the biomass of the algae blooms.

The effect of the nutrient levels on algae production is compounded by other factors. The U.S.G.S. estimates the C/I ratio to be 1.3 years at Grand Lake. A lake with such a long hydraulic residence time has been shown to be more susceptible to the effects of increased nutrient loading. Evidence also exists that the shallow, warm nature of the lake would contribute to increased plankton production. The stirring by wave action extends to the bottom of the lake, continuously recycling the nutrients and preventing their removal by sedimentation.

Eutrophication not only results in the production of more algae, but quite often results in a change in the type of algae. Generally blue-green algae become dominant, producing obnoxious blooms and changing the base of the normal food chain. The blue-greens are not utilized to a great extent as a food source by the higher life forms in the food chain; this can lead to production of less valuable fish species and the accumulation of algae because of reduced grazing by herbivores.

The U.S.G.S., ERA, and USEPA data on algae numbers and species indicate that Grand Lake follows the general pattern of eutrophication described above. All found that the blue-green algae have replaced the green algae and diatoms reported in the 1930's data as the dominant form. The U.S.G.S., on two sampling trips in 1975, found cell counts of 2,830,000 and 2,400,000 cells per ml as opposed to the average count of 150,000/liter found in the 1930's.

The exact reason blue-green algae become dominant in culturally eutrophic lakes is not known. It is a common occurrence and is quite often accompanied by the taste, odor, and aesthetic problems encountered at Grand Lake.

The occurrence and magnitude of the blooms at Grand Lake are increased by a lack of rainfall. The problems associated with the algae blooms are more prominent during periods of low lake levels, when there is no inflow or outflow.

Taste and Odor

The taste and odor problems at Grand Lake have been studied extensively. The researchers agree that the heavy algae production is the main cause of the problem, with the actinomycetes bacteria group possibly contributing, also.

The city of Celina experiences the most trouble because it uses the lake as a source of raw water. The taste and odor increases the treatment costs substantially and persist in the finished water. The recreational potential of the lake also suffers, since the odor is quite apparent around the lake and even taints the flesh of fish later in the summer.

Two organic compounds (2-methylisoborneol and Geosmin), which are known to produce the earthy-musty odors characteristic of the lake, have been isolated in the waters of Grand Lake. The actinomycetes have been shown to produce both compounds while certain algae are known to produce Geosmin. The growth of actinomycetes normally depends on the presence of algae for a food supply, so the ultimate source of the taste and odor appears to be the heavy algae bloom. The blue-green algae are usually considered the worst offenders, but some of the other types of algae can produce taste and odor also.

Sources of Pollutants

Grand Lake is affected by two types of pollutants: nutrients (which encourage the growth of algae) and bacteria. The bacteria comes mainly from poorly treated sewage while nutrients (phosphorus and nitrogen) come from sewage and surface runoff.

The drainage area of the lake lies almost entirely on the south side. All of the tributary streams enter the lake on that side and most of the shoreline development (commercial and residential) is located there. Most pollution therefore enters the lake from the south.

Sewage treatment for the businesses and residences around the shore now consists of septic tanks and small package treatment plants. Because of the soil types and high water table, septic tanks do not operate well and allow improperly treated sewage to seep into the lake and its tributaries. The small package plants cannot provide a high enough degree of treatment to protect the lake. Their efficiency is limited by their small size and by the seasonal fluctuations in waste volumes. According to EPA, the only municipal plant in the basin is at St. Henry's, which is probably far enough from the lake that its impact is not significant.

The main impact of the septic tanks and package plants is the high coliform counts found in the lake, especially around the south shore. Their effluent also contains phosphorus and nitrogen, but EPA has indicated that their contribution to the total nutrient inflow is minor.

The National Eutrophication Survey (EPA, 1973) estimated that 92 percent of the phosphorus entering the lake comes from non-point sources; these would include cropland, feedlots, barnyards, and other places where fertilizers or animal wastes could enter surface waters. The non-point sources also contribute most of the nitrogen in the lake and would also be the source of part of the coliform count. Most of these pollutants would enter tributary streams only during surface runoff, not continuously as sewage does.

The non-point sources would also include the waterfowl refuge at the southwest corner of the lake. The refuge has a population of 10,000 Canada geese, which would contribute to the nutrient and coliform content of the lake. It is doubtful that the effects are major, however.

Industrial effluents do not affect the lake. The largest industry in the basin is a farm machinery plant at Coldwater, which discharges cooling water to Coldwater Creek. Otherwise, no industrial discharges are known.

In 1972, in an effort to relieve the pollution problem at Grand Lake, the Ohio Department of Health created the Grand Lake St. Marys Special Sanitary District and banned further construction of sewage systems. Further cooperative action by Ohio EPA, the Ohio Water Development Authority, the cities of St. Marys, Celina and Montezuma and Mercer and Auglaize Counties, resulted in development of a Regional Sewage System Facilities Plan. The purpose of the plan was to determine the most cost-effective means of dealing with human pollution problems generated within the Grand Lake area.

The recommended plan proposes the construction of sanitary sewers around the lake and the utilization and expansion of the existing wastewater treatment plants at St. Marys and Celina. Neither of these facilities discharge to Grand Lake; thus, the sewage collected by the proposed sewers would be removed from the basin with no contamination to Grand Lake. It is believed that the recommended plan will relieve a significant portion of the pollution problem, especially the high coliform content. Some of the benefits of the recommended plan are:

(1) Reduction of pollution by elimination of 22 package wastewater treatment plants which presently discharge into Grand Lake.

(2) Elimination of septic tanks and tile fields which exist around the lake.

(3) Removal of a significant portion of human pollutants from the lake, thus improving water quality.

The main improvement in water quality would be the reduction of coliforms. However, domestic wastes contain high concentrations of phosphorus, which would also be eliminated from the lake by the recommended plan. The National Eutrophication Survey has indicated that the productivity of the lake is phosphorus limited, so any reduction in phosphorus should produce some improvement in trophic conditions.

Sewage effluents contain substances other than nutrients which may encourage algae growth, including vitamins and minerals. These substances will also be removed from the lake by the proposed plan; thus, the benefit in algae reduction may be greater than would be predicted from a nutrient analysis alone.

Sedimentation and Turbidity

The State of Ohio operates a continuous dredging program at Grand Lake to keep access channels open for boat traffic. This continuous requirement for dredging suggests that the lake receives a high sediment load from its drainage area. The turbid nature of the lake also would seem to confirm this conclusion.

There are other factors, however, which suggest that Grand Lake does not receive a high sediment input from its basin. A reconnaissance of the basin indicates that relief is almost non-existent, stream gradients are extremely low, and there is no visible evidence of excessive erosion. The lake is located in an area designated by the U.S.G.S. as "moderately low" in sediment yield (100-200 tons/sq. mi./yr).

The ERA sampling program included attempts to sample the deposited material at the bottom of the lake. The extreme shallowness of the deposits (2-4 mm) made sampling very difficult.

The one existing sediment survey of the lake was a reconnaissance survey of eight ranges in 1940; it is mentioned here only to acknowledge its existence. The results appear to be somewhat unrealistic and are not consistent with the known characteristics of the basin. For instance, the sedimentation rate from that survey of 2.64 ac.-ft./sq. mi/yr. corresponds to about 3,200 tons/sq. mi./yr. in an area where soil loss is normally between 100 and 200 tons/sq. mi./yr. The fact that this survey was used in conjunction with information collected in 1844 makes the results even more questionable.

The great reduction in storage capacity measured in 1940 was probably the result of encroaching marshes more than sediment input from the basin. The ODNR report, "Lake St. Marys and Its Management," (1960) indicates that "the accumulation of years of partially decomposed plants and silt and debris soon fill in the shallow areas of the lake." The report also notes that the cattail marsh advanced as much as 20 to 50 feet in one year. The sedimentation report describes heavy organic deposits of three or four feet in thickness in the marshy areas of the lake. Thus it appears that most of the material measured by the 1940 survey was due to formation of marshes or to erosion of the shoreline rather than input from the drainage basin.

Sedimentation does not appear to be seriously depleting lake storage. The main problem is that the material accumulates in places where it is especially noticeable and troublesome.

There are numerous access channels entering the lake and its tributaries, mostly on the south shore. These channels serve many private homes, rental cottages, and recreation and camping areas, providing easy access to the main lake by boat. Deposition near the mouths of these channels and tributaries is the main reason for the state dredging program.

Dredged material is disposed of on land and at sites within the lake itself. The in-lake sites are located along the shoreline, where the material is used to build additional recreation lands.

The sediment removed by the dredging is mostly silt and clay. It apparently deposits at the mouths of the channels because of the slack water there. Material carried in by streamflow on the one hand and by wave wash on the other would all tend to be deposited there.

The source of the deposited material appears to be the main question here. If the main source is material eroded by wave action, then additional bank protection measures would be helpful in reducing the problem. If the main source is inflow from the drainage basin, then soil conservation practices would be more beneficial. The lake is so shallow that it may be possible that some material comes from wave action on the lake bed, also. The ultimate solution appears to be reduction of wave action, which would reduce turbidity and bank cutting. Whether such a reduction is technologically or economically feasible is doubtful. Riprapping and other methods of shore protection appear to be the most viable alternatives for improving the situation.

The material which causes the deposition problems also contribute to the turbid condition of the lake. While the warmwater habitat standards do not have a criterion for turbidity or suspended solids, particulates in large concentration do limit the quality of an aquatic habitat. Persons familiar with Grand Lake have generally described the water as turbid or "muddy" and the data verifies this; Secchi disc readings for the EPA ranged only between 12 and 20 inches. There is no exact correlation between Secchi inches, turbidity units, percent light transmission, or suspended solids concentrations, so it is difficult to judge the actual effect of suspended solids on the aquatic community. Potentially, suspended material can have several effects on the habitat, some of which depend on the materials' light scattering effect and others on the actual bulk or weight of sediment that might settle out or accumulate. The material in suspension in Grand Lake is most likely a clay originating from the soils of the area. As such, it could limit the ability of the water to transmit light without causing an extremely high suspended solids concentration.

The Water Quality Criteria published in 1972 by EPA suggests that turbidity can impact a lake fishery by: (1) acting directly on fish swimming in water in which solids are suspended; (2) preventing the successful development of fish eggs and larvae; (3) modifying natural movements and migrations of fish; (4) reducing the food available to fish; and (5) affecting efficiency in catching the fish.

These effects are important at Grand Lake because the character and quality of its fishery began to deteriorate (at least in the opinion of many) concurrently with the increase in turbidity. The increase in turbidity apparently resulted from the clearing of the lake bed and shore of trees and stumps, and the loss of rooted aquatic vegetation in the period 1890-1900. The clearing increased the effect of wind in producing wave action, resulting in bank erosion and constant resuspension of sediment particles.

Turbidity also produces other impacts which would indirectly affect the fishery. Because suspended particles inhibit the penetration of sunlight, water temperatures are increased. Photosynthetic activity is also affected; the populations of algae and fixed aquatic plants have apparently changed drastically at Grand Lake, partly because of higher turbidities.

Conclusions

The water quality of Grand Lake has been monitored sufficiently to identify its problems and their probable causes. Further monitoring, without a specific objective, does not appear necessary.

Implementation of the proposed facilities plan should improve the bacteriological quality of the lake and may provide some degree of relief from the algae problem. Documentation of these results could be an interesting research project, but would not be especially beneficial to Grand Lake.

The sediment problems of the lake have not been as well documented. That sedimentation causes problems is apparent from the amount of dredging done by the State of Ohio. However, little is actually known about the quantities and source of sediment or the extent of deposition in areas that are not dredged.

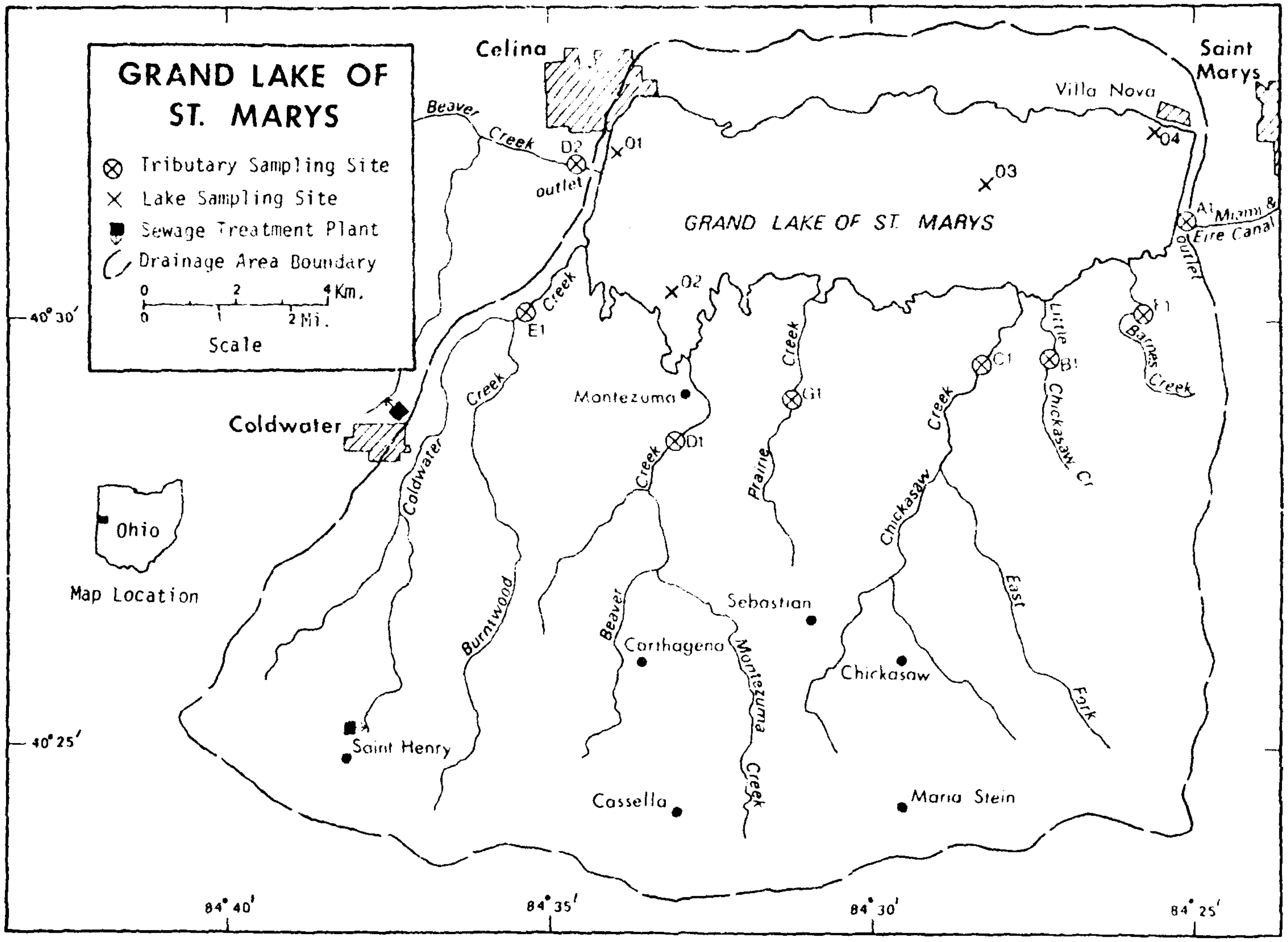
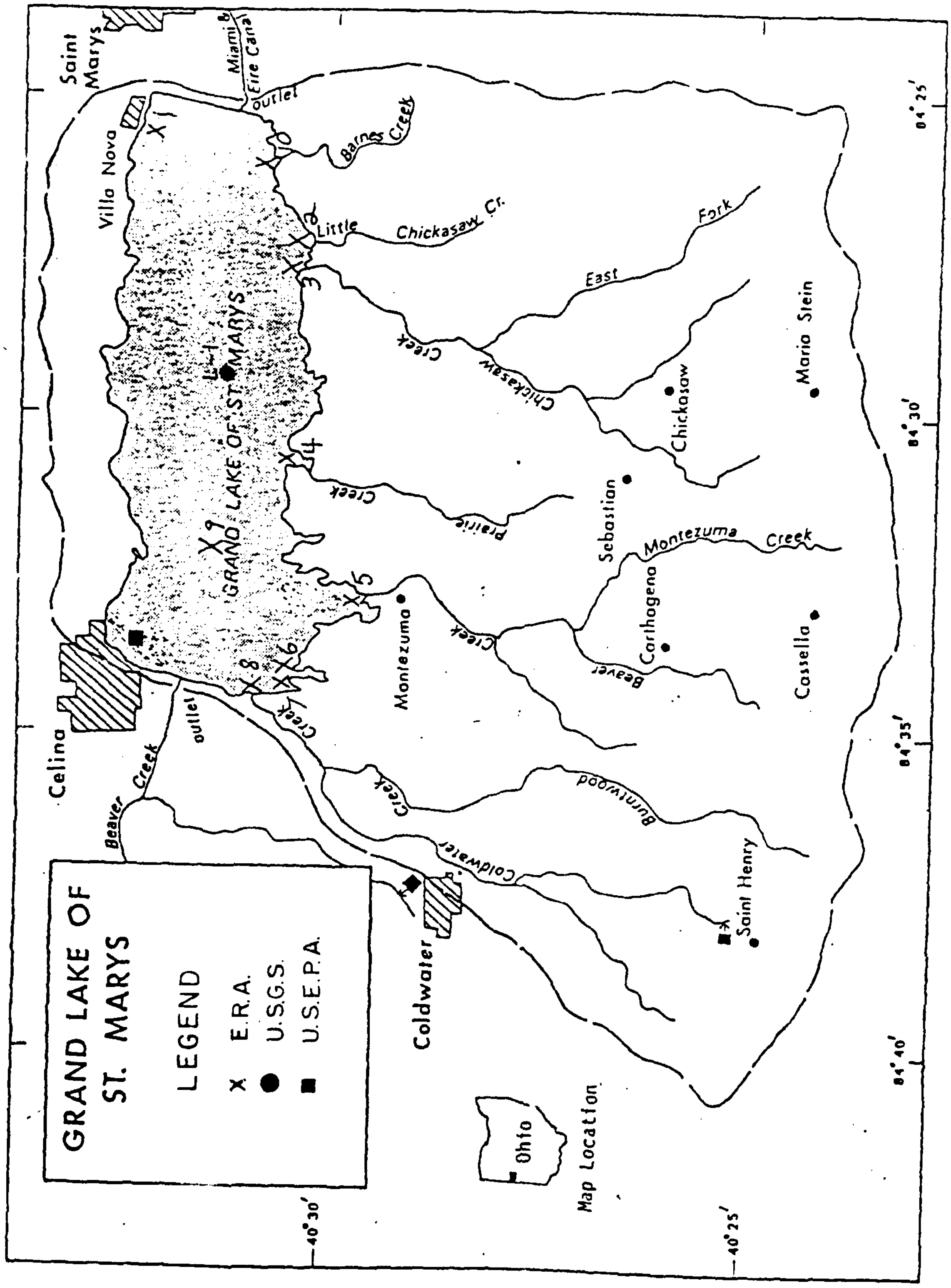


Exhibit 1 U.S. E.P.A. Sampling Stations for National Eutrophication Survey



GRAND LAKE OF ST. MARYS
LEGEND
x E.R.A.
● U.S.G.S.
■ U.S.E.P.A.
GRAND LAKE OF ST. MARYS
Saint Marys
Miami & Erie Canal
outlet
Villa Nova
Barnes Creek
Little Chickasaw Cr.
East Fork
Chickasaw Creek
Chickasaw
Mario Stein
Prairie Creek
Sebastian
Montezuma Creek
Carthagena
Montezuma
Beaver Creek
Cassella
Celina
outlet
Beaver Creek
Creek
Burntwood Creek
Coldwater Creek
Coldwater
Saint Henry
Ohio
Map Location
84°25'
84°30'
84°35'
84°40'
40°30'
40°25'

Exhibit 2

Table 1

GRAND LAKE WATER QUALITY

MERCER-AUGLAIZE ENVIRONMENTAL RESEARCH ASSOCIATION

1972-1975 AVERAGES

TEST SITE	TEMP. °C	pH	Turbidity Formazin Units	D.O. Mg/1	BOD Mg/1	Phos.-ORTHO ppm-PO_4	Phos-TOTAL ppm PO_4	NO_3-N ppm	NH_3 ppm	Fecal Coliform #/100 ml
#1	17.3	7.36	19.2	8.34	10.2	0.223	0.540	7.24	0.91	747
#2	16.8	7.38	31.1	7.80	9.9	0.350	0.546	11.43	0.97	1870+
#3	16.3	7.39	32.3	7.93	9.1	0.258	0.665	10.93	1.05	1795+
#4	17.0	7.44	31.6	8.04	9.0	0.171	0.745	10.07	0.91	2078+
#5	17.4	7.52	36.3	7.54	10.1	0.286	1.145	10.00	1.15	1877+
#6	17.4	7.68	39.4	9.29	9.2	0.193	0.975	7.58	1.05	2483+
#7	18.3	7.62	30.7	9.06	9.6	0.180	0.884	8.38	1.01	2009+
#8	17.6	7.68	27.3	9.00	10.8	0.144	0.552	7.21	1.21	3231+
#9	18.0	7.74	15.8	9.41	8.9	0.160	0.425	6.64	0.82	278
#10	16.9	7.47	37.7	7.52	9.7	0.124	0.731	9.92	1.02	1791+

[illegible] 13

40 31 55.0 084 29 14. 2
[illegible] ST MARYS [illegible]
39[illegible] OHIO

[illegible]/LAKE

112[illegible]0 751210
0000 CLASS 00

Parameter	NUMBER	MEAN	VARIANCE	STAN DEV	COEF VAR	STAND ER	MAXIMUM	MINIMUM	BEG DATE	END DATE
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[illegible]	4	26.2500	172.917	13.1495	.500945	6.57 90	[illegible].0000	15.[illegible]	75/[illegible]	7[illegible]/12
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[illegible]	4	99.99[illegible]	.018229	.135015	.001352	.[illegible]67 [illegible]	[illegible]	[illegible]	75/[illegible]	7[illegible]/12
[illegible]	9	30[illegible].777	11.8[illegible]5	3.43693	.011263	1.14[illegible]64	311.[illegible]	30[illegible]	75/[illegible]	75/[illegible]/12
[illegible]	9	[illegible].011[illegible]9	2.26117	1.50372	.166874	.501 39	1[illegible].2[illegible]00	5.3[illegible]	75/[illegible]	75/[illegible]/12
[illegible]	9	132.[illegible]	382.265	19.5514	.190436	6.51714	1[illegible]	[illegible]	75/[illegible]	75/[illegible]/12
[illegible]	4	[illegible].5[illegible]	13.[illegible]66	3.63[illegible]7	.375574	1.80[illegible]23	1[illegible]	7.[illegible]	75/[illegible]	7[illegible]/12
[illegible]	4	58.5[illegible]	37.6667	6.13732	.089596	3.06 56	76.[illegible]	63.[illegible]	75/[illegible]	7[illegible]/12
[illegible]	9	0.9[illegible]	.[illegible]	.[illegible]7366	.032049	.095[illegible]9	[illegible]	0.[illegible]	75/[illegible]	7[illegible]/12
[illegible]	4	.20[illegible]	.[illegible]4[illegible]67	.215[illegible]24	1.08012	.108 12	.[illegible]	.[illegible]	75/[illegible]	7[illegible]/12
[illegible]	4	54.0[illegible]	6.0[illegible]0	2.44949	.035273	1.22 74	56.[illegible]	51.[illegible]	75/[illegible]	7[illegible]/12
[illegible]	4	56.9979	241.333	15.5349	.263304	7.76745	77.9999	41.[illegible]	75/[illegible]	7[illegible]/12
[illegible]	4	9.2299	40.9166	6.39661	.691527	3.19[illegible]36	1[illegible].0000	.999[illegible]	75/[illegible]	7[illegible]
[illegible] TOTAL	1	227.[illegible]					227.[illegible]	227.[illegible]	75/[illegible]	7[illegible]
[illegible]	1	33.[illegible]					33.[illegible]	33.[illegible]	75/[illegible]	7[illegible]
[illegible]	4	2.1[illegible]	.966662	.979797	.466570	.489 98	[illegible]	1.[illegible]	75/[illegible]	7[illegible]
[illegible]	4	1.57[illegible]	.76[illegible]99[illegible]	.873211	.442132	.436[illegible]6	[illegible]00	1.[illegible]	75/[illegible]	7[illegible]
[illegible] TOTAL	4	.137[illegible]	.016225	.127378	.926362	.063 39	.[illegible]	.[illegible]	75/[illegible]	7[illegible]
[illegible] TOTAL	4	.01[illegible]	-.776E-1[illegible]	.000000		.000 00	.01[illegible]	.01[illegible]	75/[illegible]	[illegible]
[illegible]	4	.0175[illegible]	.001225	.035000	2.00000	.017[illegible]00	.[illegible]7[illegible]	.[illegible]	75/[illegible]	[illegible]
[illegible]	4	2.07[illegible]	1.[illegible]	1.[illegible]7[illegible]9	.445729	.[illegible]3[illegible]4	[illegible]	1.[illegible]	75/[illegible]	[illegible]
[illegible]	4	.027[illegible]	.[illegible]	.[illegible]	1.27273	.017 00	.[illegible]	.[illegible]	75/[illegible]	7[illegible]
[illegible]	4	.1575[illegible]	.000625	.025000	.158729	.012[illegible]00	.1[illegible]	.15[illegible]	75/[illegible]	7[illegible]
[illegible]	4	14.25[illegible]	14.9167	3.86221	.271032	1.93110	[illegible]	12.[illegible]	7[illegible]	7[illegible]
[illegible]	1	12.[illegible]					12.[illegible]	12.[illegible]	75/[illegible]	7[illegible]
[illegible]	1	21.0[illegible]					21.[illegible]	21.[illegible]	7[illegible]	7[illegible]
[illegible]	1	16.0[illegible]					16.[illegible]	1[illegible]	[illegible]	[illegible]
[illegible]	1	1[illegible].0[illegible]					1[illegible]	1[illegible]	75/[illegible]	7[illegible]/16
[illegible]	1	.40[illegible]					.40[illegible]	.4[illegible]	75/[illegible]	7[illegible]
[illegible]	1	15.[illegible]					15.[illegible]	15.[illegible]	[illegible]	7[illegible]
[illegible]	1	3.50[illegible]					3.5[illegible]	3.5[illegible]	7[illegible]	7[illegible]
[illegible]	1	19.0[illegible]					19.[illegible]	19.[illegible]	[illegible]	[illegible]
[illegible]	1	63.[illegible]					63.[illegible]	63.[illegible]	[illegible]	7[illegible]
[illegible]	1	.500[illegible]					.500[illegible]00	.5[illegible]	75/[illegible]	7[illegible]
[illegible]	4	.500[illegible]	.033333	.182575	.608582	.091 87	.5[illegible]	.[illegible]	75/[illegible]	7[illegible]
[illegible]	1	9.999[illegible]					9.99990	9.999	75/.5/[illegible]	7[illegible]/16
[illegible]	1	100.0[illegible]					100.000	10[illegible]	75/[illegible]	7[illegible]
[illegible]	1	40.000[illegible]					40.0[illegible]	4[illegible]	75/[illegible]	75/.5/1[illegible]

Table 2 U.S.G.S. Station L-1.

STORET

40 31 35.0 084 29 14.0 2
GRAND LK ST MARYS [illegible] MIDPOINT [illegible]
39107 OHIO

/TYPA/[illegible]/LAKE

112ARD 751210
0000 CLASS 00

PARAMETER			NUMBER	MEAN	VARIANCE	STAN DEV	COEF VAR	STAND ER	MAXIMUM	MINIMUM	BEG DATE	END DATE
01027 CADMIUM	CD,TOT	UG/L	1	.000000					.000000	.000000	75/05/16	75/05/16
01034 CHROMIUM	CR,TOT	UG/L	1	10.0000					10.0000	10.0000	75/05/16	75/05/16
01037 [illegible]	CO,TOTAL	UG/L	1	1.00000					1.00000	1.00000	75/05/16	75/05/16
01042 COPPER	CU,TOT	UG/L	1	.000000					.000000	.000000	75/05/16	75/05/16
01045 IRON	FE,TOT	UG/L	1	1000.00					1000.00	1000.00	75/05/16	75/05/16
01051 LEAD	PB,TOT	UG/L	1	3.00000					3.00000	3.00000	75/05/16	75/05/16
01055 MANGANESE	MN	UG/L	1	60.0000					60.0000	60.0000	75/05/16	75/05/16
01062 [illegible]	MO,TOT	UG/L	1	9.00000					9.00000	9.00000	75/05/16	75/05/16
01067 NICKEL	NI,TOTAL	UG/L	1	1.00000					1.00000	1.00000	75/05/16	75/05/16
01077 SILVER	AG,TOT	UG/L	1	.000000					.000000	.000000	75/05/16	75/05/16
01092 ZINC	ZN,TOT	UG/L	1	10.0000					10.0000	10.0000	75/05/16	75/05/16
01147 SELENIUM	SE,TOT	UG/L	1	1.00000					1.00000	1.00000	75/05/16	75/05/16
31616 FEC COLI	MFM-FCBR	/100 ML	4	3.00000	-.508E-05	.000000		.000000	3.00000	3.00000	75/05/16	75/08/12
31673 FECSTREP	[illegible]	/100 ML	4	3.00000	-.508E-05	.000000		.000000	[illegible]	3.[illegible]	75/05/16	75/08/12
[illegible]	[illegible]	MG/L	1	.050000					.050000	.050000	75/05/16	75/05/16
[illegible]	TOTAL	[illegible]	2	200.000	.800E-11	282843	.108786	200.000	[illegible]	2[illegible]	75/05/16	75/08/12
[illegible]	DISS-IAS	[illegible]	1	194.000					194.000	194.000	75/05/16	75/05/16
[illegible]	[illegible] PEP	ACH[illegible]	1	.200000					.200000	.200000	75/05/16	75/05/16
70507 PHOS-T	ORTHO	MG/L P	4	.010000	-.776E-10	.000000		.000000	.010000	.010000	75/05/16	75/08/12
71875 [illegible]		MG/L	4	.000000	.000000	.000000		.000000	.000000	.000000	75/05/16	75/08/12
71887 TOTAL [illegible]	AS NO3	MG/L	4	9.37[illegible]	20.1891	4.49323	.479278	2.24661	15.0000	5.7[illegible]	75/05/16	75/08/12
71900 [illegible]	HG,TOTAL	UG/L	1	.500000					.500000	.500000	75/05/16	75/05/16
72025 [illegible]	[illegible]	FEET	4	4.75000	10.2500	3.20156	.674013	1.60078	[illegible]	2.000[illegible]	75/05/16	75/08/12

Table 2 (cont'd) U.S.G.S. Station L-1.

STORET 2/13

40 32 30.0 084 34 24.0 2
CELINA
39 OHIO
OHIO RIVER 060191
WABASH RIVER
21OHIO
0001 CLASS 00

/MUN/NTRMIT/I-TAKE/WELL/STREAM/LAKE

PARAMETER				NUMBER	MEAN	VARIANCE	STAN DEV	COEF VAR	STAND ER	MAXIMUM	MINIMUM	BEG DATE	END DATE
00070	TURB	JKSN	JTU	6	16.1166	121.482	11.0219	.683882	4.49967	35.0000	1.70000	70/07/22	77/03/16
00080	COLOR	PT-CO	UNITS	4	9.00000	93.3333	9.66092	1.07343	4.83046	23.0000	1.00000	70/07/22	74/11/25
00095	CNDUCTVY	AT 25C	MICROMHO	3	738.333	369259	607.667	.823025	350.836	1440.00	355.000	73/12/17	74/11/25
00403	LAB	PH	SU	6	7.19999	.088086	.296793	.041221	.121165	7.70000	6.80000	70/07/22	77/03/16
00410	T ALK	CACO3	MG/L	6	106.667	1059.47	32.5496	.305152	13.2885	165.000	71.0000	70/07/22	77/03/16
00415	PHENLPHTH	LEIN ALK	MG/L	4	.000000	.000000	.000000		.000000	.000000	.000000	70/07/22	74/11/25
00500	RESIDUE	TOTAL	MG/L	4	515.250	249221	499.220	.968890	249.610	1264.00	250.000	70/07/22	74/11/25
00530	NH3-N	TOTAL	MG/L	5	.696000	.619830	.787293	1.13117	.352088	1.85000	.000000	73/12/17	77/03/16
00650	T PO4	PO4	MG/L	3	.133333	.003333	.057735	.433014	.033333	.200000	.100000	73/12/17	74/11/25
00900	TOT HARD	CACO3	MG/L	4	319.500	90467.6	300.778	.941403	150.389	770.000	154.000	70/07/22	74/11/25
00915	CALCIUM	CA,DISS	MG/L	1	38.0000					38.0000	38.0000	70/07/22	70/07/22
00916	CALCIUM	CA-TOT	MG/L	5	63.0000	2873.00	53.6004	.850800	23.9708	155.000	32.0000	73/12/17	77/03/16
00925	MGNSIUM	MG,DISS	MG/L	1	15.0000					15.0000	15.0000	70/07/22	70/07/22
00927	MGNSIUM	MG,TOT	MG/L	5	31.6000	646.801	25.4323	.804819	11.3737	77.0000	19.0000	73/12/17	77/03/16
00929	SODIUM	NA,TOT	MG/L	5	26.0000	888.000	29.7993	1.14613	13.3267	79.0000	8.00000	73/12/17	77/03/16
00930	SODIUM	NA,DISS	MG/L	1	11.0000					11.0000	11.0000	70/07/22	70/07/22
00937	PTSSIUM	K,TOT	MG/L	3	4.03333	.803337	.896291	.222221	.517474	4.60000	3.00000	73/12/17	74/11/25
00940	CHLORIDE	CL	MG/L	6	20.6667	39.6672	6.31405	.305518	2.57770	27.0000	10.0000	70/07/22	77/03/16
00945	SULFATE	SO4-TOT	MG/L	6	185.667	87724.6	296.184	1.59524	120.916	790.000	51.0000	70/07/22	77/03/16
00950	FLUORIDE	F,DISS	MG/L	6	.540000	.497840	.705578	1.30663	.288051	1.96000	.250000	70/07/22	77/03/16
01007	BARIUM	BA,TOT	UG/L	5	.000000	.000000	.000000		.000000	.000000	.000000	73/12/17	77/03/16
01012	BERYLIUM	BE,TOT	UG/L	3	.000000	.000000	.000000		.000000	.000000	.000000	73/12/17	74/11/25
01027	CADMIUM	CD,TOT	UG/L	5	.000000	.000000	.000000		.000000	.000000	.000000	73/12/17	77/03/16
01034	CHROMIUM	CR,TOT	UG/L	5	.000000	.000000	.000000		.000000	.000000	.000000	73/12/17	77/03/16
01042	COPPER	CU,TOT	UG/L	3	10.0000	300.000	17.3205	1.73205	10.0000	30.0000	.000000	73/12/17	74/11/25
01045	IRON	FE,TOT	UG/L	6	1195.00	1297970	1139.24	.953340	465.093	3210.00	100.000	70/07/22	77/03/16
01051	LEAD	PB,TOT	UG/L	5	1.40000	9.80000	3.13049	2.23607	1.40000	7.00000	.000000	73/12/17	77/03/16
01055	MANGNESE	MN	UG/L	6	86.6667	2026.67	45.0186	.519445	18.3787	130.000	30.0000	70/07/22	77/03/16
01067	NICKEL	NI,TOTAL	UG/L	3	.000000	.000000	.000000		.000000	.000000	.000000	73/12/17	74/11/25
01077	SILVER	AG,TOT	UG/L	5	.000000	.000000	.000000		.000000	.000000	.000000	73/12/17	77/03/16
01092	ZINC	ZN,TOT	UG/L	3	.000000	.000000	.000000		.000000	.000000	.000000	73/12/17	74/11/25
01105	ALUMINUM	AL,TOT	UG/L	3	200.000	30000.0	173.205	.866025	100.000	300.000	.000000	73/12/17	74/11/25
31503	TOT COLI	MPN CONF	/100 ML	1	570.000					570.000	570.000	75/06/01	75/06/01
38260	MBAS		MG/L	3	.040000	.001300	.036056	.901389	.020817	.070000	.000000	73/12/17	74/11/25
39330	ALDRIN		TOT UG/L	1	.000000					.000000	.000000	76/04/19	76/04/19
39340	GAMMABHC	LINDANE	TOT UG/L	1	.000000					.000000	.000000	76/04/19	76/04/19
39350	CHLRDANE	TECH&MET	TOT UG/L	1	.000000					.000000	.000000	76/04/19	76/04/19
39360	DDD	WHL SMPL	UG/L	1	.000000					.000000	.000000	76/04/19	76/04/19
39365	DDE	WHL SMPL	UG/L	1	.000000					.000000	.000000	76/04/19	76/04/19

Table 3 U.S.E.P.A. Celina raw water.

STORET

.. .01
40 32 30.0 084 34 24.0 2
CELINA
39 OHIO
OHIO RIVER 060191
WABASH RIVER
21OHIO
0001 CLASS 00

/MUN/NTRTMT/INTAKE/WELL/STREAM/LAKE

PARAMETER			NUMBER	MEAN	VARIANCE	STAN DEV	COEF VAR	STAND ER	MAXIMUM	MINIMUM	BEG DATE	END DATE
39370 DDT	WHL SMPL	UG/L	1	.000000					.000000	.000000	76/04/19	76/04/19
39380 DIELDRIN		TOT UG/L	1	.000000					.000000	.000000	76/04/19	76/04/19
39390 ENDRIN		TOT UG/L	1	.000000					.000000	.000000	76/04/19	76/04/19
39410 HEPTCHLR		TOT UG/L	1	.000000					.000000	.000000	76/04/19	76/04/19
39420 HPCHLREP		TOT UG/L	1	.000000					.000000	.000000	76/04/19	76/04/19
39[illegible] [illegible]XYCLR	WHL SMPL	UG/L	1	.000000					.000000	.000000	76/04/19	76/04/19
39530 MALATHN	WHL SMPL	UG/L	1	.000000					.000000	.000000	76/04/19	76/04/19
39540 PARATHN	WHL SMPL	UG/L	1	.000000					.000000	.000000	76/04/19	76/04/19
39600 [illegible]	WHL SMPL	UG/L	1	.000000					.000000	.000000	76/04/19	76/04/19
39782 LINDANE	WHL SMPL	UG/L	1	.000000					.000000	.000000	76/04/19	76/04/19
70311 [illegible]	CACO3	STD L	4	7.42500	.042577	.206342	.027790	.103171	7.70000	7.20000	76/07/[illegible]	7[illegible]/11/25
70023 [illegible]LK	CACO3	STD L	6	114.167	576.175	24.0036	.210251	9.79945	155.000	84.0000	76/07/[illegible]	77/[illegible]

ATTACHMENT 1
19

Table 3 (cont'd) U.S.E.P.A. Celina raw water.

STORET

/PUN/TRE TD/INTAKE/WELL/STREAM/LAKE

40 32 30.0 084 34 24.0 2
CELINA
39 OHIO
OHIO RIVER 060191
WABASH RIVER
21OHIO
0001 CLASS 00

PARAMETER				NUMBER	MEAN	VARIANCE	STAN DEV	COEF VAR	STAND ER	MAXIMUM	MINIMUM	BEG DATE	END DATE
00070	TURB	JKSN	JTU	2	1,30000	,180002	,424267	,326359	,300002	1,60000	1,00000	70/07/22	75/05/21
00080	COLOR	PT-CO	UNITS	1	,000000					,000000	,000000	70/07/22	70/07/22
00403	LAB	PH	SU	3	9,60000	,130127	,360731	,037576	,208268	10,0000	9,30000	70/07/22	77/12/14
00410	T ALK	CACO3	MG/L	3	24,0000	76,0000	8,71780	,363242	5,03322	30,0000	14,0000	70/07/22	77/12/14
00415	P -PH-	LFIN ALK	MG/L	1	39,0000					39,0000	39,0000	70/07/22	70/07/22
00500	RESIDUE	TOTAL	MG/L	1	222,000					222,000	222,000	70/07/22	70/07/22
00515	RESIDUE	DISS-105	C MG/L	1	255,000					255,000	255,000	77/12/14	77/12/14
00620	[illegible]	TOTAL	MG/L	3	,160000	,009300	,096436	,602728	,055678	,230000	,050000	70/07/22	77/12/14
00900	T HARD	CACO3	MG/L	1	100,000					100,000	100,000	70/07/22	70/07/22
00915	CALCIUM	CA,DISS	MG/L	1	29,6000					29,6000	29,6000	70/07/22	70/07/22
00916	CALCIUM	CA-TOT	MG/L	2	25,0000	2,00000	1,41421	,056569	1,00000	26,0000	24,0000	76/06/[illegible]	77/12/14
00925	MGNSIUM	MG,DISS	MG/L	1	6,00000					6,00000	6,00000	70/07/22	70/07/22
00927	MGNSIUM	MG,TOT	MG/L	2	10,0000	8,00000	2,82843	,282843	2,00000	12,0000	8,00000	76/06/[illegible]	77/12/14
00929	SODIUM	NA,TOT	MG/L	2	32,0000	200,000	14,1421	,441942	10,0000	42,0000	22,0000	76/06/[illegible]	77/12/14
00930	SODIUM	NA,DISS	MG/L	1	18,0000					18,0000	18,0000	70/07/22	70/07/22
00935	PTSSIUM	K,DISS	MG/L	1	4,58000					4,58000	4,58000	70/07/[illegible]	70/07/22
00940	CHLORIDE	CL	MG/L	3	37,3333	49,3340	7,02381	,188138	4,05520	44,0000	30,0000	70/07/22	77/12/14
00945	SULFATE	SO4-TOT	MG/L	3	82,3333	633,336	25,1662	,305662	14,5297	109,000	59,0000	70/07/22	77/12/14
00950	FLUORIDE	F,DISS	MG/L	3	,216667	,000433	,020616	,096076	,012018	,240000	,200000	70/07/22	77/12/14
01002	ARSENIC	AS,TOT	UG/L	1	10,0000					10,0000	10,0000	77/12/14	77/12/14
01007	BARIUM	BA,TOT	UG/L	2	100,000	20000,0	141,421	1,41421	100,000	200,000	,000000	76/06/[illegible]	77/12/14
01025	CADMIUM	CD,DISS	UG/L	1	,000000					,000000	,000000	70/07/[illegible]	70/07/22
01027	CADMIUM	CD,TOT	UG/L	2	2,50000	12,5000	3,53553	1,41421	2,50000	5,00000	,000000	76/06/[illegible]	77/12/14
01030	CHROMIUM	CR,DISS	UG/L	1	,000000					,000000	,000000	70/07/22	70/07/22
01034	CHROMIUM	CR,TOT	UG/L	2	15,0000	450,000	21,2132	1,41421	15,0000	30,0000	,000000	76/06/[illegible]	77/12/14
01040	COPPER	CU,DISS	UG/L	1	,000000					,000000	,000000	70/07/22	70/07/22
01042	COPPER	CU,TOT	UG/L	1	50,0000					50,0000	50,0000	77/12/14	77/12/14
01045	IRON	FE,TOT	UG/L	3	13,3333	233,333	15,2753	1,14564	6,81917	30,0000	,000000	70/07/[illegible]	77/12/14
01049	LEAD	PB,DISS	UG/L	1	,000000					,000000	,000000	70/07/22	70/07/22
01051	LEAD	PB,TOT	UG/L	2	2,50000	12,5000	3,53553	1,41421	2,50000	5,00000	,000000	76/06/[illegible]	77/12/14
01055	MNGNESE	MN	UG/L	3	23,3333	433,334	20,8167	,892143	12,0185	40,0000	,000000	70/07/[illegible]	77/12/14
01065	NICKEL	NI,DISS	UG/L	1	10,0000					10,0000	10,0000	70/07/22	70/07/22
01075	SILVER	AG,DISS	UG/L	1	,000000					,000000	,000000	70/07/22	70/07/22
01077	SILVER	AG,TOT	UG/L	2	15,0000	450,000	21,2132	1,41421	15,0000	30,0000	,000000	76/06/[illegible]	77/12/14
01090	ZINC	ZN,DISS	UG/L	1	30,0000					30,0000	30,0000	70/07/22	70/07/22
01092	ZINC	ZN,TOT	UG/L	1	30,0000					30,0000	30,0000	77/12/[illegible]	77/12/14
01147	SELENIUM	SE,TOT	UG/L	1	5,00000					5,00000	5,00000	77/12/14	77/12/14
01501	ALPHA	TOTAL	PC/L	3	1,00000	,000000	,000000		,000000	1,00000	1,00000	75/01/[illegible]	75/05/21
31505	TOT COLI	MPN CONF	/100ML	1	,000000					,000000	,000000	75/05/[illegible]	75/05/[illegible]

Table 4 U.S.E.P.A. **Celina** finished water.

STORET

40 52 30.0 084 34 24.0 2
CELINA
39 OHIO
OHIO RIVER
WABASH RIVER
21OHIO
0001 CLASS 00

660191

/MUN/TREATED/INTAKE/WELL/STREAM/LAKE

PARAMETER			NUMBER	MEAN	VARIANCE	STAN DEV	COEF VAR	STAND ER	MAXIMUM	MINIMUM	BEG DATE	END DATE
382·0 ·GAS		MG/L	1	.050000					.050000	.050000	77/12/[illegible]	77/12/14
3939· E· ··		TOT MG/L	1	.030000					.030000	.030000	77/11/[illegible]	77/11/16
3947· T· ·APHEN		TOT MG/L	1	.500000					.500000	.500000	77/11/[illegible]	77/11/16
39··· ·· ·YCLR	AHL SMPL	UG/L	1	.150000					.150000	.150000	77/11/[illegible]	77/11/16
39782 LI ·A·E	AHL S-PL	UG/L	1	.010000					.010000	.010000	77/11/[illegible]	77/11/16
7·311 ··	CACO3	STAPL	1	9.60000					9.60000	9.60000	7·/07/[illegible]	7·/07/22
71900 ME·C·RY	HG,TOTAL	UG/L	1	.500000					.500000	.500000	77/12/[illegible]	77/12/14
74023 ALK	CACO3	STAPL	3	24.3333	20.3337	4.50929	.185313	2.60544	29.0000	20.0000	7·/07/[illegible]	77/12/14

ATTACHMENT 1
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Table 4 (cont'd) U.S.E.P.A. **Celina finished water.**

STORET RETRIEVAL DATE 75/01/27

392701
40 32 07.0 084 34 11.0
LAKE SAINT MARYS
39107 OHIO

11EPALES 3 — 2111202 0006 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/05/04	09 30	0000	12.7		10	400	7.20	98	0.110	2.000	0.100	0.012
	09 30	0004	12.7	8.6		380	7.70	99	0.110	2.200	0.110	0.012
73/08/01	12 00	0000	24.2	6.8	18	344	9.10	96	0.120	2.200	0.160	0.018
73/10/11	14 35	0000	20.4	7.8	8	330	9.10	88	0.100	1.200	0.060	0.041

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/05/04	09 30	0000	0.188	56.0
	09 30	0004	0.176	
73/08/01	12 00	0000	0.136	86.2
73/10/11	14 35	0000	0.480	61.8

Table 5 U.S.E.P.A. National Eutrophication Survey (N.E.S.)

STORET RETRIEVAL DATE 75/01/27

392702
40 30 34.0 084 33 12.0
LAKE SAINT MARYS
39107 OHIO

11EPALES 2111202
3 0006 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/05/04	10 00	0000	11.9		3	400	8.00	107	0.090	2.200	0.090	0.012
	10 00	0003	12.2	9.0		400	8.10	108	0.090	2.400	0.100	0.018
73/08/01	11 40	0000	23.4	7.2	16	350	8.60	94	0.130	2.000	0.170	0.014
73/10/11	14 50	0000	19.4	8.0	16	319	8.80	89	0.080	1.700	0.050	0.033

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/05/04	10 00	0000	0.140	75.9
	10 00	0003	0.157	
73/08/01	11 40	0000	0.131	84.1
73/10/11	14 50	0000	0.123	63.2

Table 6 N.E.S. Station 02

STORET RETRIEVAL DATE 75/01/27

392703
40 31 38.0 084 28 18.0
LAKE SAINT MARYS
39107 OHIO

11EPALES
3

2111202
0007 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/05/04	10 30	0000	12.2		2	370	8.10	102	0.110	3.200	0.110	0.012
	10 30	0005	12.2	8.8		400	8.20	108	0.090	3.400	0.100	0.014
73/08/01	11 00	0000	23.7	8.0	18	338	8.80	88	0.090	2.200	0.100	0.010
73/10/11	15 10	0000	19.8	10.8	39	313	9.10	89	0.080	1.400	0.050	0.032
	15 10	0004	19.7			309						

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/05/04	10 30	0000	0.219	144.5
	10 30	0005	0.268	
73/08/01	11 00	0000	0.115	88.4
73/10/11	15 10	0000	0.089	45.3

Table 7 N.E.S. Station 03

STORET RETRIEVAL DATE 75/01/27

392704
40 32 29.0 084 25 39.0
LAKE SAINT MARYS
39011 OHIO

11EPALES 2111202
3 0006 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/05/04	10 50	0000	12.0		3	380	8.10	105	0.110	2.800	0.130	0.014
	10 50	0003	12.1	9.4		380	8.10	111	0.130	2.700	0.130	0.011
73/08/01	11 00	0000	23.9	8.2	18	339	8.90	91	0.090	2.000	0.150	0.011
73/10/11	15 20	0000	21.2	11.0	39	321	9.20	87	0.070	1.200	0.050	0.023

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/05/04	10 50	0000	0.303	127.3
	10 50	0003	0.257	
73/08/01	11 00	0000	0.128	69.7
73/10/11	15 20	0000	0.083	47.4

Table 8 N.E.S. Station 04

STORET RETRIEVAL DATE 75/02/03

3927A1
40 31 16.0 084 25 17.0
MIAMI AND ERIE CANAL
39139 7.5 ST MARYS
O/GRAND LAKE OF ST MARYS
AT FLOODGATE NEAR BULKHEAD
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/05/06	07 45		0.010K	2.100	0.011	0.014	0.190
73/06/09	14 25		0.010K	1.260	0.128	0.017	0.115
73/07/15	14 15		0.027	2.600	0.046	0.028	0.125
73/08/12	09 15		0.022	1.800	0.019	0.017	0.115
73/09/09	13 40		0.015	1.800	0.021	0.010	0.123
73/10/13	10 25		0.038	1.850	0.052	0.012	0.135
73/11/11	11 00		0.056	0.900	0.028	0.015	0.102
73/12/08	10 00		0.440	1.100	0.036	0.024	0.095
74/01/13	10 40		0.430	1.800	0.140	0.010	0.065
74/02/17	10 30		1.260	1.600	0.090	0.015	0.145
74/03/03	11 15		1.500	2.100	0.050	0.035	0.280
74/03/19	19 40		1.180	2.000	0.020	0.055	0.200
74/04/02	17 45		1.440	2.500	0.030	0.075	0.240
74/04/21	11 30		0.288	2.400	0.027	0.035	0.190

K VALUE KNOWN TO BE
LESS THAN INDICATED

Table 9 N.E.S. Station A1

STORET RETRIEVAL DATE 75/02/03

392781
40 29 40.0 084 27 25.0
LITTLE CHICKASAW CREEK
39 7.5 NEW BREMEN
T/GRAND LAKE OF ST MARYS
ST RT 703 BRDG NEAR COUNTY LINE JCT
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/05/06	08 20		2.500	1.260	0.060	0.042	0.080
73/06/09	14 55		4.800	1.900	0.126	0.088	0.152
73/07/15	14 40		2.600	1.470	0.154	0.120	0.220
73/08/12	09 50		6.000	3.900	0.230	0.405	1.050
73/09/09	13 50		0.410	1.260	0.110	0.019	0.090
73/10/13	11 10		0.010K	1.650	0.042	0.020	0.135
73/11/11	11 45		0.040	1.800	0.132	0.072	0.190
73/12/08	10 40		3.700	1.100	0.176	0.148	0.180
74/01/13	09 30		3.960	1.400	0.440	0.130	0.280
74/02/17	11 20		3.780	0.700	0.140	0.085	0.180
74/03/03	10 25		4.500	0.700	0.040	0.060	0.150
74/03/19	19 55		3.700	0.700	0.050	0.060	0.115
74/04/02	17 50		4.200	1.025	0.080	0.075	0.160
74/04/21	11 15		2.700	0.900	0.060	0.040	0.045

K VALUE KNOWN TO BE
LESS THAN INDICATED

Table 10 N.E.S. Station B1

STORET RETRIEVAL DATE 75/02/03

3927C1
40 29 40.0 084 28 25.0
CHICKASAW CREEK
39 7.5 NEW BREMEN
T/GRAND LAKE OF ST MARYS
ST RT 703 BRDG NEAR JCT WITH BEHM RD
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/05/06	08 30		2.200	1.200	0.052	0.084	0.150
73/06/09	15 10		0.074	1.300	0.024	0.023	0.230
73/07/15	14 55		0.990	1.760	0.120	0.031	0.145
73/08/12	10 10		3.900	4.100	0.260	0.460	1.330
73/09/09	14 05		0.056	1.760	0.025	0.044	0.220
73/10/13	11 20		0.020	2.100	0.120	0.069	0.325
73/11/11	12 05		0.560	2.400	0.690	0.240	0.375
73/12/08	11 00		3.080	1.400	0.430	0.270	0.339
74/01/13	09 50		3.200	1.500	0.600	0.260	0.345
74/02/17	11 45		3.780	1.400	0.240	0.135	0.210
74/03/03	10 05		3.960	1.100	0.120	0.120	0.250
74/03/19	20 05		3.700	0.700	0.115	0.125	0.195
74/04/02	18 15		3.700	1.200	0.090	0.120	0.220
74/04/21	11 00		2.400	1.000	0.025	0.090	0.120

Table 11 N.E.S. Station C1

STORET RETRIEVAL DATE 75/02/03

392701
40 28 46.0 084 33 02.0
BEAVER CREEK
39 7.5 MONTEZUMA
T/GRAND LAKE OF ST MARYS
GUADALUPE RD BRDG .5 MI S OF MONTEZUMA
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/05/06	09 00		1.100	1.400	0.035	0.048	0.115
73/06/09	15 55		3.300	1.760	0.220	0.120	0.200
73/07/15	15 00		0.115	1.320	0.160	0.033	0.135
73/08/12	09 35		5.500	5.100	0.540	0.450	1.450
73/09/09	14 30		0.040	1.260	0.071	0.072	0.240
73/10/13	12 45		0.010K	0.350	0.036	0.054	0.070
73/11/11	14 00		0.580	2.400	0.700	0.176	0.290
73/12/08	11 46		3.300	1.300	0.270	0.216	0.290
74/01/12	11 30		3.200	1.000	0.312	0.160	0.220
74/02/17	12 25		3.780	0.900	0.195	0.125	0.195
74/03/03	09 15		4.300	1.000	0.065	0.085	0.210
74/03/19	20 30		3.520	0.800	0.085	0.100	0.165
74/04/02	16 30		3.700	1.300	0.090	0.100	0.195
74/04/21	10 25		1.380	1.100	0.040	0.045	0.115

K VALUE KNOWN TO BE
LESS THAN INDICATED

Table 12 N.E.S. Station D1

ATTACHMENT 1

STORET RETRIEVAL DATE 75/02/03

3927D2
40 32 05.0 084 34 40.0
BEAVER CREEK
39 7.5 CELINA
O/GRAND LAKE OF ST MARYS
US 127 BRDG S OF CELINA
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/05/06	09 20		0.086	2.730	0.094	0.016	0.180
73/06/09	16 40		0.200	2.400	0.120	0.019	0.125
73/07/15	14 14		0.027	2.250	0.027	0.023	0.150
73/08/12	10 10		0.094	1.100	0.039	0.022	0.135
73/09/09	14 55		0.010K	2.000	0.020	0.033	0.180
73/10/13	14 15		0.180	1.340	0.515	0.010	0.280
73/11/11	14 15		0.860	2.300	0.950	0.044	0.220
73/12/08	12 30		0.330	0.800	0.044	0.032	0.120
74/01/12	10 30		1.010	1.100	0.156	0.024	0.080
74/02/17	12 40		1.700	1.650	0.075	0.030	0.143
74/03/03	08 50		1.300	3.000	0.060	0.050	0.375
74/03/19	21 05		1.100	1.600	0.020	0.040	0.165
74/04/02	18 30		0.650	3.000	0.045	0.025	0.300
74/04/21	09 30		0.330	2.700	0.015	0.035	0.195

K VALUE KNOWN TO BE
LESS THAN INDICATED

Table 13 N.E.S. Station D2

ATTACHMENT 1

STORET RETRIEVAL DATE 75/02/03

3927E1
40 30 15.0 084 35 30.0
COLDWATER CREEK
39 7.5 CELINA
I/GRAND LAKE OF ST MARYS
COLDWATER CREEK RD BRDG NW OF MONTEZUMA
11EPALES 2111204
4
0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/05/06	09 10		1.200	1.150	0.037	0.200	0.270
73/06/09	16 20		3.000	1.900	0.189	0.252	0.340
73/07/15	14 21		0.640	2.300	0.115	0.042	0.230
73/08/12	09 55		6.700	4.600	0.480	0.360	1.200
73/09/09	14 45		0.086	1.980	0.180	0.220	0.450
73/10/13	13 45		0.066	3.200	0.490	0.970	1.100
73/11/11	13 55		0.760	1.880	0.645	1.440	1.600
73/12/08	12 05		3.700	2.000	0.570	0.480	0.600
74/01/12	11 00		3.360	1.100	0.470	0.224	0.300
74/02/17	13 10		3.700	0.800	0.175	0.145	0.210
74/03/03	08 30		4.300	1.200	0.100	0.165	0.330
74/03/19	20 55		3.780	0.800	0.060	0.140	0.235
74/04/02	18 00		3.800	1.200	0.090	0.160	0.250
74/04/21	09 15		1.400	1.200	0.045	0.240	0.330

Table 14 N.E.S. Station E1

ATTACHMENT 1

STORET RETRIEVAL DATE 75/02/03

3927F1
40 30 15.0 084 26 00.0
BARNES CREEK
39 7.5 ST MARYS
T/GRAND LAKE OF ST MARYS
RT 364 BRDG 4 MI SW OF ST MARYS
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/05/06	08 10		3.300	1.470	0.056	0.033	0.115
73/06/09	14 40		0.010K	1.260	0.011	0.010	0.220
73/07/15	14 30		2.700	2.700	0.090	0.019	0.165
73/08/12	09 35		6.700	3.570	0.320	0.350	0.700
73/09/09	13 45		0.010K	2.520	0.046	0.040	0.310
73/10/13	10 45		0.015	3.500	0.060	0.042	0.490
73/11/11	11 25		0.750	1.950	0.216	0.024	0.140
73/12/08	10 25		3.300	0.800	0.152	0.124	0.180
74/01/12	10 15		3.900	1.000	0.132	0.116	0.165
74/02/17	11 00		4.100	0.600	0.085	0.060	0.105
74/03/03	10 50		4.600	0.700	0.025	0.045	0.120
74/03/19	19 50		3.900	0.700	0.030	0.065	0.115
74/04/02	18 05		4.100	1.000	0.065	0.060	0.185
74/04/21	11 20		2.800	1.100	0.035	0.050	0.150

K VALUE KNOWN TO BE
LESS THAN INDICATED

Table 15 N.E.S. Station F1

ATTACHMENT 1

STORET RETRIEVAL DATE 75/02/03

392761
40 29 15.0 084 31 30.0
PRAIRIE CREEK
39 7.5 MONTEZUMA
T/GRAND LAKE OF ST MARYS
RT 219 1.5 MI E OF MONTEZUMA
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/05/06	08 45		2.700	2.100	0.110	0.176	0.250
73/06/09	15 35		6.450	1.380	0.088	0.016	0.240
73/07/15	14 50		0.290	0.990	0.048	0.240	0.360
73/08/12	09 10		5.600	3.700	0.240	0.620	1.000
73/09/09	14 20		0.720	1.700	0.180	0.700	1.050
73/10/13	11 50		0.010K		9.600	1.470	
73/12/08	11 20		2.940	1.800	0.400	0.400	0.590
74/01/12	12 20		3.300	1.300	0.390	0.288	0.380
74/02/17	12 05		3.900	1.100	0.180	0.150	0.320
74/03/03	09 40		4.500	0.900	0.050	0.092	0.195
74/03/19	20 15		3.780	0.800	0.060	0.135	0.270
74/04/02	17 15		4.300	1.000	0.085	0.150	0.240
74/04/21	10 50		2.500	1.700	0.075	0.220	0.320

K VALUE KNOWN TO BE
LESS THAN INDICATED

Table 16 N.E.S. Station C1

ATTACHMENT 2

IN-LAKE SEDIMENT REPORT

INTRODUCTION

An investigation of sediment in Grand Lake St. Marys was made at nine locations (Plate 1) around the offshore perimeter and lake center using Eckman Dredge sampler and thin wall sampler to obtain sediment samples. The Eckman Dredge obtained samples from the top of the sediment and the thin wall sampler attempted to take samples of the total depth. Sample station descriptions and pertinent data are given on Table 1.

The sediment found on the bed of Grand Lake St. Marys varied from highly organic silts and clays to peat. The organic silts and clays are very soft and mucky with decayed leaves, roots and algae. The material is presently being deposited by a combination of stream carried silts and clays mixed with algal decay in the lake proper. There are also similar remnants from the past marshy condition which existed prior to inundation by the lake. Peat is fibrous, partly decomposed vegetation, formed in a marsh or swampy condition. The deposits of organic materials are of varying thickness overlying glacial till, a very stiff to hard sandy clay.

Water depth at the nine sites sampled varied from 4.0 to almost 8 feet. Not all the thin wall samples taken were able to penetrate the full depth of the organic material and reach glacial till. The thickness of the highly organic, mucky, silty clay varied from 0.6 feet to 7.6 feet. The samples which encountered the stiff glacial till did so at depths of 5.0 to 10.6 feet. Near the center of the lake, only peat was encountered, with no indication of silt or clay type sediments. Near the mouth of Coldwater Creek, approximately 5 feet of sandy clay was found overlying the highly organic silty clay muck.

WATER AND SEDIMENT ANALYSIS

Water and sediment samples were collected at the nine sites and were tested for the purpose of determining the effects dredging would have on nutrient release. Elutriate samples were established for each sample by mixing the sediment with the raw water under specific laboratory conditions and filtering the supernatant. Phosphorus and nitrogen determinations were made on the raw water, sediment, and the elutriate samples for all nine stations. Station 3 was also analyzed for metals.

Productivity is the main water quality concern in Grand Lake St. Marys. Phosphorus concentration is normally the most important consideration for control of algal growth and was the focal point of this investigation. The Ohio standards require that "total phosphorus shall be limited to the extent necessary to prevent nuisance growths of algae..." Grand Lake St. Marys, however, has encountered more than occasional blooms in the past several years and any new source of phosphorus to the lake should be scrutinized.

The heavy algal growth, extreme shallowness, and very effective mixing by wind/wave action have been the important factors in keeping Grand Lake St. Marys well oxygenated, in spite of abnormally high biochemical oxygen demand (BOD). This lack of an anaerobic state has been an important factor in retarding a much freer exchange of phosphorus between the sediment and the water above.

Table 2 shows significant phosphorus in the sediments at all nine stations (270 mg/kg to 580 mg/kg) with stations 1 and 5 being somewhat lower than the others. In the raw water samples, total phosphorus values were generally higher at stations along the west and south shores. These same areas, however, showed lower dissolved phosphorus values. The dissolved phosphorus in the elutriate samples compared to the raw water showed significant increases in all nine samples. There was no apparent relationship between the amount of phosphorus in the raw water or in the sediment with concentrations observed in the elutriate samples at the nine stations. The important consideration here was that the sediment in all cases did release a significant amount of phosphorus to the water. In the nine elutriate samples, dissolved phosphorus ranged from 140 µg/l at station 6 to 290 µg/l at station 8.

Nitrogen concentrations were also analyzed in the water, sediment and elutriate samples. The raw water was tested for ammonia, Kjeldahl and nitrate plus nitrite nitrogen. Results are shown in Table 3. Low concentrations of ammonia and nitrate plus nitrite were observed with Kjeldahl nitrogen ranging between 1.6 mg/l to 3.1 mg/l, representing basically organic nitrogen. In the sediment samples nitrate plus nitrite was in very low concentrations (less than 10 mg/kg). Ammonia nitrogen ranged between 80 mg/kg at station 1 to 650 mg/kg at station 6 representing a significant amount of ammonia in the sediment. Kjeldahl values ranged between 1,200 mg/kg to 5,400 mg/kg representing expected high concentrations of organic nitrogen found naturally in soils. In almost all cases the elutriate test showed ammonia to be the predominant form of nitrogen being released from the sediment. The concentrations of ammonia nitrogen in the elutriate samples ranged between 1.2 mg/l to 20.7 mg/l representing moderate to high releases from the sediments. Mixing of the sediments is definitely a potential source of nitrogen to the lake, but is not considered as crucial as the release of phosphorus because of the availability of other sources of nitrogen in concentrations suitable for productivity.

Samples collected at station 3, near Celina, were also analyzed for the effects of sediment disturbance on metal concentrations. Results are shown in Table 4. Eleven metals were tested from the raw water and elutriate samples. Cadmium, chromium, copper, lead, nickel, zinc and selenium showed little or no increase in concentration in the elutriate sample compared to the filtered raw water sample. Concentrations of dissolved iron and manganese increased from 160 µg/l and less than 10 µg/l to 1,487 µg/l and 1,230 µg/l, respectively after mixing. Dissolved arsenic concentration increased from less than 1 µg/l to 39 µg/l and dissolved aluminum from 127 µg/l to 1,050 µg/l. Although these increases pose no problem to human health, both the iron and the manganese could cause aesthetic problems if the concentrations were to remain elevated for an appreciable period of time.

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GRAND LAKE SAINT MARYS, OHIO, SURVEY REPORT FOR FLOOD CONTROL A--ETC(U)
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AD
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1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

There was interest in the high amounts of organic material in the top layer of the sediment and samples collected with the Eckman Dredge were analyzed to determine the percent of total volatile solids (TVS) versus total solids (TS). Data are shown in Table 4. The higher percentages were in the western end of the lake with a range of 3.0 percent at station 8 to 12.3 percent at station 4 in the center of the lake. These values are indicative of the large amount of algal blooms in Grand Lake St. Marys.

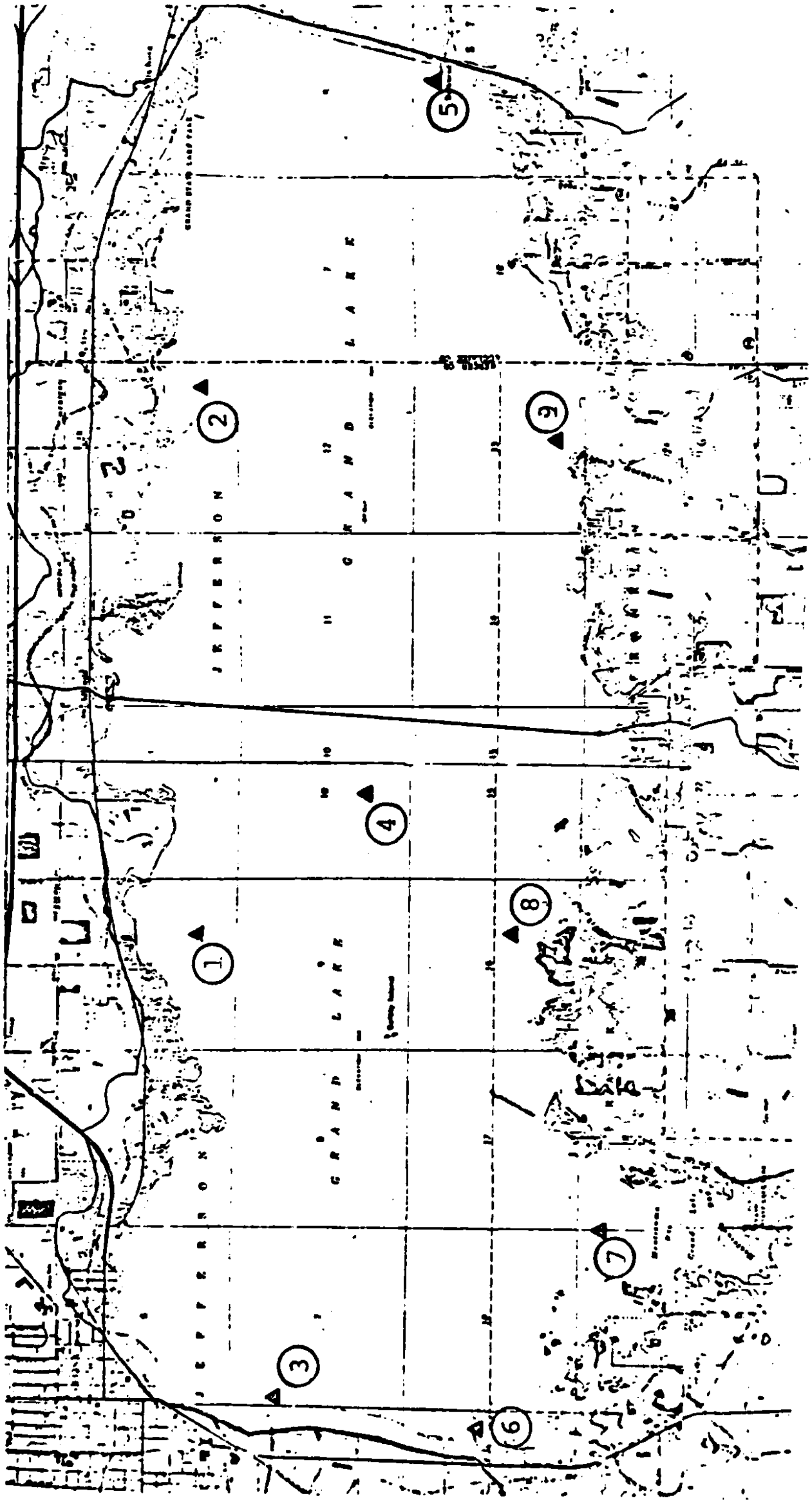
During sampling of sediment it should be noted that a zone of floc occurred in about the bottom six to 12 inches of the water column. This zone consists of highly organic solids which remain in suspension due to their low mass to volume ratio. Normal wind/wave action contributes to this quasi--equilibrium state with motor boats and other more concentrated water disturbances causing this material to suspend throughout the water column causing turbid water. This material being in a quasi-equilibrium state and already in suspension should not contribute significantly to the dissolved nutrient load when disturbed.

EFFECTS OF DREDGING

Dredging in Grand Lake St. Marys will allow the spoil consisting of the coarser fractions such as sand and silt, to become stable; however, the highly organic muck encountered over much of the lake will have a tendency to disperse in suspension around the discharge of the dredge. In order to stockpile the muck, it must be adequately contained until it drains and consolidates.

The sediment at the bottom of Grand Lake St. Marys has become a sink for nutrients and does have the potential for significant nutrient release when mixed into the water column. The short term effects of dredging on lake water quality cannot be fully predicted but nutrient release from dredging should be viewed as a point source of phosphorus and nitrogen and dealt with just as any other point source of nutrients. Problem concentrations of nutrients already exist at Grand Lake St. Marys as do problems with algal growth. Additional loading of nutrients may cause an already bad situation to get worse or may have no effect on productivity if nutrients are not the limiting factor for productivity here. Increased turbidity from dredging may cause a decrease in productivity. Grand Lake St. Marys as a whole, because of its size, should not be greatly affected by localized nutrient loadings from dredging on a small scale.

While our studies, were not detailed enough to definitely establish or disclaim that there may be a significant change in sediment characteristics with depth, visual observation of the core samples did not indicate this probability. From the standpoint of long term water quality enhancement, there is no apparent benefit in dredging at Grand Lake St. Marys short of dredging the entire lake down to the glacial till bottom.



Location Map: Sampling Points

ATTACHMENT 2
4

PLATE 1

TABLE 1
SAMPLE STATIONS

Sample Station	Description	Total Depth of Sample [1/] ft	Water Depth ft	Solid Sample Thickness ft	Solid Sample Thickness Over Glacial Till, ft	Nature of Material Overlying Glacial Till
1	1000' South of Scotty's Beauty Beach. Potential long-term accumulation area along North shore, never or not recently dredged; within the prelake swamp.	12.7	6.3	6.4	6.4+	Organic silty clay
2	Vicinity of Holiday Park at point 800' due west of Mercer/Auglaize County line and 1000' south of nearest shore. Along north shore, never (or not recently) dredged; within the prelake swamp.	8.2	7.5	0.7	0.4	Peat over silty, sandy clay
3	Potential accumulation area approximately 40 yards from western embankment outlet structure.	13.1	5.5	7.6	7.6+	Organic silty clay
4	Approximate geographical center of lake 2000 yards SW of Wright State shore, Area never dredged, in deepest part of lake, within the pre-lake swamp.	14.8	7.8	7.0	7.0+	Peat
5	Potential accumulation area approximately 30 yards from eastern embankment bulkhead	8.4	5.2	3.2	2.9	Organic Silty clay
6	Sediment deposition ar ıear mouth of Coldwater Creek.	9.9	4.0	5.9	5.9+	Sandy clay w/small gravel over organic silty clay
7	Offshore point approximately 1,000 yards due west of Windy Point State Park and north of Montezuma Bay representing area never or not recently dredged, within the pre-lake swamp and once-plentiful cattail marsh.	10.2	5.8	4.4	4.2	Highly organic silty clay

TABLE 1 (Con't)
SAMPLE STATIONS

Sample Station	Description	Total Depth of Sample [1/] ft	Water Depth ft	Solid Sample Thickness ft	Solid Sample Thickness Over Glacial Till, ft	Nature of Material Overlying Glacial Till
8	Offshore point between Bass Landing and north of Prairie Creek, 300 yards from shore and 200 yards east of line with Kittle Road. Represents area never or not recently dredged and area within once-plentiful cattail marsh.	5.6	5.0	0.6	0	Water (gray glacial till on bottom)
9	Sediment deposition area 300 yards from mouth of Big Chickasaw Creek.	11.0	4.0	7.0	6.6	Organic silty clay

1/ Water surface to bottom of core

TABLE 2
PHOSPHORUS DATA

Station	Water Column Total Phosphorus µg/l	Water Column Dissolved Phosphorus µg/l	Elutriate Dissolved Phosphorus µg/l	Mud Total Phosphorus mg/kg
1	160	120	180	270
2	110	60	140	460
3	230	50	270	580
4	170	60	170	470
5	90	90	220	280
6	240	20	140	580
7	190	20	150	520
8	190	20	290	410
9	270	20	150	402

TABLE 3
NITROGEN DATA

STATION	Ammonia Water mg/l	Ammonia Elutriate mg/l	Ammonia Mud mg/kg	Kjeldahl Water mg/l	Kjeldahl Elutriate mg/l	Kjeldahl Mud mg/kg	$NO_3 + NO_2$ Water mg/l	$NO_3 + NO_2$ Elutriate mg/l	$NO_3 + NO_2$ Mud mg/kg
1 (a)	<0.1	9.3	80	2.7	9.3	5400	<0.1	<0.1	<10
2	<0.1	5.5	240	2.5	5.5	1800	<0.1	<0.1	<10
3	<0.1	20.7	490	3.1	20.7	2000	<0.1	<0.1	<10
4	<0.1	4.8	330	2.8	4.8	5200	<0.1	<0.1	<10
5	<0.1	1.2	460	2.2	1.2	1400	<0.1	<0.1	<10
6	0.6	1.3	650	1.6	1.9	2310	<0.1	<0.1	<10
7	<0.1	3.7	92	2.2	3.7	2200	<0.1	<0.1	<10
8	<0.1	6.3	110	3.0	35.0	1900	<0.1	<0.1	<10
9	0.5	17.0	186	2.2	19.8	1200	<0.1	<0.1	<10

(a) < symbol for less than value given

TABLE 4

STATION 3
DISSOLVED METALS DATA

Metals	Concentration µg/L Water Column	 Elutriate
Arsenic (As)	<1.0	39
Cadmium (Cd)	<1.0	<1.0
Chromium (Cr)	<1.0	<1.0
Copper (Cu)	<5.0	<5.0
Iron (Fe)	160	14870
Lead (Pb)	<2.0	<2.0
Manganese (Mn)	<10.0	1230
Nickel (Ni)	<5.0	8
Zinc (Zn)	<50.0	<50.0
Aluminum (Al)	127	1050
Selenium (Se)	<1.0	<1.0

TABLE 5

SOLIDS DATA

Sample Station	Percent Volatile Solids (Total Volatile Solids/Total Solids X 100)
1	10.1
2	3.6
3	10.0
4	12.3
5	5.1
6	6.6
7	7.5
8	3.0
9	5.0

SECTION D

FORMULATION AND EVALUATION OF ALTERNATIVES

SECTION D

FORMULATION AND EVALUATION OF ALTERNATIVES

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SECTION D

FORMULATION AND EVALUATION OF ALTERNATIVES

INTRODUCTION

The following section is intended to present and discuss the range of alternatives considered and studied for the Grand Lake St. Marys study area. The first section discusses "Initial Screening" and contains alternatives that have been considered as inadequate solutions by themselves. The second section contains those alternatives that were under more active consideration. Each alternative will contain information if applicable on: description; impacts and effects; costs; economic data - benefits and benefits to cost ratio; and comments on economic, technical, and institutional feasibility. Possible alternatives are discussed in terms of three general problem categories: flooding, lake water quality and erosion/sedimentation.

INITIAL SCREENING

As an initial screening of the alternatives listed on Table D-1, the following section offers comments on those alternatives which have not been given detailed consideration.

Downstream Flooding (Beaver Creek)

Natural Impoundments

Relatively few natural impoundments exist, outside of Grand Lake St. Marys itself, either naturally or as might be modified to retard peak flows entering from the uncontrolled drainage area of Beaver Creek. Use of natural impoundments was given no further consideration.

TABLE D-1

LIST OF ALTERNATIVES CONSIDERED

DOWNSTREAM FLOODING (BEAVER CREEK)

Measures to Modify Flooding Prior to Reaching Critical Damage Areas

- Detention Basins in Lake Watershed
- Diversion to St. Marys River via Fourmile Creek
- Natural Impoundments (NS)
- Weather Modifications (NS)
- Lake Regulation (NS)

Measures to Modify Flooding at Critical Damage Areas

- Channel Modification
  - Clearing, Cleaning and Snagging
  - Channel Enlargement
- Agricultural Levees
- *Pre-flood Emergency Action* (NS)

Measures to Modify Actual Damages (Prevention)

- Flood Proofing (NS)
- Permanent Evacuation (NS)

Measures to Modify Individual Economic Losses while Permitting Major Damages

- Flood Forecasting and Temporary Flood Evacuation (NS)
- Flood Insurance (NS)

LAKESHORE FLOODING

Measures to Modify Flooding Prior to Reaching Critical Damage Areas

- Detention Basins in Lake Watersheds
- Diversion to St. Marys River via Fourmile Creek
- Spillway/*Outlet Modification*
- Natural Impoundments
- Lake Regulation

Measures to Modify Flooding at Critical Damage Areas

- Reduce Wind Setup (Breakwaters, Groins)
- Protect Low-lying Areas (Shoreline *Levees*)

Measures to Prevent Actual Damages

- Flood Proofing (NS)
- Permanent Evacuation (NS)
- Structure Relocation (NS)
- Floodproofing Future Structures (NS)

Measures to Modify Individual Economic Losses while Permitting Damages

- Temporary Evacuation (NS)
- Flood Insurance (NS)

LAKE WATER QUALITY IMPROVEMENT

Measures to Reduce Nutrient Inflow (External Source Controls)

- Treatment of Wastewater Inflows (Point Source Controls)
- Control of Non-Point Sources
  - Agricultural Land Management
  - Livestock Waste Management
  - Runoff Treatment
- Other Non-Point Source Controls

Measures to Disrupt Internal Nutrient Cycles (In-Lake Controls)

- *Dredging*
- Destratification/Aeration
- Nutrient Inactivation/Precipitation/Bottom Sealing
- Dilution
- Drawdown

Measures to Accelerate Nutrient Outflow

- *Biotic Harvesting of Algae, Aquatic Plants, Rough Fish*

Measures to Control Erosion and Sedimentation

- Shoreline, Streambank and Watershed Erosion Control Measures
- Sedimentation Ponds

NS - refers to non-structural protection measures

Weather Modifications

The effectiveness of identifying and then modifying potential storm centers is not believed to be sufficiently accurate at this time to warrant further consideration for the study area.

Pre-flood Emergency Action

Flood fighting is, to a limited extent, a current practice by persons being flooded along Beaver Creek. It takes the form of knowing, by years of attendant experience, when releases from the lake are expected to contribute to field flooding. Unfortunately, there are no established physical emergency actions that can be employed because potential flooding problems are not localized, but extend throughout the entire reach of Beaver Creek.

Flood Proofing and Permanent Evacuation

These alternatives would appear to offer minimum opportunity since only a few structures are located in areas subject to flooding. These alternatives are not viable or realistic solutions to rural and agricultural flood problems.

Flood Plain Zoning, Land Use Regulation

There are no existing comprehensive zoning ordinances which prohibit building in the flood plain. However, flood plain zoning and land use regulation offer little opportunity by themselves along Beaver Creek since the major damages occur to cropland. No change or variance in this existing land use is expected in the future.

Flood Forecasting and Temporary Flood Evacuation

Flood forecasting is and will be used, but the predictive capability problems associated with a drainage/lake system such as at

Grand Lake makes this solution generally ineffective. As with permanent evacuation, temporary evacuation is not a realistic solution to rural and agricultural flood problems because of the limited number of structures and property (contents).

Flood Insurance

Flood insurance does not prevent flood damage to either existing or future development, but rather indemnifies a policy holder for financial losses suffered during a flood. Insurance available through the National Flood Insurance Program does not cover growing crops, or livestock, and therefore is not available for agricultural crop damages. The Federal Crop Insurance Act of 1970 (FCIA), however, offers farmers new alternatives for reducing crop production risks from natural disasters such as flooding. For the 1981 crop year farmers may elect Agricultural Stabilization and Conservation Service (ASCS) disaster payments, Federal Crop Insurance Corporation (FCIC) payments, or both, depending upon whether their FCIC premiums are subsidized.

Beginning in 1981 the ASCS disaster payment program will be discontinued. Disaster payments will be replaced by a crop insurance program which permits farmers to select the level of protection desired and pay a corresponding premium. Mercer and Auglaize Counties will offer the new insurance program in 1981 and 1982. Since this Federal program is available to affected farmers, no further evaluation is necessary in this study.

Lakeshore Flooding

Natural Impoundments

Examination of topographic maps and aerial photographs has determined that few natural impoundments exist either naturally or as might be modified to retard peak flows entering from the lake's watershed. Those that do exist have insufficient capacity to result in flood damage reduction to lake shore property.

Nonstructural Alternatives

For this evaluation, the analysis was performed using available flood damage survey data which is described in more detail later in this discussion. The data indicates some 130 to 142 structures are located individually or in subdivision groupings about the south side of the lake. Although the structures are primarily residential in nature, there are a number of business and/or commercial units in the area as well.

The above-described development is subject to flood damage due to a number of factors associated with the lake. This evaluation and discussion concerns the possible application of nonstructural measures to provide relief from physical and economic damage due to flooding.

Data and information utilized in the evaluation of nonstructural alternatives consisted principally of lake level hydrographs, exceedence frequencies, flood damage appraisal interviews with a number of property owners as well as findings of studies performed under contract for the Louisville District.

The most obvious remedy to alleviate damages due to flooding of structures and other improvements in flood-prone areas is to remove those structures and utilize the vacated land for other uses more compatible with the risk of flooding. Permanent evacuation is an expensive measure and difficult to justify physically, economically or socially.

A slight modification of the above alternative - relocation of the structures - makes the economic picture somewhat better, but again, the relocation alternative is expensive and difficult to justify.

Both of the above alternatives have little expectation of feasibility unless the structures are of relatively high value and/or subject to fairly frequent flooding. Prudent builders and/or occupants in the flood plain normally would not choose frequently flooded sites; however, changed physical or hydrologic conditions could produce more frequent flooding.

Other protective type nonstructural measures such as raise in place, flood proofing, temporary evacuation and flood warning systems offer means to reduce or eliminate flood damages.

Management-type structural measures such as flood plain zoning, subdivision regulations and building codes address themselves principally to prevent damages to future development.

Flood insurance, while having a limiting effect only on flood damages to future development by requiring the management measures, such as those listed above, does offer financial protection from flood damages to owners and occupants of existing development. The National Flood Insurance Program requires the participating cities and counties to manage the flood plain to minimize flood damages.

Permanent Evacuation

Future structural damage can be prevented by permanently evacuating persons and property from the flood plain if lands are purchased in fee; however, whether such measures are feasible depends upon the value of lands and existing structures and the availability of alternative development sites. By evacuating all flood-affected structural development from the flood plain, about $150,000 in annual flood damages would be prevented. However, lake south shore damageable property valued at $6,390,000, amortized over 50 years, would total about $400,000. Annual costs of evacuation with and without recreation benefits are $572,000 and $551,000, respectively. Total annual benefits with and without recreation are estimated at $275,000 and $249,000, respectively. Benefit-to-cost estimates for the alternative showed a ratio of 0.48 with conversion of vacated lands to recreation and a ratio of 0.45 without conversion to recreation. Since costs (which do not include such items as utilities, land, and relocation costs) exceed benefits which could be derived, this alternative was considered economically impractical and not considered further. Additionally, this alternative would not be socially acceptable since it would involve displacement of many residences, many of which were located adjacent to Grand Lake St. Marys specifically to take advantage of its scenic and recreational values.

Relocation

Relocating flood-prone structures is a protective measure that would be technically feasible since a great majority of the residential structues affected are constructed on raised foundations. From a social standpoint, however, this alternative does not meet objectives since it would require relocation from an area having scenic and recreational value to residents who located there for that reason. In addition, this alternative is economically infeasible. Annual costs for relocating some 131 structures including acquisition of flood-free land, site preparation, transfer of structures and miscellaneous expenses amount to $790,000 without recreation benefits. With conversion of the vacated lands to recreation use, annual costs amount to $807,000. Annual benefits are estimated at $627,000 and $601,000, with and without recreation, giving benefit-cost ratios of 0.77 and 0.76, respectively.

Floodproofing Existing Dwellings

Floodproofing, which involves the modification of structures by waterproofing or raising them to prevent floodwater intrusion, may be undertaken by individual owners or as a group action. These measures are usually applied through building codes to new structures within the designated flood-prone area. Existing flooded structures adjacent to the lake in the study area, however, are predominantly residential and of frame construction. Application of waterproofing measures to groups of structures is inhibited by the predominance of single family structures on individual lots. Waterproofing was rejected for two reasons. First, the nature of flooding-- wave action-- would mitigate against protecting the structure from flooding since closures or flood walls constructed immediately adjacent to the structures would allow impact of waves and floodwaters on the structures. Due to the power exhibited by the wave action, this measure was deemed unacceptable.

Second, since the structures are built over crawl spaces, any protective walls or flood proofing measure would not only have to seal the crawl space, but would have to provide protection for the structure at and above the first floor. This is considered an extremely expensive measure and unacceptable in meeting study objectives.

Raise-in-Place

This protective type nonstructural measure offers the greatest opportunity to meeting objectives in that flooding and its impacts are reduced or eliminated while preserving the use of the area to the highest extent possible.

Since the great majority of the structures are one story without basements, the analysis was made utilizing the following assumptions:

Type --1 story, no basement (1 SNB)
Structure Value (Vs) = $30,000 (average)
Content Value (Vc) = $10,500
(Vc/Vs = 0.35)
Flood Hazard Factor (FHF) = 4.0

Distribution in the flood zone was evaluated as follows:

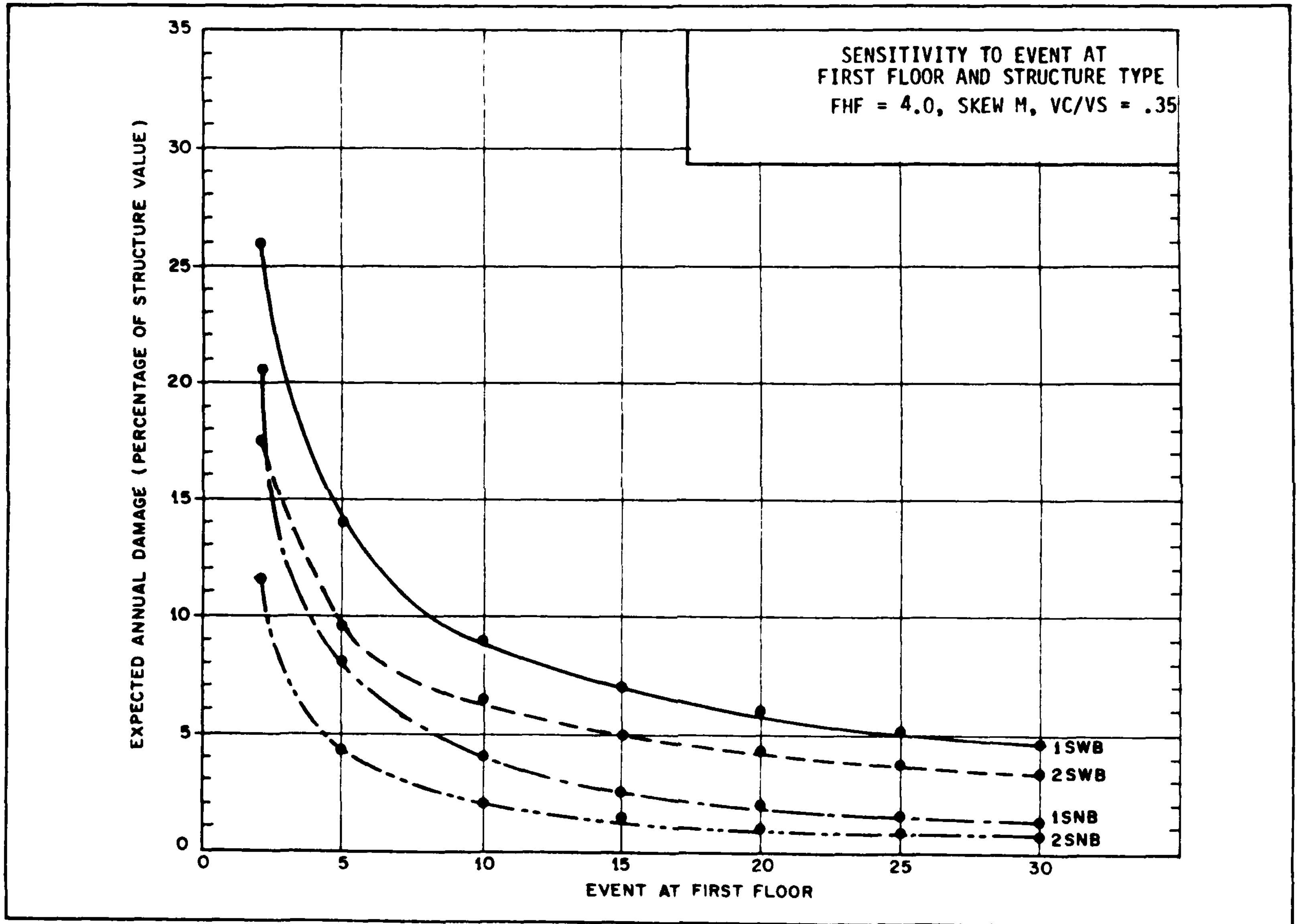
Minimum Number of Structures	Existing 1st Floor Elevation	Height to be Raised (feet)
8	877.75	0
12	876.75	1
18	875.75	2
25	874.75	3
31	873.75	4
37	872.75	5
131		

Expected annual damages were computed from Corps of Engineers Hydrologic Engineering Center (HEC) information (Figure D-1) from "Physical and Economic Feasibility of Nonstructural Floodplain Management Measures."[1]

The incremental analysis of the raise in place alternative is presented in Table D-2. As shown in the table a high percentage of the units would be affected. At the higher elevations, those considered for the raise-in-place measure would become marginally infeasible. However, the benefits generated for raising those units at lower elevations would be sufficient to maintain a positive benefit to cost ratio.

Relatively high unit costs for raise-in-place were used in this determination to permit some treatment of the structures at their new elevations specifically for aesthetic purposes. This could take the form of a raised wood deck.

The findings of this analysis are generally supported in the information presented in the above reference (Figures D-2 and D-3) for 1SNB structures raised 3 and 5 feet.



SOURCE: Corps of Engineers[(1)]

FIGURE D-1

TABLE D-2

EVALUATION OF NONSTRUCTURAL ALTERNATIVE RAISE-IN-PLACE
FREQUENCY 100-YEAR (ESTIMATED)
GRAND LAKE ST. MARYS, OHIO

No. of Units	No. to Raise	Height to Raise	Total Str Value	First Costs			Average Annual Benefits			
				Base Cost	Cont.	Total	Damages	Benefits Without Recreation	Costs Without Recreation	Benefit-Cost Ratios Without Recreation
8	-0-	-0-					-0-	-0-		
12	12	1'	$360.0	$ 79.2	$ 31.9	$ 111.1	$ 5.2	$ 5.2	$ 8.2	$ 0.63
18	18	2'	540.0	118.8	47.9	166.7	10.8	10.0	12.3	0.81
25	25	3'	750.0	187.5	75.6	263.1	18.8	17.5	19.4	1.1
31	31	4'	930.0	260.4	104.9	365.3	37.2	34.8	26.9	1.3
37	37	5'	1111.0	333.0	134.2	467.2	88.8	82.7	34.4	2.4
131	123		$3690.0	$978.9	$394.5	$ 1373.4	$161.0	$150.2	$101.1	$ 1.49

Flood Proofing Future Facilities

As will be discussed below, Mercer County, as a participant in the National Flood Insurance Program, will be required to adopt ordinances or other controls to regulate land use and construction within the 100-year flood plain (land area inundated once every hundred years, on the average). The 100-year flood plain corresponds, tentatively, to a Grand Lake elevation of 875.0 feet NGVD.

With this alternative an increment would be added to the existing regulated land use to require all future development to be floodproofed to the level of the Standard Project Flood, which is a flood representing the critical flood runoff volume and peak discharge that may be expected from the most severe combination of meteorologic and hydraulic conditions that are considered reasonably characteristic of the hydrologic region involved, excluding extremely rare combinations. Floodproofing, in this sense, would consist of elevating future buildings on pads or piles, constructing dikes, providing watertight closures and anchorage systems, waterproofing or using any other such method designed to resist inundation. Expenses would be borne by individual property owners. With this plan, the increased costs of flood proofing may tend to discourage development in the Standard Project Flood plain, thus satisfying the concerns of fish and wildlife agencies and environmental interests. However, this plan would provide no measure of flood protection to existing development on the lake rim, a problem which, to a limited extent, concerns individuals and local government in that area. In addition, economic and individual costs of floodproofing new and replacement structures may prove to be excessive and would be the responsibility of local interests.

Temporary Evacuation

Information collected during field surveys and interviews indicated that some warning of high lake levels and/or wind conditions permitted

TABLE D-13

POTENTIAL REVENUE FROM GRAND LAND VISITATION

Year	Lake Visitation (Visitor-Days)	Potential Revenue 1/	Net Revenue Relative to 1973 Visitation
1970	1,711,800	$ 6,847,200	
1971	1,636,200	6,544,800	
1972	2,106,100	8,424,400	
1973	2,448,500	9,794,000	
1974	1,725,200	6,900,800	- $ 2,893,200
1975	1,658,800	6,635,200	- 3,158,800
1976	1,489,900	5,959,600	- 3,834,400
1977	1,474,950 2/	5,899,800	- 3,894,200
1978	1,479,018 2/	5,912,100	- 3,881,900
1979	1,219,637 2/	4,878,500	- 4,915,500
2000	3,000,000 3/	12,000,000	+ 2,206,000
2020	3,600,000 3/	14,400,000	+ 4,406,000

1/ Based on $4.00 per visitor-day.
2/ Visitation figures are for fiscal year, not calendar year (Source: ODNR).
3/ Projected.

accessible on the tributaries to Grand Lake. In addition, about an equal length of boat access channels to private dwellings exists along the south shore. To guarantee that these channels satisfy their principal recreational purpose, periodic dredging must be performed. According to the State of Ohio major access areas are dredged approximately every 3 years.

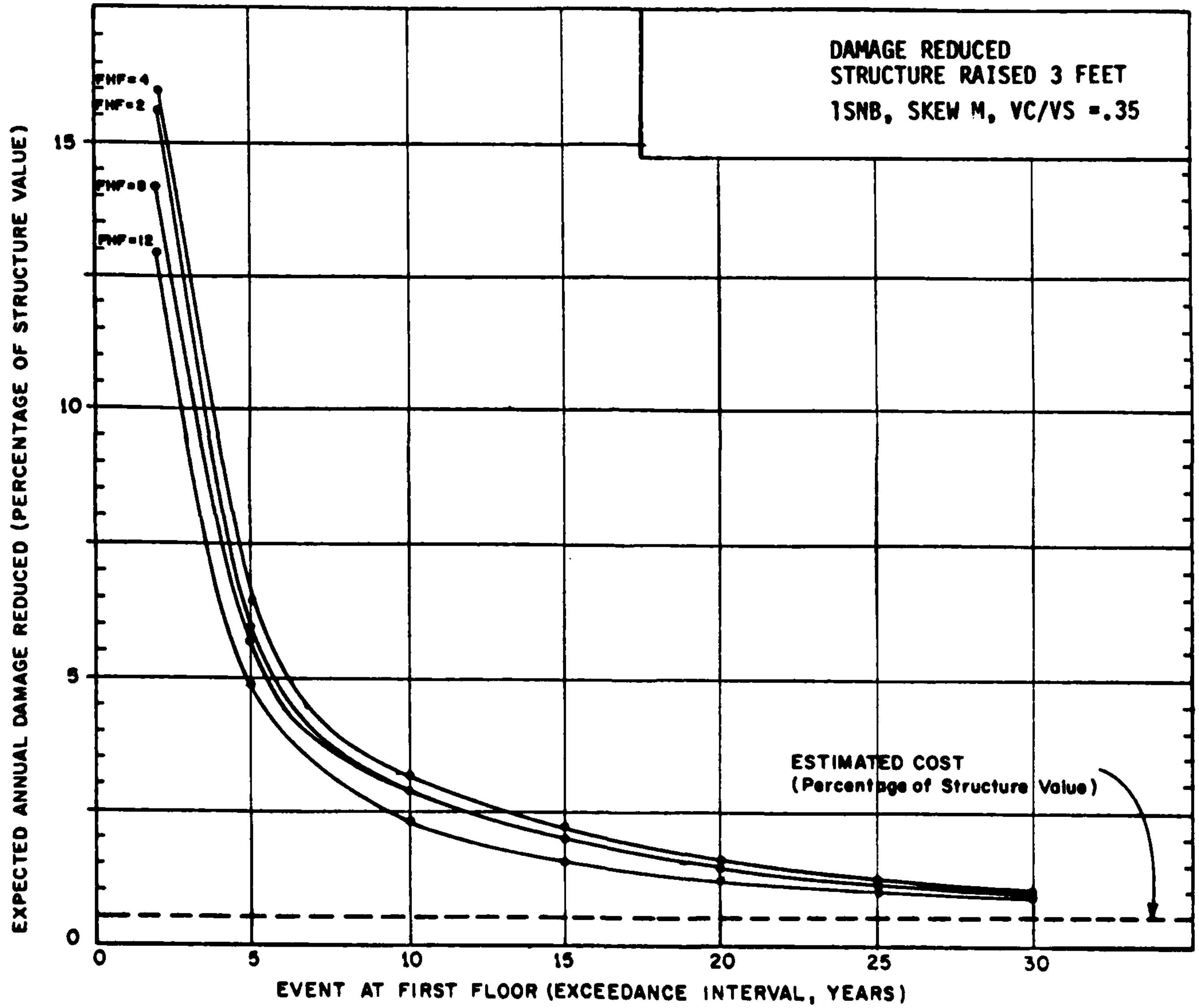
Table D-14 presents estimated costs of maintenance dredging. These values are based on a unit cost of $2.00/cubic yard, a 25-foot channel width, and 2 feet of sediment removal. The corresponding cost per 50 feet of channel length is $185, or about $60 per year. This latter figure is illustrative of a channel along a typical residential frontage, and provides input to the issue of cost sharing for maintenance dredging of private boat access channels.

TABLE D-14

COST OF MAINTENANCE DREDGING:
TRIBUTARIES AND BOAT ACCESS CHANNELS

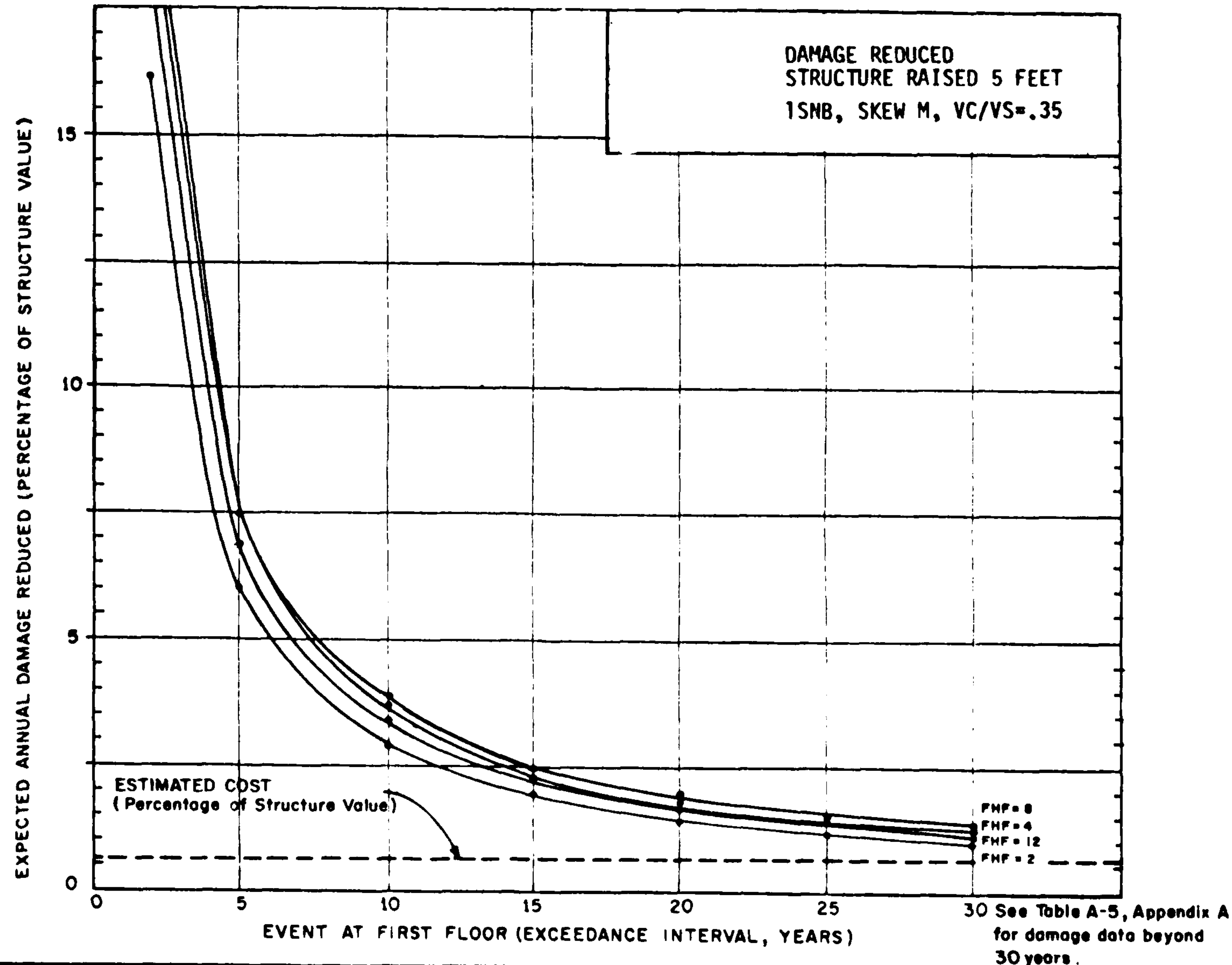
Channel	Length (feet)	Cost to Dredge Every 3 Years	Dredging Cost per Year
Coldwater Creek	9,000	$ 33,000	$ 11,000
Chickasaw Creek	7,500	28,000	9,300
Little Chickasaw Creek	3,000	11,000	3,700
Prairie Creek	4,500	17,000	5,600
Beaver Creek	7,500	28,000	9,300
Barnes Creek	3,000	11,000	3,700
Monroe Creek	2,000	7,500	2,500
Boat Access Channels	36,000	133,000	44,000

The major concern with this type of dredging is the proper disposal of the spoil material. The current method of placing the spoil on the channel banks is technically deficient due to the susceptibility of the material to erode back into the channel. The proper containment of the



SOURCE: Corps of Engineers(1)

FIGURE D-2



SOURCE: Corps of Engineers(1)

FIGURE D-3

emergency actions prior to evacuating the premises prior to actual flooding. Temporary evacuation, while questionable in regard to levels of damages prevented or reduced, does offer the principal means of protecting life and limb, the personal safety aspect of risks associated with flooding.

To be fully effective, an evacuation plan must provide for a given format of responses when it is determined that flooding is about to occur. To develop the maximum effectiveness of a temporary evacuation plan, a flood warning system must be utilized to signal the threat of flooding.

Flood Warning System

In the case of Grand Lake, a warning system would appear to be fairly straightforward in gaging the critical parameters (factors) of lake levels, wind velocity and wind direction, as follows:

Lake Levels Water surface elevations at critical stage can easily be signaled by a sensor in a freeze-proof wet wall. This would be important in that lake levels higher than the rule curve maximum (elevation 870.75) would be indicative of a potential flooding period.

Wind Velocity An anemometer at one or more locations about the lake would provide for gaging high wind velocities over broad areas or more localized conditions.

Wind Direction Winds from the west and the north are potentially the most damaging as far as wave action and wind setup are concerned. Therefore wind direction should also be measured and utilized in an overall warning system.

These three factors, seen as having a compounding effect in producing the most damaging conditions, can be integrated into a signal analyzing device which would set off a warning system. Such warning systems are generally displayed in police or fire department headquarters which are 24-hour duty stations.

The effectiveness of an evacuation plan and response of the community to it cannot be accurately predetermined and, consequently, neither can potential flood damage reduction.

Flood Insurance

Flood insurance, at least in some aspects, is both a protective measure and a management measure. It is considered separately in this discussion in that it does little or nothing to prevent damages from flooding. Rather, it indemnifies the property owner against economic loss due to flooding. Flood insurance may indirectly prevent some flood damages by the awareness that the property owner is or may be in the flood plain. This, however, would require follow-up action on the part of the property owner to prevent physical damage from flooding.

Flood insurance is primarily considered a management measure since the program requires a trade-off from the community to join the insurance program. That trade-off consists of the following: the program in general and individual flood insurance policies provide economic or financial protection up to given levels depending on the initial (emergency) phase or full participation (regular) phase, in which the community is enrolled. The community, on the other hand, agrees to manage the program and, also, to manage the specific use of the flood plain within the guidelines of the program. This flood plain management feature of the program requires that any new development in the flood plain be accomplished in such a manner to prevent or minimize damages by floods at least up to the 100-year event.

The emergency phase provides subsidized flood insurance to flood-prone occupants up to a stated amount on structure and contents, as follows:

Flood Insurance Coverage
Under Emergency Phase
National Flood Insurance Program

Type Structure	Coverage	
	Structure	Contents
Residential	$ 35,000	$ 10,000
Small Business	100,000	100,000
Other	100,000	100,000

Upon completion of a flood insurance study, the communities would be converted to the regular program in which coverage is substantially higher in each category and rates are on an actuarial (risk) basis.

Participation in the National Flood Insurance Program is a local, option in which Mercer County is enrolled in the first or "emergency" phase and limited Federally subsidized coverage is available to all property owners. A flood insurance study (F.I.S.) to convert from the emergency to the "regular" phase has not been scheduled for Mercer County as of February 1981. Auglaize County was identified by the Federal Emergency Management Agency as having flood-prone areas, but to date (February 1981) the county has chosen not to participate in the program.

Since this Federal program is available to local governments, no further evaluation in this study is deemed necessary.

Lake Water Quality

Water quality improvement measures considered but deemed inappropriate for various reasons are as follows:

Destratification/Aeration

Artificial aeration is a process in which air or oxygen is added to the lake by mechanical means to improve dissolved oxygen conditions for fishery and water quality purposes. Artificial aeration is generally applicable to eutrophic lakes that are deep enough to stratify thermally and in which the hypolimnion is essentially devoid of dissolved oxygen and thus uninhabitable by aerobic (oxygen-consuming) organisms. The objective is to increase oxygen concentrations throughout the lake and promote the rate of oxidation and decomposition of organic bottom sediments and organic matter in the water column. Besides being cost prohibitive for a lake of this size, the method is not a practical alternative for improving water quality at Grand Lake St. Marys since (1) oxygen levels in the lake are generally high and fairly well distributed from top to bottom because of natural lake mixing; (2) the lake does not stratify thermally because of its shallow depth; and (3) the method would not, in itself, restore lake water quality since it treats the symptoms of overfertilization rather than the source.

Runoff Treatment, Flocculant Addition, and Lake Bottom Sealing

The primary mechanism to be investigated in the runoff treatment and flocculant addition alternative is the inactivation of soluble orthophosphate by aluminum or iron flocculants, with consequent transfer to the sediments. Each of these nutrient inactivation/precipitation methods has been a documented lake restoration technique, especially in the case of small, eutrophic lakes. The method involves chemical or inert material addition that will bond with, absorb, or otherwise immobilize necessary algal nutrients, thereby preventing them from being utilized by these organisms for their growth. The primary difference between the two alternatives is that runoff treatment infers a continuous chemical feed, while flocculant addition involves a single application over the lake surface. In the case of bottom sealing, the use of fly ash (the residue remaining from the burning of coal) and a synthetic fabric filter are each considered. Because all of these measures are generally infeasible for the conditions at Grand Lake, a brief presentation is given to demonstrate the principal constraints.

The anticipated beneficial impact of the three methods is an improvement in water quality resulting from the inactivation and consequent unavailability of phosphorus for primary production. In most cases, dissolved oxygen levels and water transparency are increased as a result of the inhibition of algal growth. The use of a fabric filter would additionally eliminate sediment resuspension and its attendant turbidity and phosphorus renewal problems.

For several reasons, these benefits will be less significant in the case of Grand Lake than in other reported applications. First, Grand Lake is shallow and wind-induced mixing keeps the lake well-oxygenated throughout its depth with no stable thermocline development. The release of sediment phosphorus under anaerobic condition is, therefore, not a widespread problem. Second, the orthophosphate (the target of these techniques) accounts for only ten percent of the total phosphorus due to a high degree of phosphate adsorption onto suspended sediments. Related to this sediment resuspension is the fact that the chemical flocs or the fly ash will not permanently settle to the bottom as they would in deeper water bodies.

The adverse impacts on water quality could potentially override any improvements and create more critical problems than currently exist at Grand Lake. In general, the aluminum or iron flocs will remain in suspension and be shifted by wind-driven currents to lakeshore areas, creating adverse aesthetic and possibly public health conditions. Of special concern is the continuous feed of chemicals for runoff treatment, since the trap efficiency of the lake is reportedly high. Given the commercial grade of alum commonly used, substantial increases in alkalinity, hardness, and sulfate would occur and impact on the Celina water treatment operation.

The use of fly ash is even more constrained by potential water quality problems. Trace materials in the fly ash are particularly problematical. For example, using a typical fly ash composition and a 4 cm bottom layer of fly ash, the concentration of copper in Grand Lake could violate Ohio stream standards if only one percent of the copper available in the ash is released over a short period. The use of Grand Lake for water supply purposes further aggravates this concern.

The impact of chemical flocs or fly ash on fish and wildlife at Grand Lake cannot be evaluated at this time. Extensive testing would be required before any of these alternatives could be implemented. Benthic organisms would appear to be the most susceptible to an environmental stress, although past applications do not indicate severe consequences. Use of a fabric filter will have the greatest impact on lake bottom habitats.

The use of chemical flocculants or fly ash is limited most by the turbulent nature of the lake bottom, since this negates the primary purpose of permanent removal of phosphorus to the sediments. The physical dimensions of the Grand Lake basin further constrain the implementation of these alternatives. Calculations based on previous studies and USEPA design manuals indicate that runoff treatment based on average annual flows to Grand Lake would require about 300 tons of alum or ferric chloride ($FeCl_3$) annually, whereas flocculant addition would necessitate approximately 1,500 tons of aluminum sulfate ($AlSO_4$) every three years. An even more noteworthy finding is that over five million tons of fly ash are needed to cover the lake bottom to a depth of 4 cm. This represents ten percent of the annual national production of fly ash.

The use of chemical treatment of tributary flows is limited by the extreme fluctuations in the flow rate and the need to vary the chemical feed rate accordingly. The use of fly ash will be prohibited outright if it is eventually classified as a hazardous material under the Resource Conservation and Recovery Act. In the case of a fabric filter, the physical limitations are obvious. Securing the fabric to the lake bottom so as not to interfere with recreational boating is an especially difficult task.

An important limitation of any of these methods is that they are temporary. For example, chemical flocculants or fly ash would be needed approximately every three years. In a sense, these methods are most applicable when a major nutrient reduction program is implemented and the technique serves to "seal off" historical nutrient build-up.

Even though these three alternatives can be deemed infeasible due to a physical and environmental constraints, a consideration of the respe:tive costs is included for completeness. The fabric filter is most obviously cost prohibitive, the total being $121 million based on $0.20 per square foot. The cost of fly ash would ordinarily be low due to the supplier's willingness to provide the ash as an alternative to disposal. However, the volume requirements at Grand Lake cannot be met by local supplies and transportation costs alone could be exorbitant. (For example, approximately 300,000 truckloads of dry ash would be required.)

Chemical addition to tributary inflows has a relatively low cost due to the low concentration of total phosphorus (relative to sanitary sewage). For example, the cost of chemicals, feeder equipment, and labor to treat the major tributaries is about $100,000 annually. The problem is that the sludge produced would aggravate environmental and water quality concerns, and facilities for its removal would be cost prohibitive. This would essentially require a tertiary treatment plant for a flow of 43.3 MGD, or about 12 times the design flow rate for the Celina treatment plant under the proposed sewage system.

In the case of flocculant addition to Grand Lake, a consideration of total costs for past studies leads to a cost of $232,000 per year for a three-year application cycle. Again, flocculant removal would probably be necessary.

Dilution/Flushing

Dilution/flushing has been examined as a means of alleviating excessive algal (and macrophyte) growth by reducing nutrient levels within the lake. It is accomplished by replacing nutrient-rich lake water with nutrient-poor water from another source and hence removing nutrients contained in the phytoplankton as well as those dissolved in the water. One method involves pumping water out of the lake to allow increased inflow of nutrient-poor groundwater. Another involves rerouting nutrient-poor water to the lake from other surface waters or obtaining it from pumped groundwater sources. The former method has been tried before at Snake Lake, Wisconsin, but only temporary effects were achieved.

Several factors preclude use of the technique at Grand Lake St. Marys. First, there is no adequate, dependable supply of dilution water in the region that can replace the lake contents. Surface water supplies such as the St. Marys River and Lake Loramie can generally be considered undependable and would be expensive sources to develop. In the case of dilution with Lake Loramie water, costs of diverting replacement water to the lake would approach $14,000,000 which is cost prohibitive. In addition, Lake Loramie would have to be completely drained to supply Grand Lake with only one foot (13,000 acre-feet) of water. Second, the existing groundwater in the region is high in minerals and would not be a suitable source unless treated prior to installation.

An important limitation to this technique is that the dilution water must contain substantially less nutrients than the lake water to accomplish the desired objectives. This means that economic considerations and logistics limit its use to lakes in close proximity to a low nutrient water supply source. This is not the case in the Grand Lake St. Marys area.

Drawdown

Drawdown is a technique used for lake water quality improvement wherein the lake level is drawn down, partially or totally, to expose and consolidate bottom sediments. The primary benefit of a drawdown action would be (1) the physical stabilization of the upper flocculent sediment zone or fluff region resulting in a presumed decrease in nutrient release or regeneration from the sediments, and (2) the flushing of the lake basin of nutrient-rich water, thereby allowing it to be replaced with nutrient-poor water. In lowering the water level the sediments are exposed to air which results in drying the chemical alterations by oxidation which apparently accelerates microbial conversion of organic forms of nutrients to inorganic forms.

Consolidation of flocculent sediments by drying is considered irreversible and would result in secondary benefits of a deepening of the lake basin and an increase in lake volume. It would be anticipated that the sediments would be oxidized and would not resuspend upon reflooding. In addition, exposure and drying of the lake bottom would provide opportunities for removal of bottom stumps, logs, and other stickups, leveling of high and low spots, and rough fish eradication. Drawdown can also result in control in submerged rooted aquatic plants and production of higher, desirable algal and fish forms.

On the surface, drawdown appears to be an appropriate measure to use at Grand Lake because of the many benefits it would impart, but there are other considerations and drawbacks which make it either unsuitable or infeasible. For one, it would be difficult under present operating conditions to release water from the lake at a greater rate than that entering without inducing some flood damage downstream in Beaver Creek and/or the St. Marys Feeder Canal. In addition, the existing lake outlet facilities are inadequate to accomplish the drawdown over a short period of time without extensive supplemental pumping. To be effective the lake must be completely drained and the water table must be maintained below the surface of the lake sediment surface, a task that would be difficult to attain given the many high and low spots on the lake bottom and the generally high groundwater table in the area.

Without further testing, it is believed that any consequent consolidation of the sediments could be short-lived due to the magnitude of the wind-induced bottom mixing in the shallow regions of the lake.

Another drawback is that the drawdown would have to be accomplished and maintained for at least one warm-weather recreation season in order to dry out and consolidate the sediments. This could potentially result in a multi-million dollar loss to the local economy in addition to a severe loss of aesthetic enjoyment, recreation, and fish and wildlife resources.

With regard to refilling, it is doubtful, without extensive reduction of incoming nutrients, that the make-up water will be of such a nutrient-poor quality to realize anything but short-term improvement.

Another important drawback involves the potentially severe nuisance conditions created by offensive odors for an extended period of time from decomposition of fish and organics. The most important constraint is the significant reduction in water supply storage for an extended period which would adversely affect the water supply of Celina which has no other developed source other than the lake itself.

Biotic Harvesting of Nutrient Organisms

Algae harvesting, or the physical removal of algal blooms, has been considered as an alternative for improving water quality. In order to be effective, the algal biomass must be in relatively high concentrations for removal by mechanical means. This method would be particularly ineffective and impractical to apply at Grand Lake because of the large lake surface area, and the short duration and widespread dispersal of algal blooms on the lake. Macrophyte (aquatic plant) harvesting can aid in reversal of eutrophic conditions in some lakes, but control of excessive growths poses difficult problems from practical, economic, and aesthetic standpoints. The technical feasibility of plant harvesting at Grand Lake can be discarded because of the current lack of heavy concentration of macrophyte growth. The largest beds are water milfoil in Riley Bay (north shore), but these provide habitat for benthic organisms, young-of-the-year fish, and wildlife. Macrophyte areas at Grand Lake should be preserved for these reasons except in areas impeding boater access.

Other Alternative Considerations

A review of various documents and letters presented by individuals, organizations and agencies from time to time throughout the course of the study, has produced alternative suggestions that were given consideration. These suggestions include the following:

1. Locating and uncovering under-the-lake springs that could provide a source of cold water to the Lake.

2. Providing a supplemental water feeder from Lake Loramie to Grand Lake as a source of water during low water conditions.

3. Development of the Harbor Point County Park area for recreational purposes.

4. Seeding dredge disposal areas.

The following comments apply to each of the suggestions:

Springs. No data exists as to the location, number, and flows of such springs although they are known to exist. The potential flows from these springs would be more dependent on the relative hydrostatic heads (pressure) than on the degree of "coverage by silt" or total number of such springs, and are probably still feeding the lake if indeed they once did. Any attempt to uncover the springs would be difficult, if not fruitless, due to the continual movement of bottom sediment (due to bottom circulation patterns) and consequential re-covering of the springs in the short-term.

Lake Loramie Feeder. Based on the existing topography of the Grand Lake watershed, a logical route for the suggested feeder would be northerly from Lake Loramie through the existing Miami-Erie Canal System; thence westerly along Route 219 (the historic dry feeder route) to Barnes Creek with subsequent inflow to Grand Lake (Plate D-1).

Assuming that the old lock system on the Miami-Erie Canal is no longer in service, a piping system would be required. Preliminary calculations indicate that a 7-foot diameter conduit would be required to supply enough water to raise the Grand Lake water level by one foot in thirty days, at a cost of $14 million. This alternative, at these costs, would appear cost prohibitive. In addition, under low flow conditions, Lake Loramie would be at no more than normal pool with 13,000 acre-feet of impounded water. To raise Grand Lake by one foot requires more than 13,000 acre-feet of water. Lake Loramie would have to be drained to achieve a significant improvement at Grand Lake. It is possible that enough excess water from Lake Loramie would be available, but only when Grand Lake would not require it.

The same physical constraints apply to the alternative of using Lake Loramie supplemented flows for purposes of improving Grand Lake water quality through dilution as has been discussed in a previous section.

Harbor Point Development. The development of Harbor Point for recreational purposes is too site specific for the types of remedial measures considered in this study.

Seeding of Dredge Disposal Sites. The seeding of dredge disposal sites is a feasible alternative that does not require a detailed analysis. In addition to erosion control, an important advantage of this measure is the potential inhibition of undesirable weed and cottonwood growth. One shortcoming is that the seeding will not provide permanent protection due to the gradual undercutting and sloughing of the banks.

ALTERNATIVES CONSIDERED IN DETAIL

This section of Formulation of Alternatives discusses alternatives that have been given active and more detailed consideration, either because they have been suggested by local, regional and state interests, or because they would appear to have technical merit.

Flood Control

Structural flood damage reduction plans considered for Beaver Creek and lakeshore together included detention basins, diversion and spillway/outlet modifications. In addition, nonstructural reservoir regulation alternatives were examined. Structural flood damage reduction plans considered for Beaver Creek alone included channel improvement alternatives -- clearing, cleaning and snagging; channel enlargement, and agricultural levees. Structural flood damage reduction plans considered for lakeshore only included breakwaters, groins, and shoreline levees.

Detention Basins

This alternative refers to structures in which runoff from the watershed above Grand Lake would be detained in the basin during peak flood flows and then released downstream to the lake as soon as conditions permit.

The rationale of this alternative was to determine the feasibility of providing flood control storage on tributaries of the lake to restrict surcharging of the existing west spillway to a maximum of one foot. A combined network of four small detention structures was considered, one for each of the major tributaries to the lake: Coldwater Creek, upper Beaver Creek, Chickasaw Creek, and Little Chickasaw Creek (see Plate D-2). The retention structure would control areas of 9.3, 18.9, 15.3, and 6.6 square miles, respectively, for a total of 50.1 square miles or 45 percent of the Grand Lake watershed. Detention structure sites were located as shown on Plate D-2 based on maximum drainage area controlled and maximum storage available versus structural, residential and topographic limitations.

The maximum control storage volume for this alternative is approximately 29,530 acre-feet (A-F). The total capacity of the four damsites considered is 10,828 A-F and, therefore, lacks approximately 18,700 A-F for the alternative. This maximum flood control storage (10,828 A-F) is limited at each of the four sites by rim of basin elevations because of low topographic relief. In addition, top of dam capacities at each location could not be realized in actual operation because of overtopping and freeboard considerations. Additional locations would only provide a capacity of 300 to 500 A-F maximum storage based on topographic limitations.

For this alternative several assumptions, as follows, were made to determine the reduction of observed peak pool elevation for the lake: (1) the full 10,828 A-F is available for flood storage; (2) a general basin-wide storm pattern produces sufficient runoff intensity to fill each basin to capacity regardless of their outflows; (3) starting pool elevations are the same as the observed condition prior to the storm; and (4) observed outflows for the lake, for each storm event, up to the time of the observed peak pool elevation. These assumptions, in effect, produce the maximum lake pool reductions possible. The following information shows historical flood events, in descending order of magnitude and their computed reductions.

Observed Data		Estimated Modification	
Date	Pool Elevation	Pool Elevation	Reduction in Feet
15 Jan 1930	872.83	872.11	0.72
21-22 May 1943	872.67	871.94	0.73
25 April 1972	872.67	871.94	0.73
9-10 April 1938	872.42	871.67	0.75
7- 8 April 1978	872.17	871.40	0.77

Based on pool elevation-frequency analysis, the Grand Lake pool elevation of 871.75 (one foot above west bank spillway crest) is equaled or exceeded once every 4 or 5 years under existing conditions. Assuming the retarding basins provide the maximum reductions possible at top of dam capacities, the modified exceedence interval for elevation 871.75

would be once every 14 to 16 years. This would result in a significant reduction in average annual flood damages on the south shore for the no-wave condition for all but rare storm events. However, a guideline design outflow rate of 5 cfs per square mile would total 250 cfs from the four retarding basins. This inflow into the lake plus inflows from the remaining uncontrolled area is considered a substantial west bank outflow rate in order to maintain a stationary lake pool and would result in no substantial flood damage reductions in the Beaver Creek flood plain.

Total first cost of this combined detention basin system is estimated at $14,859,000 and total equivalent annual charges are estimated at $1,389,000. Total average annual damages (AAD) along Beaver Creek and the lake shore are estimated at $235,000. Elimination of all AAD would result in a benefit to cost ratio of 0.17. Since total reduction of AAD is not realistic, the B/C ratio would be less than indicated.

The economic analysis for this alternative was based strictly on flood control benefits. However, additional benefits could be realized through dual purpose use of retention basins as sediment ponds for settlement of suspended particulate matter entering from the watershed. However, adding this benefit would still not result in a favorable alternative.

Although actual economic benefits and flood damage reductions have not been assessed, estimated annual costs exceed potential maximum annual benefits. This alternative is, therefore, economically infeasible and was dropped from further consideration either as a single alternative or in conjunction with other alternatives.

Diversion

Another structural alternative examined in detail for combined flood damage reduction involved diversion of lake overflows to the St. Marys River via Fourmile Creek (see Plate D-3). The rationale of this alternative consideration is that the lake is located on a drainage divide in which the western 59 percent of the drainage area (66.2 square miles) is within the Wabash River Basin and the eastern 41 percent (45.9 square miles) is in the Maumee River Basin. Because the west spillway crest is 19 inches lower than the east bulkhead crest, a greater proportion of overflow from the lake is discharged to the west.

The primary objectives of this alternative were to reduce flood damages along Beaver Creek by allowing outflows from the lake in proportion to the historical drainage areas of the lake watershed and also prevent surcharging the existing west spillway by no more than one foot, which elevation (871.75) is the start of lakeshore flood damages.

The alternative represents a new lake outlet and presumes that no modification of the two existing outlet structures is undertaken.

The alternative requires a new outlet structure and approximately 2 miles of deep-cut channel connecting the Grand Lake pool, through a portion of the Grand Lake State Park (just west of Villa Nova on the north side of the lake), to the near headwater area of Fourmile Creek in the vicinity of U.S. Route 33. The selected route crosses the drainage divide which is at an estimated rim elevation of 904 feet NGVD. Selection of this diversion channel route was predicated on a "best fit" to existing topography after consideration of other St. Marys River tributary locations north of the lake. This route had also been identified in the Wabash River Basin Comprehensive Study (prepared by the Wabash River Coordinating Committee and dated June 1971), which recommended that this plan be examined in subsequent studies of Grand Lake St. Marys.

Examination of 53 years (1927-1979) of lake pool elevations indicated two severe inflow periods occurring at critical times. These inflows to the lake were experienced during a 6-day period in mid-May 1943, producing 11,750 day-second-feet, and a 6-dav period in early June 1958, resulting in approximately 11,300 day-second-feet. Both events occurred during prime crop and recreational seasons.

To limit the Grand Lake pool elevation to a maximum of 1-foot rise above west spillway crest for these two floods, a total mean daily outflow of approximately 818 cfs and 843 cfs would be required, respectively. These flows would be required through the severe inflow periods (mid-May 1973 and early June 1958) disregarding downstream conditions. Applying the 59 percent criteria would require west bank outflows of 483 cfs and 438 cfs for the two inflow periods. The estimated capacity of the four west bank gates, assumed operational and at pool elevation 870.75, is 450 cfs. Therefore, a combination of fully open gates and spillway overflows would be required to pass these proportional flows.

The suggested Fourmile Creek diversion channel is, then, designed to carry the remaining 41 percent of inflows or 335 cfs and 305 cfs for the two periods studied. Four trapezoidal channel designs were investigated, with a 15-foot bottom width and 3-foot horizontal/1-foot vertical side slopes used for the economic analysis.

Total first costs of the diversion channel and the outlet structure are estimated at $3,511,000 and total equivalent annual costs are estimated at $299,000. If it is assumed that total annual benefits, in the form of complete elimination of Beaver Creek and lake shore average annual damages estimated at $235,000 could be realized by this alternative, the resulting benefit to cost ratio would be 0.78.

Although actual economic benefits and flood damage reduction impacts have not been assessed, estimated costs of this alternative exceed potential flood damage reduction benefits along lakeshore and Beaver Creek. The alternative also has the potential of transferring flood damages along the diversion alignment and also to the St. Marys River. Because of an unfavorable economic result, this diversion alternative is eliminated as a viable plan for flood damage reduction.

Diversion to St. Marys River via St. Marys Feeder Canal

The purpose of this alternative consideration was to investigate modification of the existing eastern embankment spillway system to provide an east/west split of spillway discharge proportional to the historical drainage areas contributing to the lake. The historical lake drainage area contributions are 59 percent to the western outlet and 41 percent to the eastern outlet. The alternative suggests a more equitable balance of outflows that has potential to relieve flooding problems along Beaver Creek.

This alternative was addressed in a report entitled, "Grand Lake St. Marys, Miami and Erie Canal, Improvement Study," August 1979, prepared for the Ohio Department of Administrative Services, Division of Public Works, by Burgess and Niple, Ltd.[2] The plan as proposed by the engineer includes, among other items, a major improvement to the existing eastern lock system consisting of replacement of the present bulkheads with a new concrete ogee spillway having the same crest elevation as the present west spillway (elevation 870.75) and channel improvements which provide for greater flow capacity through the St. Marys Feeder Canal.

This cited report included discharge rating curves (Figure D-4) for the existing east and west bank spillways (derived from "Phase I Inspection Report," National Dam Safety Program, December 1978, prepared for the U.S. Army Engineer District, Pittsburgh, by Burgess and Niple, Ltd.)[3] The analysis and proposed improvement to the east embankment spillway appears to be satisfactory to provide the suggested east/west split of spillway discharge.

Conduit discharge potential for both the east bank and west bank was neglected, however, by Burgess and Niple in the analysis of this alternative. The west embankment structure contains four gated 30-inch diameter conduits with an estimated total capacity of 450 cfs at lake pool elevation 870.75 (from Figure D-5). The east embankment structure contains one gated 42-inch diameter conduit with an estimated capacity of 145 cfs at pool elevation 870.75 (from Figure D-6). Both discharge rating curves, Figures D-5 and D-6, were developed from available information by the Louisville District and are considered adequate for

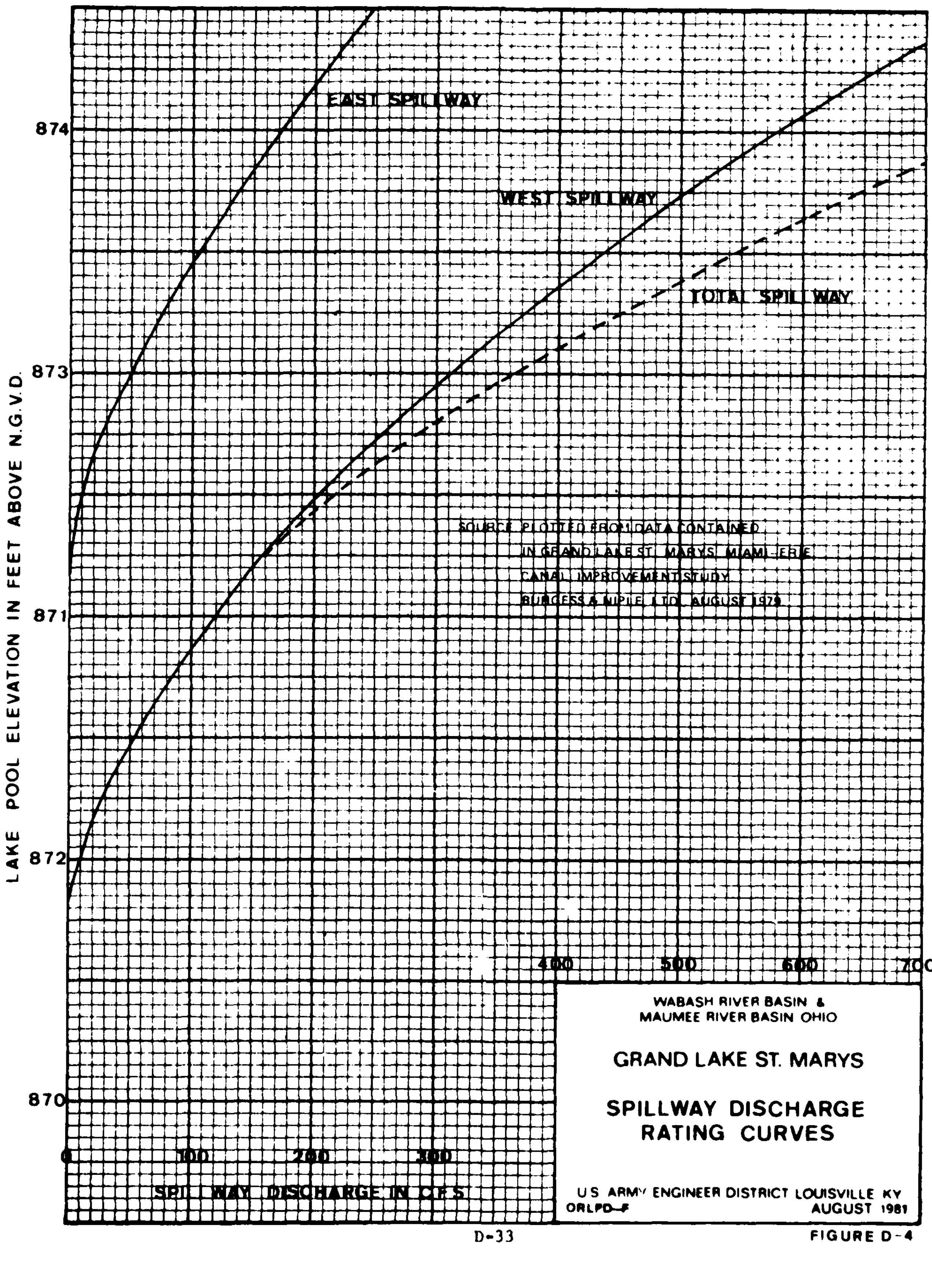
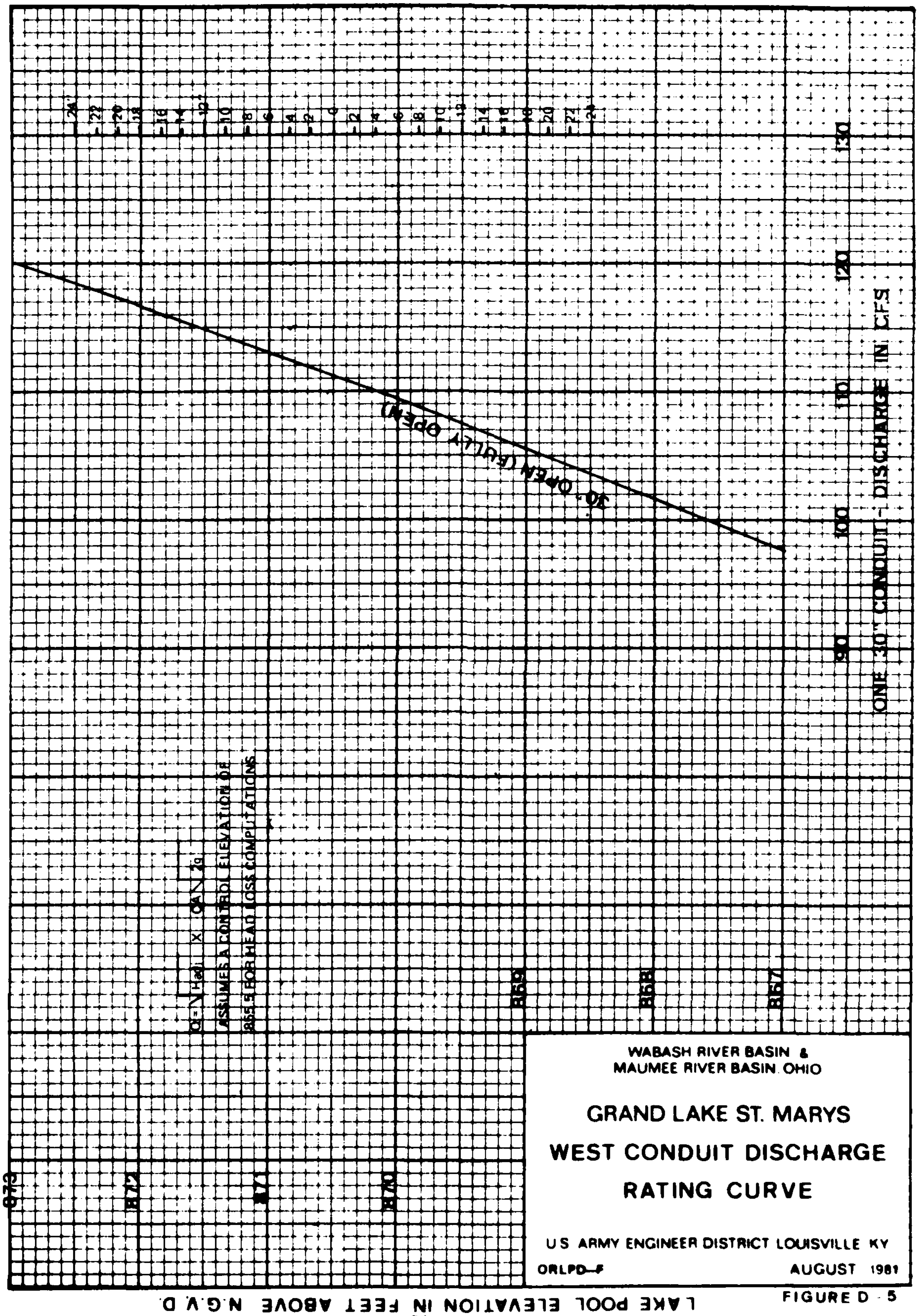

EAST SPILLWAY
WEST SPILLWAY
TOTAL SPILLWAY
SOURCE PLOTTED FROM DATA CONTAINED
IN GRAND LAKE ST. MARYS, MIAMI-ERIE
CANAL IMPROVEMENT STUDY
BURGESS & NIPLE, LTD. AUGUST 1979
LAKE POOL ELEVATION IN FEET ABOVE N.G.V.D.
874
873
871
872
870
0
100
200
300
400
500
600
700
SPILLWAY DISCHARGE IN CFS
WABASH RIVER BASIN &
MAUMEE RIVER BASIN OHIO
GRAND LAKE ST. MARYS
SPILLWAY DISCHARGE
RATING CURVES
U.S. ARMY ENGINEER DISTRICT LOUISVILLE KY
ORLPD-F
AUGUST 1981

FIGURE D-4



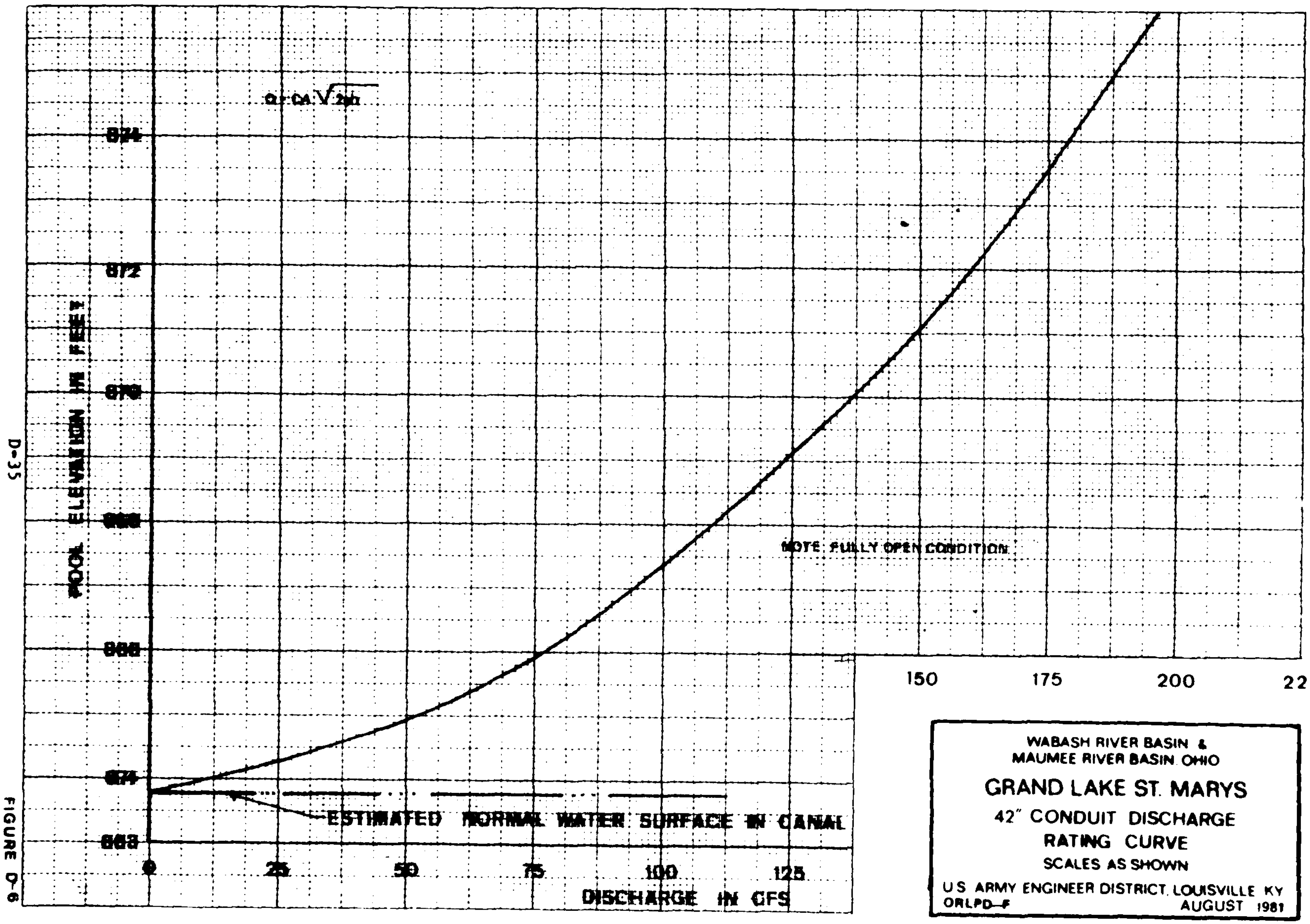
WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS
WEST CONDUIT DISCHARGE
RATING CURVE

U.S. ARMY ENGINEER DISTRICT LOUISVILLE KY

ORLPD-F AUGUST 1981

FIGURE D-5



D-35

FIGURE D-6

this survey report. Through an inspection of the existing conduit discharge rating curves, the desired 41/59 percent proportional discharge cannot be met for total discharge capacity.

Figure D-7 is a combined (conduit plus spillway) discharge rating for existing and modified conditions. The existing west embankment discharge rating curve includes four fully open gates plus spillway flow. The existing and modified east embankment discharge capacities are also presented. To satisfy the proportional discharge split, for total outflow capacity conditions, an additional 42-inch diameter conduit, or equivalent, would need to be added to the proposed Burgess and Niple east spillway modification plan.

According to the cited report, the proposed spillway/outlet channel modification is expected to result in: (1) a decrease in outflows to Beaver Creek; (2) approximately the same maximum lake elevation, and (3) greater increases in outflows from the eastern embankment outlet to the St. Marys Feeder Canal. The proposed spillway/outlet channel modification is expected to decrease outflows to Beaver Creek, but are of such low magnitude, being on the order of 5 cfs and 15 cfs for 25-year and 100-year recurrence intervals, respectively, as to result in negligible flood damage reductions along Beaver Creek. In addition, since the expansive lake surface is capable of storing large volumes of inflow, the spillway/outlet channel improvement proposed, though allowing a large increase in eastward outflows, creates only a slight decrease in lake levels in the order of 0.1 inch thereby negating any flood damage reduction benefits to the lake shore.

Lake Regulation (Re-Regulation)

Considerable public interest has been expressed in alternative lake regulation methods for the purpose of reducing flood damages along the lake shore and Beaver Creek, as well as for providing greater dependability in obtaining and maintaining the seasonal pool level. Alternatives considered in this study have included variations in: (a) winter

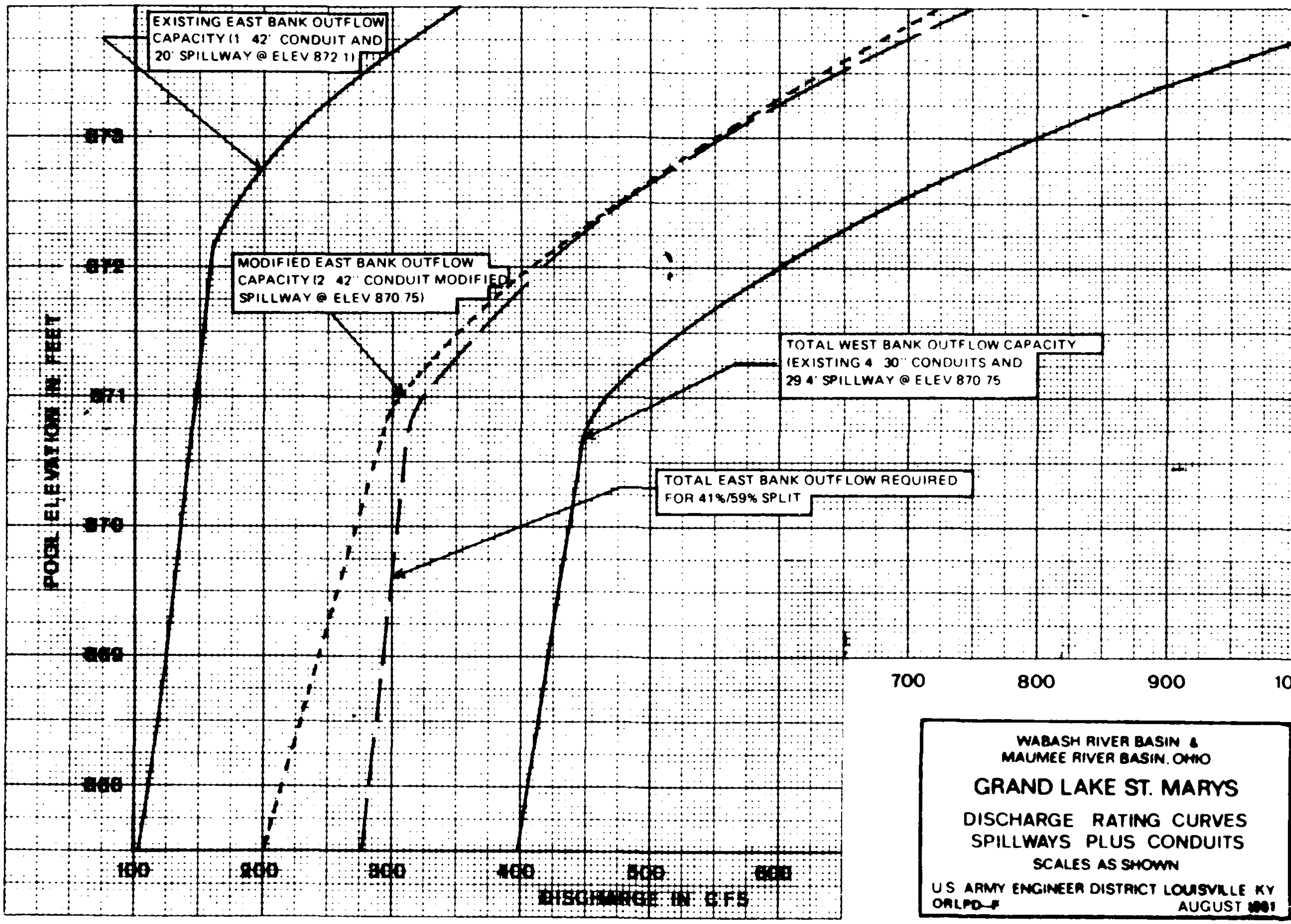

EXISTING EAST BANK OUTFLOW CAPACITY (1 42" CONDUIT AND 20' SPILLWAY @ ELEV 872.1)
MODIFIED EAST BANK OUTFLOW CAPACITY (2 42" CONDUIT MODIFIED SPILLWAY @ ELEV 870.75)
TOTAL WEST BANK OUTFLOW CAPACITY (EXISTING 4 30" CONDUITS AND 29.4' SPILLWAY @ ELEV 870.75
TOTAL EAST BANK OUTFLOW REQUIRED FOR 41%/59% SPLIT
POOL ELEVATION IN FEET
873
872
871
870
869
868
100
200
300
400
500
600
700
800
900
1000
DISCHARGE IN CFS
WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO
GRAND LAKE ST. MARYS
DISCHARGE RATING CURVES
SPILLWAYS PLUS CONDUITS
SCALES AS SHOWN
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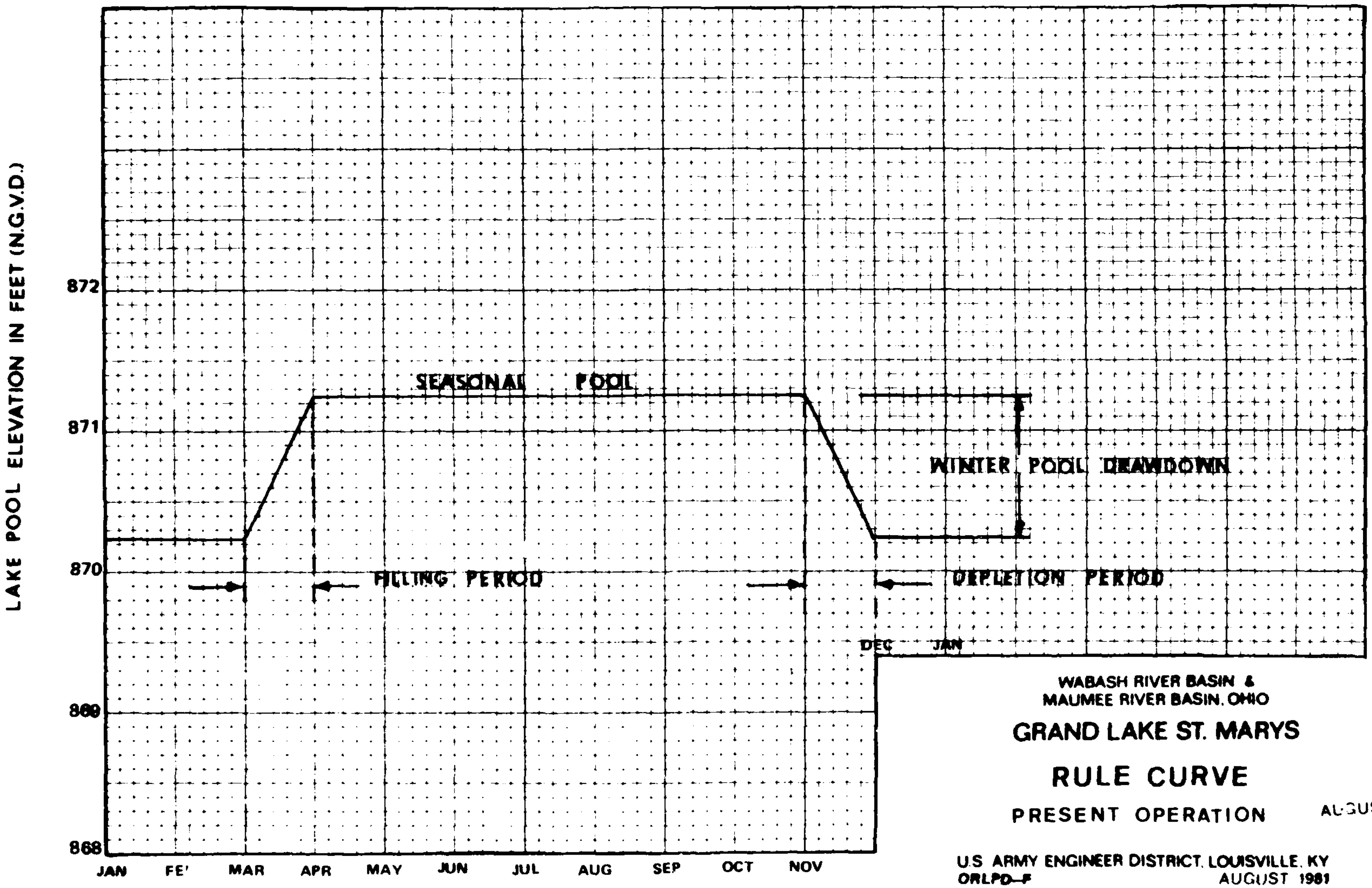
FIGURE D-7

pool drawdown -- provide flood control storage to reduce flooding along south shore and Beaver Creek; (b) initiation of pool filling -- attain recreation pool requirements; and (c) controlled releases -- reduce flood damages along Beaver Creek and also south shore. Figure D-8 identifies the current operation schedule and defines the above characteristics.

Filling Period. Three alternative winter pool drawdown levels were evaluated -- 1-foot, 2-foot, and 4-foot below the west bank spillway crest (elevation 870.75). Based on preliminary lake capacity data, the 1-foot, 2-foot, and 4-foot drawdown plans would require sufficient inflow to recover 6,330 day/second/feet (dsf); 11,900 dsf; and 21,500 dsf, respectively, for the return to recreation pool, elevation 870.75. A mass inflow curve (Figure D-9) was developed using the months of March and April (1969-1978) to determine the various time periods required to return the lake to recreation pool (the start of the recreation season is considered to be in the period of late March to mid-April). For the 1-foot drawdown alternative, pool filling could be initiated on 3 March-16 March to attain recreation pool by 31 March-15 April. The 2-foot drawdown would require approximately the full two-month period (March-April), while the 4-foot drawdown would not be recovered during the time period investigated. (This evaluation was based on average inflow conditions for the 10-year period, not an individual year basis.) This mass inflow examination indicates the necessity of an early March initial filing date to recover recreation pool by a desirable date.

Depletion Period. The time required to deplete recreation pool storage varies with the extent of total drawdown and inflow during the depletion period. For a west bank conduit release of 200 cfs and zero inflow into the lake, the 1-foot, 2-foot, and 4-foot drawdown minimum pool depletion time periods were determined to be 32 days, 60 days, and 107 days, respectively. To provide maximum available storage during maximum rainfall runoff period of December through March, pool drawdown for flood control storage should be completed by 1 December. For the three drawdown alternatives being considered, initial drawdown dates of 30 October, 1 October, or 16 August would be required.



WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

RULE CURVE

PRESENT OPERATION AUGUST

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FIGURE D-8

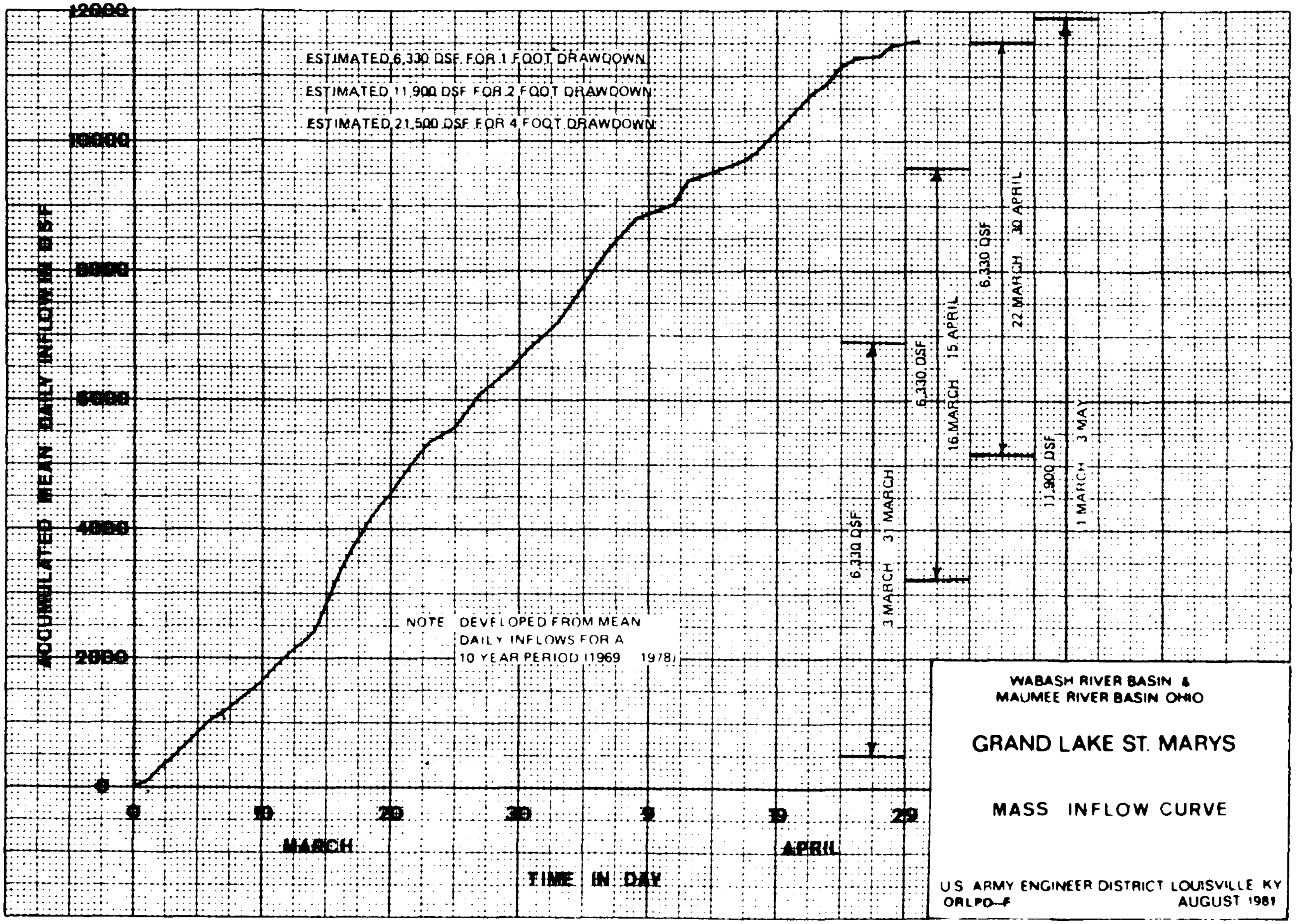
ESTIMATED 6,330 DSF FOR 1 FOOT DRAWDOWN
ESTIMATED 11,900 DSF FOR 2 FOOT DRAWDOWN
ESTIMATED 21,500 DSF FOR 4 FOOT DRAWDOWN
ACCUMULATED MEAN DAILY INFLOW IN DSF
12000
10000
8000
6000
4000
2000
0
0
10
20
30
9
19
29
MARCH
APRIL
TIME IN DAY
NOTE DEVELOPED FROM MEAN DAILY INFLOWS FOR A 10 YEAR PERIOD (1969 1978)
6,330 DSF
3 MARCH 31 MARCH
6,330 DSF
16 MARCH 15 APRIL
6,330 DSF
22 MARCH 30 APRIL
11,900 DSF
1 MARCH 3 MAY
WABASH RIVER BASIN &
MAUMEE RIVER BASIN OHIO
GRAND LAKE ST. MARYS
MASS INFLOW CURVE
U.S. ARMY ENGINEER DISTRICT LOUISVILLE KY
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FIGURE D-9

Winter Drawdown. As was previously indicated, three winter pool elevations were initially selected (869.75, 868.75, 866.75) representing a 1-foot, 2-foot, and a 4-foot drawdown below the west bank spillway crest. Because of the depletion and filling impacts of the 4-foot drawdown alternative on the recreation pool and the resulting exposure of mudflats, this alternative was not considered further. Associated with the two remaining pool drawdown alternatives, two west bank outflow release conditions were considered: (1) a maximium combined conduit plus spillway overflow of 200 cfs; and (2) a 200 cfs conduit flow plus uncontrolled spillway discharges.

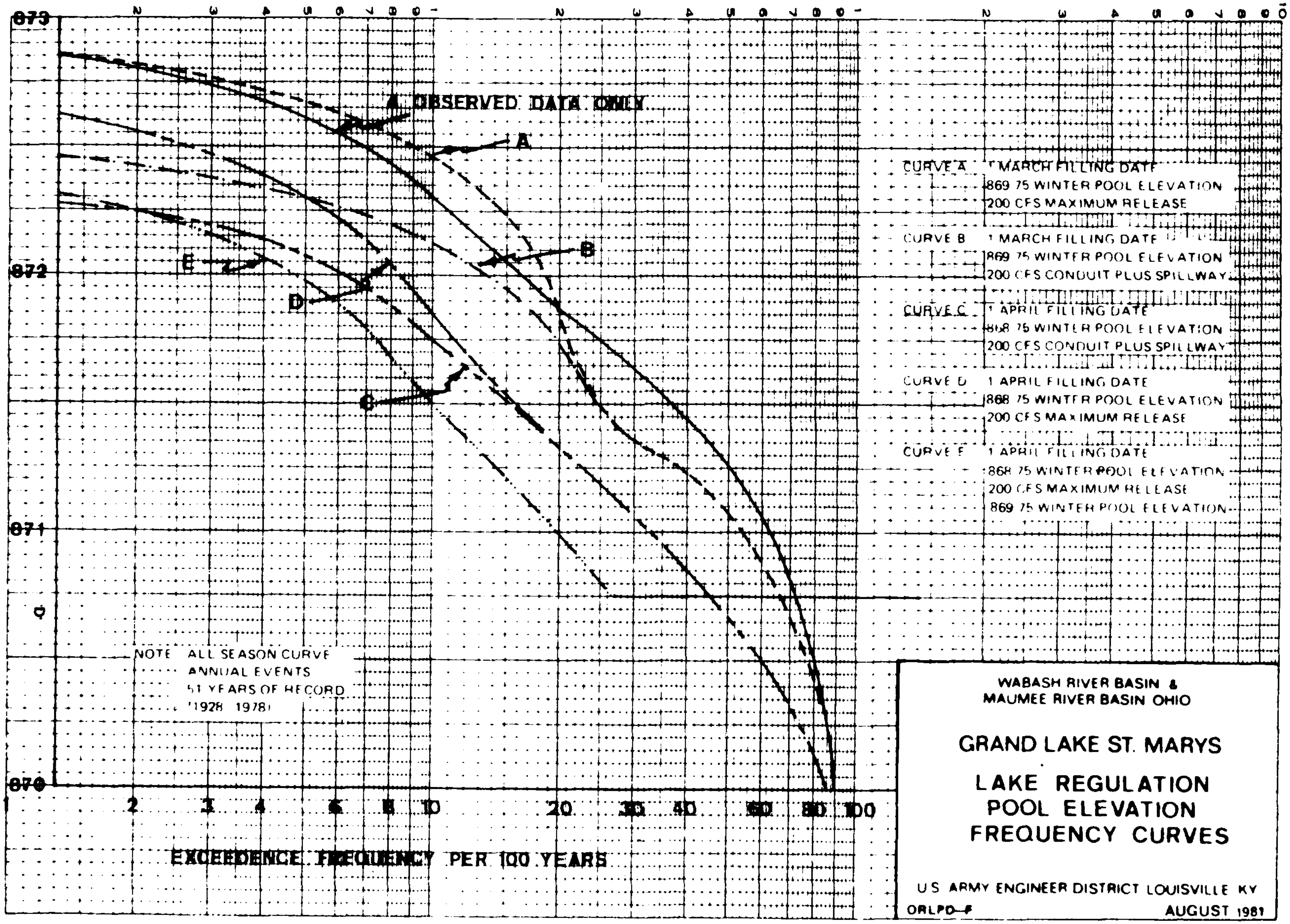
Figure D-10 displays the elevation-frequency relationships of the observed conditions for the period of record (Curve A^1), the existing operation schedule (Curve A), and four variations for filling, drawdown, and west bank releases. In reviewing Figure D-10 it is apparent that:

a. Winter pool drawdown alone will not alleviate excessive pool elevation problems;

b. An increase in the receiving stream(s) flow capacity must be achieved to obtain an optimum control of pool fluctuations; and

c. A filling date of 1 April would have a substantial impact in attainment of the recreational pool elevation.

From the perspective of maximizing attainment of the recreation pool and minimizing the flood damages along the south shore, a winter pool drawdown of 1-foot, a 1 March filling date, and a 200 cfs conduit plus spillway discharge (Curve D, Figure D-10) represents a potential tradeoff to the existing operation schedule represented by Curve A. Selection of Curve D requires consideration of the practicability of increasing outflows to Beaver Creek for reductions in flood damages along the south shore. Based on an economic evaluation, adoption of Curve D operation schedule would result in an average annual flood damage reduction (when compared to Curve B) to the south shore of $21,500; however, this alternative would induce flood damages along Beaver Creek by an average annual amount of $2,100.



WABASH RIVER BASIN &
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GRAND LAKE ST. MARYS

LAKE REGULATION
POOL ELEVATION
FREQUENCY CURVES

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FIGURE D-10

Clearing, Cleaning and Snagging

A clearing, cleaning and snagging alternative has been considered for Beaver Creek. This alternative consists of removal of flow-obstructing objects such as logs, rocks, debris, and bank vegetation for the purpose of restoring the channel to provide better hydraulic capacity and flow characteristics. In general, while usually being the least costly method of channel improvement, clearing, cleaning, and snagging alternatives are probably the least effective in reducing potential flood flow heights. In addition, these types of alternatives usually provide short term solutions to immediate problems since subsequent new vegetative growth and high flows may redeposit additional obstructions requiring that the clearing and snagging operation be repeated at some later time.

A clearing, cleaning, snagging alternative was investigated from mile 0 to 9.2 and from mile 10.2 to the outlet of Grand Lake, and would consist of cleaning the channel area of debris, log jams and shoals, and cleaning each bank of restrictive growth while leaving the stumps of woody growth. Some channel excavation and reshaping would be required. Stumping would not be included in this alternative in order to preserve streambank stability and fish and wildlife habitat to the extent possible. A 1-mile section between mile 9.2 and 10.2 has been improved sufficiently over the past years and is excluded from the analysis.

This channel improvement would provide a one-year, all season level of protection which is a good level of protection for the use being made of the flood plain. Reductions in flow elevations range from 1.0 foot in the lower reaches and upper reaches to 1.5 feet in the middle reach of Beaver Creek. These water level reductions are sufficient to minimize overbank flooding to the maximum extent, but prolonged flows will not be carried low enough in Beaver Creek such that tile drainage systems can function properly.

First cost of this alternative is estimated at $1,000,000. The annual costs of $97,000 (based on the current operation schedule for

Grand Lake St. Marys) and annual benefits of $38,000, result in a benefit to cost ratio of 0.4:1.0. Since annual costs exceed annual benefits, this alternative is economically infeasible.

Channel Enlargement

In general, these types of alternatives consist of modifying an existing watercourse to follow its original course, or constructing entirely new channels. In existing channels the modifications can take a variety of forms such as deepening or widening, side slope changes, pavement lining, and redesigning bridge piers and other obstructions. Riprap or other side slope protection may be added to prevent bank erosion. This alternative necessitates channel excavation, and although expensive, is an effective method to increase the flow capacity beyond its natural state. The results are usually long term provided that maintenance practices prevent the accumulation of debris.

This alternative consists of channel improvement on Beaver Creek from its mouth to the downstream western embankment outlet of Grand Lake. Two sizes of channel improvements were studied for the purposes of increasing the maximum release rate and reducing downstream flooding. The improved channels are designed to hold 5- and 10-year degrees of protection. A side slope of 1 vertical and 2 horizontal was considered in order to assure some degree of certainty against erosion. The alternative necessitates excavation on both sides of the channel. The smaller improved channel alternative (5-year - Alternative C) would have a bottom width of 40 feet at the upstream limit and 65 feet at the downstream limit. The larger improved channel alternative (10-year Alternative D) would have a bottom width of 60 feet at the upstream limit and 70 feet at the downstream limit. The two channel modification alternatives would essentially reduce the existing 5- and 10-year events to a level equivalent to the existing 1-year (all season) event. The project limits were established in order to alleviate overbank flooding in the entire Beaver Creek reach.

The costs and benefits for these two plans are presented below in Table D-3.

TABLE D-3

ESTIMATED BENEFITS AND COSTS
OF CHANNEL MODIFICATION
BEAVER CREEK (MILE 0 TO MILE 10.6)
($1,000)

Degree of Protection	Construction Cost	Annual Cost	Annual Benefits	Benefit to Cost Ratio
5-year	1,609,000	228,000	70,818	0.31
10-year	5,342,000	523,600	77,121	0.15

As can be seen in Table D-3, benefit to cost ratios for both channel designs are well below unity, making each of these alternatives economically infeasible. As shown in Figure D-11, improvement of the benefit/costs relationship is highly unlikely for smaller channel sizes.

Agricultural Levees (Beaver Creek)

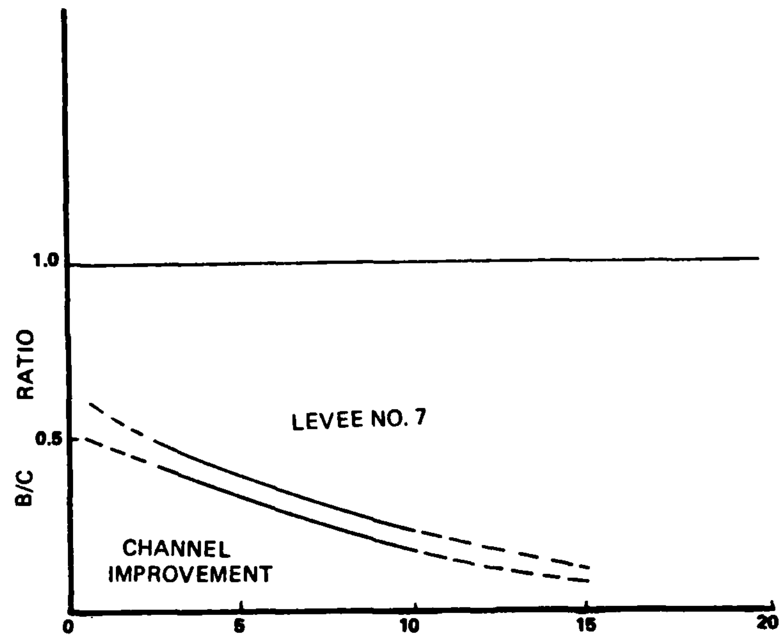
This alternative provides a possible means of reducing agricultural flood damages associated with the uncontrolled watershed runoff and any releases from Grand Lake. Two levee sizes were reviewed. This levee system was segmented and located on both sides of Beaver Creek (see Plate D-4). Hydrologic profiles and low bank elevations were used to determine the height, length, and location of each segment. For a 10-year level of protection, 12.5 miles of levee wold be required and protection afforded to 1,148 acres along Beaver Creek. Total first costs are estimated at $4,000,000 and annual equivalent costs for the improvement are estimated at $315,000. High operation and maintenance costs due to frequent overtopping and requirements for pumping runoff behind the levees contribute to the infeasibility of this alternative. For a 10-year degree of protection, annual benefits in the form of damages prevented amount to $60,700. The estimated annual cost and benefits of $315,000 and $60,700, respectively, result in a benefit/cost ratio of 0.19:1.0 making this alternative levee system economically infeasible. Individual levee data are presented in Table D-4. Figure D-11 also shows that improvement of the benefit/cost relationship is unlikely for lower degrees of protection.

Lakeshore Flooding

Breakwaters

Breakwaters are structures constructed to reduce wave height for the purpose of protecting shorelines or sheltering harbors. They are classified as either (1) fixed (permanent), or (2) mobile (transportable). Fixed breakwaters have, until recently, been used for many situations, but due to variable requirements for protection against wave action, increased attention has been given mobile systems. Fixed breakwaters can be constructed of earth, stone, rubble, or concrete and can be shore-connected or placed in areas of open water. Reduction of incident wave heights by fixed breakwaters is accomplished primarily by reflection of wave energy, which can create very large horizontal forces on a fixed breakwater. However, some fixed breakwaters can cause a reduction in wave height by a combination of reflection and forced dissipation through wave breaking. The relative amounts of energy dissipated or reflected depends on the slope of the breakwater, the depth of water, the wave height, and the wave steepness.

Due to the construction cost of fixed breakwaters, much attention has been directed toward other methods of wave attenuation, namely mobile breakwaters. The primary objective of the mobile breakwater is to interact with the upper portions of the waves where most of the energy is concentrated. As a result, the requirements for their design and construction are considerably different from those of a fixed breakwater.



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GRAND LAKE ST. MARYS

RELATIONSHIP OF
BENEFIT/COST RATIO
TO DEGREE OF PROTECTION

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FIGURE D-11

TABLE D-4

BEAVER CREEK LEVEE PLAN

Item	Levee Unit 1 10-Year	Levee Unit 2 10-Year	Levee Unit 3 10-Year	Levee Unit 4 10-Year	Levee Unit 5 10-Year	Levee Unit 6 10-Year	Levee Unit 7 10-Year
Drainage area behind levee (acres)	1,943	425	440	1,419	718	433	1,276
Area protected (acres)	303	122	76	167	55	88	337
Length of levee (feet)	11,100	8,600	5,500	12,000	8,500	6,500	14,000
Estimated Project Cost							
Federal cost ($1,000)	$ 516	$ 371	$ 295	$ 572	$ 225	$ 307	$ 966
Nonfederal cost ($1,000)	79	69	56	150	198	52	164
Total Project Cost	$ 595	$ 440	$ 351	$ 722	$ 423	$ 359	$1,130
Estimated Annual Charges							
Federal charges ($1,000)	$ 38.2	$ 27.5	$ 21.9	$ 42.4	$ 16.8	$ 22.9	$ 70.0
Nonfederal charges ($1,000)	8.8	7.5	5.7	14.5	17.0	5.7	16.1
Total Project	$ 47.0	$ 35.0	$ 27.6	$ 56.9	$ 33.8	$ 28.6	$ 86.1
Annual Economic Benefits							
Average annual benefits	16.02	6.5	4.0	8.8	2.9	4.6	17.8
Benefit to cost ratio	.34:1	.19:1	.14:1	.16:1	.09:1	.16:1	.21:1

Floating breakwaters, the only type of mobile breakwater judged feasible for Grand Lake, can generally be classified as (1) flexible floating structures, and (2) rigid floating structures. Flexible floating breakwaters usually extend a small fraction of the water depth below the surface. As a result, little wave attenuation is realized through wave reflection and smaller mooring forces are developed. Many types of flexible floating structures have been investigated, and each incorporates (to varying degrees) viscous damping, destruction of wave orbital motion, and/or energy absorption within the structure to attenuate waves. In almost all cases, the length of the breakwater in the direction of wave propagation must be longer than the wave length.

A rigid floating breakwater must extend deep enough below the surface to encounter a majority of the wave energy. This is not the rule, however, since rigid floating slabs behave more like flexible floating structures when the structure length is much longer than the incident wave length. Most of the rigid floating structures investigated attenuate waves through various combinations of energy dissipation within the structure, out of phase damping, wave interaction between incident and reflected waves, and other wave interferences caused by the breakwater. Since most of the wave energy is reflected in a rigid structure than in a flexible structure, higher mooring forces are developed.

Of the many types of fixed and floating breakwater design concepts available, five were selected as possibilities for application to Grand Lake including two types of fixed breakwaters, a rigid floating structure, and two flexible floating structures. The fixed breakwaters include dredge islands and the rubblemound breakwater. The rubblemound breakwater was chosen because it is essentially the least expensive of the conventional fixed breakwaters, and material for construction is available locally. A rigid floating concrete breakwater was chosen since it has had application in similar wave environments. Two designs for flexible floating tire breakwaters were also evaluated. Floating tire breakwaters have received considerable attention in the eastern United States as an inexpensive alternative for reducing wave action in inland lakes.

Various results of the analytical modeling study can be used to investigate an idealized case in which a breakwater is indistinguishable from a lake boundary. That is, the breakwater serves to completely isolate the upwind and downwind lake segments. The possible transmission of a wave across a floating breakwater is not accounted for, and the effects of diffraction around the end of the breakwater are ignored. In effect, the one-dimensional nature of the model prohibits an investigation of the efficiency of a breakwater that spans only a part of the lake. Nevertheless, the results are of value in that they provide an upper bound on the expected wave reductions.

Breakwaters were considered for use at Grand Lake St. Marys because of their potential to resolve several problems relating to lakeshore flooding and erosion, water quality, and recreation. The following paragraphs evaluate the beneficial and adverse impacts of breakwaters in these areas.

Lakeshore Flooding and Erosion. Breakwaters have application to several of the physical problems identified in Grand Lake including lakeshore flooding, severe wave action, and shoreline erosion.

Flooding of shorelines due to wind setup was shown to be possible, particularly if water levels in Grand Lake are high. For example, displacement of the mean water surface at the eastern embankment for a 50 mph westerly wind was shown to be 1.35 feet. Wind setup in water bodies like Grand Lake is most prevalent when the prevailing winds and major axis are coincident and there are no significant obstructions to horizontal water movements. Therefore, in the case of Grand Lake, relief could be provided by strategic placement of fixed breakwaters such as dredge islands or rubblemound breakwaters. On the other hand, floating breakwaters would directly respond to a long-period water surface change and would have virtually no effect on wind setup. This is because wind setup simply establishes a hydrostatic pressure gradient to balance wind stress and is not caused by short-period wave action for which floating breakwaters are designed.

Breakwaters can also serve to reduce shoreline erosion and wave action. In general, breakwaters used for obtaining these objectives would need to be evaluated on a site-by-site basis. However, the short-period wave height has been found to increase in an approximate exponential manner with distance along the lake axis (Figure D-12) and significant reductions in wave action over the entire lake would require an extremely complex and extensive breakwater system. For example, with reference to Figure D-12, reducing the fetch along the major axis of Grand Lake by two-thirds (33 percent of maximum fetch) results in only a 10 percent decrease in maximum significant wave heights. To achieve a 50 percent reduction in wave height at a shore, the breakwater would have to be located within about 2,000 feet of the shore (5 percent of maximum fetch).

Water Quality. The primary water quality related impact of breakwaters is to reduce wave-induced sediment reentrainment and transport within the lake. The engineering analysis related to sediment movement illustrated the capability of wind-generated waves on Grand Lake to erode sediment from the lake bottom and maintain it within the water column. These processes have created high levels of turbidity within the lake. This is evidenced by the secchi disk readings of the EPA[4] which ranged from only 12 to 20 inches at the lake.

Conceivably, were wave action to be reduced to a point where turbidity was significantly reduced, potential adverse water quality problems may arise. In particular, reducing turbidity in the shallow portions of the lake could lead to increased aquatic plant growth. This in turn may have a negative impact on boater access and safety. The value of suspended sediment within the water column in providing a sink for nutrients has not been evaluated. However, there is evidence, based on the water quality modeling performed, that the sediment may contain a high proportion of the nutrients supplied to the lake. Therefore, were the suspended sediment reduced, the potential for algal blooms could increase.

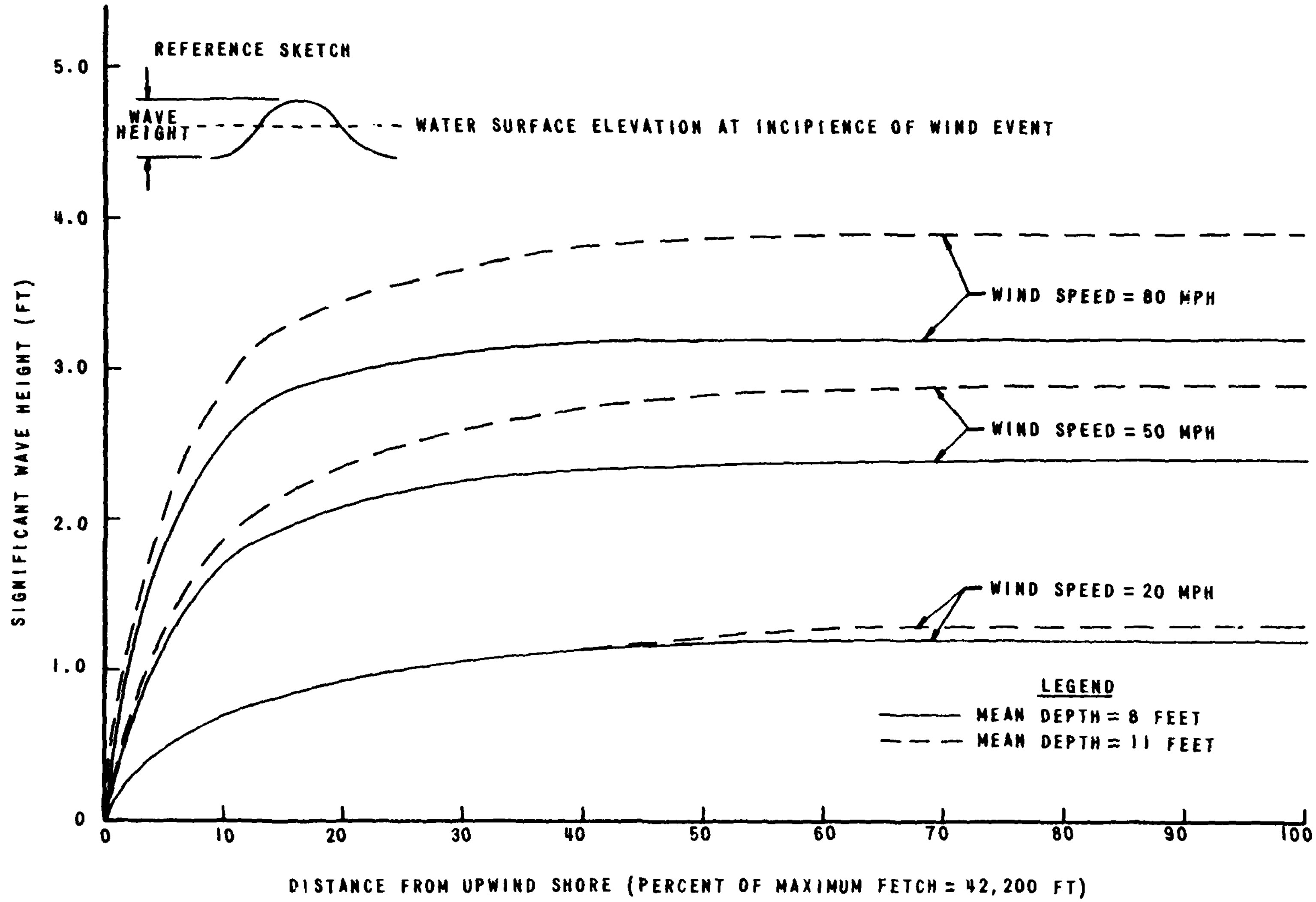

FIGURE D-12. Significant Wave Height along Major (East-West) Axis for Selected Wind Speeds

A general improvement of Grand Lake's fishery is a major beneficial impact resulting from reduced turbidity. However, reducing turbidity by reducing wave action could have an adverse effect on dissolved oxygen levels within the lake since wave action is a very effective reaeration mechanism. Were breakwaters to be implemented on a scale large enough to result in segmentation of Grand Lake, additional impacts on water quality would need to be considered. In particular, segmentation would reduce the exchange of water between the segmented areas. It is possible that certain areas of the lake would receive a disproportionate share of the annual nutrient load. Segmentation could, therefore, have a negative impact on water quality in these areas.

As with any construction activity within Grand Lake, temporary, localized adverse impacts on water quality can be expected during the construction of breakwaters. Increases in turbidity and the associated transport of nutrients into the water column are probable.

Water-Related Recreation. Many of the benefits to be expected from breakwater construction in Grand Lake are associated with water-based recreational activities. The consequential creation of stillwater areas is expected to promote water skiing and sailboating activities, consistent with an overall increased interest in these sports. Boater safety could also be increased, since the leeward side of the breakwaters will provide a protected access route to shore. On the other hand, boating access to all portions of the lake will be obstructed. Provision must be made for boat passage at the ends or at designated points along the breakwaters. A minor adverse impact is that the length of existing speed lanes could be reduced.

As discussed earlier, breakwaters could have a beneficial impact on the lake's fishery. Related to this is the increased use of Grand Lake by sport fishermen. Shore-connected breakwaters, provided with walkways for safety, could provide excellent access to deeper portions of Grand Lake and alleviate a basic need for boats. This should be a major consideration in any breakwater proposal for Grand Lake.

Technical Feasibility. Fixed breakwater design requires investigation of many parameters, which vary according to the type of structure. For an earth or rock structure, the most important considerations are the depth of water and the foundation material. To assure stability of rock breakwaters, a trapezoidal cross section is usually specified. Therefore, for small increases in depth, increasing percentages of material are required. A major disadvantage of fixed breakwaters is that they cannot be easily moved in cases where adverse environmental impacts are created by its construction.

Floating breakwater design is also dependent on many parameters. However, in contrast to fixed breakwaters, they can be constructed without much regard to water depth or foundation conditions. Mooring floating breakwaters becomes a major consideration, as do the construction materials. Determining locations for achieving the maximum benefit from breakwaters could be simplified by the use of floating breakwaters. If the benefits derived from the initial placement are found to be less than desirable, floating breakwaters may be moved to other sites requiring wave protection.

Several disadvantages also exist. Floating breakwaters, in general, require more maintenance and do not provide the same degree of wave protection as fixed structures. Based on experiences with floating breakwaters, year-round mooring in severe ice conditions is not possible. Floating breakwaters can be a hazard to navigation and a source of liability if not effectively marked.

Based on this investigation, the conditions at Grand Lake are amenable for construction of either fixed or floating breakwaters. The shallow lake depth can be considered an advantage for fixed breakwater construction. The foundation characteristics are considered to be satisfactory. Since dredge islands are currently being constructed on Grand Lake and are being considered for wave protection, foundation considerations are probably not required.

Based on a wave forecast analysis, the wave climate in Grand Lake is conducive to floating breakwaters. Since wave heights are on the order of 3 feet and wave periods on the order of four seconds, floating breakwaters can be constructed at a reasonable cost and provide significant wave protection. Mooring floating breakwaters to piles is recommended in shallow water conditions such as those encountered in Grand Lake.

The most significant physical constraint on the use of floating breakwaters in Grand Lake is ice formation. Since Grand Lake is shallow its ability to store heat is minimal and ice inevitably forms as the heat is released to the atmosphere during the winter season. A much greater concern is related to the stability of the ice cover. Since Grand Lake's surface area is so large, there is little chance of forming a stable ice cover. Wind-induced stresses at the air-ice interface can lead to the eventual deformation of the ice cover. This deformation can cause significant damage to floating breakwaters and their mooring systems. To avoid ice damage to these structures, provisions for moving the breakwaters to areas sheltered from ice movement are required. Ice formation around the structures should not cause damage as long as ice movement is eliminated.

Economic Feasibility. Based on preliminary designs and costs of previous applications for the types of breakwater under consideration, unit costs for breakwater construction in Grand Lake were developed. The results are tabulated as follows:

Breakwater Alternative	Unit Cost (per Lineal Foot)
Dredge Island Containment	$ 200
Rubblemound	$ 450
Floating Concrete	$ 300
Floating Tire	$ 50

Costs for dredge island type breakwaters reflect the need for containment dikes on each side of the breakwater. The unit cost for rubblemound breakwaters was based on a typical trapezoidal cross section in 8 feet of water as recommended by the Corps of Engineers Shore Protection Manual.(5) The unit cost for floating concrete breakwaters was based on a design wave height of 3 feet and a wave period of four seconds, and includes mooring and installation costs. The unit cost for floating tire breakwaters was taken from previous applications information and represents a lower limit since a substantial portion of the material and labor can be donated.

A total cost figure for breakwaters would be dependent on several factors including location, orientation and spacing in the lake. Because an overall plan has not been developed, only representative costs can be given. However, to provide order of magnitude costs that are consistent with the analytical methods used, the generalized length of breakwater is equated to the width of the lake (12,000 feet) or to breakwaters placed parallel to the length of the south shore. This latter orientation has a greater potential for alleviation or reduction of south shore erosion and flooding problems. Costs related to breakwaters are given in Table D-5.

TABLE D-5

COSTS RELATED TO BREAKWATERS

Item	Dredge Island ($200/LF)	Rubble-Mound ($450/LF)	Floating Concrete ($300/LF)	Floating Tire ($50/LF)
Cost to span lake width (12,000 feet)	$2,400,000	$ 5,400,000	$ 3,600,000	$ 600,000
Costs to span south shore (40,000 feet)	$8,000,000	$18,000,000	$12,000,000	$2,000,000

Based on analyses conducted in this study, a single breakwater is not expected to produce enough of an effect on lake water quality or physical conditions (shore erosion, wave heights) to result in measurable direct or indirect monetary benefits. An extensive series of breakwaters would be required before benefits based solely on improvements to these problems could be realized.

In contrast, a large number of breakwaters is not required to possibly achieve a noticeable increase in lake usage. The benefits to boating and fishing of even a single, strategically located breakwater have already been presented. As such, there may be increased income potential from increased or reestablished lake visitation due to the improvements. For example, the approximate $4,000,000 annual loss in revenue that apparently has occurred over the last several years relative to 1973 visitation levels would be nearly sufficient to justify constructing any type of breakwater across the width of Grand Lake. Even though a one-to-one correspondence between lake visitation patterns should not be construed from this discussion, the results do have value for comparative purposes. It is judged that, from a recreational usage standpoint, an expenditure of $4,000,000 dollars on breakwater construction would be preferred to the 2,000,000 cubic yards of dredging that could be done for the same amount. This same preference would also apply to water quality and physical lake condition improvements.

The most significant benefits to be realized would be for recreation with respect to boating and fishing in the form of income potential due to increased or restored lake visitation.

Groins

Groins spaced along the south shore of Grand Lake have been suggested as a possible means of alleviating shoreline erosion and local flooding problems. Groins are constructed to build, widen, or stabilize an existing beach by trapping littoral material. The structures keep wave action from reaching the erodible backshore.

Analytical results of the wind and wave field situation and the northerly exposure of the south shore have revealed that westerly winds are not the major concern for south shore protection. This means that groins, connected to shore and oriented generally perpendicular to the south shore, may not be very effective in alleviating the worst problem conditions. Breakwaters parallel to the south shore could prove more beneficial.

Overall impacts and costs of groin are similar to those discussed for breakwaters. One noteworthy aspect is that groins often result in localized sediment build-up due to the created current patterns. However, this condition applies more to longshore transport in coastal regions, and the short-term intensity and directional shifts of wind-driven currents at Grand Lake should minimize its occurrence. There is no evidence of localized sediment deposits near the existing Windy Point breakwater.

Based on a unit cost of $300 per lineal foot of lake shore protected, it is estimated that a groin system constructed along the south shore would cost upwards of $12,000,000. Groins perpendicular to the south shore are not expected to achieve the desired impact of shoreline protection and from a benefit standpoint are not perceived to be economically feasible.

Shoreline Levees

The concept of shoreline levees has been considered as a measure to reduce flood damage due to high, uncontrolled lake levels resulting from isolated storm events. Two specific levee heights, 2 feet and 5 feet, were selected for detailed analysis based on stage-frequency data for lake levels. A reference elevation of 870 feet N.G.V.D. was used, since this elevation is representative of the mean water surface elevation and also provides a reference line for analytical purposes on USGS topographic mapping. A 2-foot high levee with a top elevation of 872 would serve basically as a safeguard against persistent minor flooding during high water periods. Such a levee would provide protection for storms of up to 10-year recurrence interval. If the lake is at its mean elevation of approximately 870 feet, the levee would also contain wave action for wind speeds up to 50 mph. The combined effects of waves and high-water conditions reduce these criteria somewhat, but the overall reason for a two-foot levee is not diminished. It cannot be anticipated that a two-foot levee will protect against extreme hydrological conditions capable of causing significant structural and economic damages.

The latter type of protection would be the planning intent of a five-foot high levee. The selection of this particular height was convenient for analytical purposes due to the availabilty of an 875-foot contour on existing topographic mapping. More importantly, the hydrologic and hydraulic basis is that the maximum water surface elevation associated with a one-half probable maximum flood (PMF) storm event is approximately 875 feet N.G.V.D.

Impacts. The most apparent benefit associated with shoreline levees (dikes) is the reduction of flooding and its attendant damages. Both nuisance flooding conditions resulting from wave action and severe floods due to single storm events can be mitigated. An equally important benefit of levees is protection against wind and wave-driven ice and the resultant damages. On the other hand, an alleviation of the persistent drainage problems along the south shore is not anticipated. In fact, unless adequate internal drainage is provided at a high cost, ponding and drainage problems could be aggravated.

A principal adverse impact of levees is the associated disruption of waterfront land, a large percentage of which is privately-owned, landscaped property. A 30-foot right-of-way could be required to satisfy recommended design features for the five-foot levee. Another adverse impact is that levees will impede lake access for both private landowners and visitors. A negative aesthetic impact also occurs since the view of the lake is obstructed, primarily in the case of the five-foot levee.

Adverse impacts on wildlife could occur during and subsequent to levee construction. The disturbance of the landscape, particularly in those areas where access routes must transgress wooded areas, will disrupt native wildlife populations and could affect feeding habitats. The eventual hindrance of lake access created by a levee could also result in a shift in wildlife watering patterns. If proper internal drainage is not provided in these undeveloped areas, low-lying areas could periodically and temporarily become wetlands. This would likewise disrupt wildlife, and could prevent the establishment of a stable indigenous population of lower-order animal and plant species.

Technical Feasibility. The technical and physical feasibility of levees is limited by two factors. First, levees will prevent surface runoff from the protected areas, and alternate means of drainage must be formulated and implemented. This would be especially difficult in developed areas since topographic relief is limited. The use of a storm sewer system is constrained at Grand Lake by the high groundwater table near the shorelines. The most feasible (but not totally effective) alternative would be to collect water from roadways and paved areas, with subsequent pumpout from a number of collection points. A regrading program would be necessary.

Due to existing subsurface and groundwater conditions, a greater concern is the potential for levee underflow when the lake level is high. That is, if the lake level rises on the lakeward side of the levee, the hydrostatic imbalance could initiate water movement under the levee and into the protected area thereby reducing the utility of the levee. Engineering solutions to prevent or retard this flow could be developed, but the additional cost of implementation would be high.

The institutional constraints on levee construction could be the most critical factor. This is particularly true at Grand Lake, where the lakeshore property of highest value and most critical to protect is privately owned. In order for a levee to be effective, no "breaks" in its continuity can be allowed thereby requiring 100 percent cooperation from affected landowners.

To evaluate the economic feasibility of a levee system for affected areas of Grand Lake, a particular developed area typical of conditions on the south shore was selected. This area is located west of Moorman Road and State Route 703 (see Plate D-5). Due to the generally flat near-shore area, the length of levee necessary to achieve the desired protection is equated to the length of the 870 foot contour, with tie-in to higher ground across undeveloped areas where appropriate. Two cases of levee layout were examined. The first retains total channel access to the lake, while the second minimizes levee length by cutting off these access channels. The former system is not an impairment to boater access, but the latter would either render most channels inaccessible or require locks for passage.

Table D-6 presents data and associated total project construction costs and benefits for this typical application. It can be seen that levees are not cost effective for the expected level of reduced damages for this example location. It is also observed that since there are numerous private access channels, levee requirements and costs are nearly tripled.

TABLE D-6

BENEFIT AND COST DATA FOR
SHORE LEVEE FLOOD CONTROL ALTERNATIVE
AREA WEST OF MOORMAN ROAD

	Access Channels Maintained		Levees Across Access Channels	
Levee Height (feet)	2	5	2	5
Levee Length (lineal feet)	14,000	14,000	5,000	5,000
Total First Cost	$ 957,000	$1,752,500	$ 342,000	$ 626,000
Equivalent Annual Cost	71,450	130,000	26,200	47,100
Annual Average Benefits	23,000	23,000	23,000	23,000
Benefit to Cost Ratio	0.32:1.0	0.18:1.0	0.88:1.0	0.49:1.0

Extending the benefit/cost analysis for levee construction to other affected areas is complicated by the wide range of valuations of dwellings along the south shore. Information provided by local realtors indicates that several properties with older cottages are essentially selling for the cost of the land parcel, whereas the value of dwellings in the newer developments approach (and no doubt exceed) $100,000. To approach the question from a different vantage point, the break-even point for the case of a five-foot levee in the example application is about $11,500 per dwelling if protection against total loss of each structure is assumed. This is a reasonable average value for south shore dwellings, and would appear to justify levee construction. However, full loss of dwellings cannot be anticipated from a flooding event that would be controlled by a five-foot levee. Even if a net benefit did result, the technical and institutional constraints on levees are felt to be limiting factors.

In addition to economic constraints, several adverse impacts are associated with a levee system for lakeshore flood protection. The levees could aggravate internal drainage and ponding problems behind them. Levees would disrupt privately-owned waterfront property and require wide easements (up to 30 feet) for their construction. Levees would significantly reduce boater access to open water and boat docks particularly for the channel crossing alternative. Levees would significantly obstruct the lake view. Moreover, success of the levee system requires no breaks in continuity and would necessitate total cooperation with landowners.

Lake Water Quality Improvement Alternatives

Treatment of Wastewater Inflows (Point Source Controls)

The deterioration of Grand Lake is attributed, in part, to contamination by domestic wastewaters. A great portion of homes, resorts, and other public and private facilities surrounding the lake are not connected to public facilities and, therefore, use individual on-site (septic tank-drain field) systems or small package sewage treatment plants. In addition, one municipal point source, namely the St. Henrys Sewage Treatment Plant, discharges to Coldwater Creek, which is a tributary to the lake. These methods of treatment have shortcomings which result in improperly treated sewage seeping or discharging into the lake. Improperly functioning systems aggravate the lake's water quality problem in addition to increasing viral and bacterial levels and affecting lake use for recreational activities. It is estimated that these sources contribute 8 percent of the total annual phosphorus loading to the lake (2,805 kilograms). Elimination of septic tank and point source discharge problems would relieve a sizeable portion of the lake's pollution problems, especially the high bacteria count.

The St. Henrys wastewater treatment plant contributes approximately 4 percent of the total loading to Grand Lake via Coldwater Creek; therefore, an explanation of methods of eliminating this source of phosphorus is in order. This plant currently discharges an average of 127,600 gallons per day (0.13 mgd) of treated effluent having a phosphorous concentration estimated at approximately 0.12 mg/L.[4] Since Coldwater Creek has a design low flow of zero at the dischage point, tertiary treatment to supplement the existing secondary treatment would be required to meet stream quality standards. Currently, there is no unit process available to further reduce the concentration of phosphorus in the effluent prior to discharge to Coldwater Creek. To remove the remaining phosphorus, the effluent would have to be either evaporated, diverted to another basin, or disposed of through a land treatment alternative. Evaporation is impractical because of high cost for a plant of this size. The capital cost of a multiple effect evaporator to treat 0.2 mgd is in excess of $800,000. In addition, operating costs are high because of the energy requirements to drive the evaporator. There are two ways to divert the wastewater treatment plant effluent from Coldwater Creek. The effluent can be transported by pipeline and redischarged into the Wabash River south of St. Henry. This is a distance of approximately 3 miles. A pipeline system comprised of force main, pump station and gravity sewer would cost approximately $820,000

(1980 dollars). This alternative, however, is further constrained by the same low flow conditions in the Wabash River as in Coldwater Creek. The second bypass alternative is to apply the effluent to land. Preliminary review indicates the topography and soils in the St. Henry area would be suitable for land application. The cost of implementing this alternative was estimated to be approximately $1,200,000 based on 0.2 mgd (1980 dollars), 0.5 mile conveyance, 10 week storage, 2 inches per week application rate, underdrains, and a 70-acre site.

Several approaches are possible in dealing with wastewater inflows from areas immediately tributary to the lake. The first involves collection, treatment, and disposal of effluent directly to the lake. The method requires high levels of treatment, at great expense, to remove excess nutrients (phosphorus and nitrogen) prior to discharge to the lake. The second treatment/disposal approach is to collect, divert, and treat domestic wastewater away from the perimeter of the lake. No treated effluent would be allowed to discharge to the lake.

Both concepts were the subject of studies included in the Grand Lake Regional Sewer System Plan.[6] The first approach (Plan D) considered a new treatment facility to be constructed on the southside of the lake to handle all flows from existing and future developed areas. Since this facility would discharge treated effluent directly to the lake, strict effluent limits would be imposed, particularly for biochemical oxygen demand and nutrients. Treatment to the degree required (8 mg/L BOD_5) is not possible with conventional secondary treatment. Tertiary (advanced secondary) treatment would be required. The second approach (Plan A) proposed to divide the immediate lake area at the Mercer-Auglaize County line with the Cities of Celina and St. Marys providing conveyance and wastewater treatment on the basis of their respective county sewage flows in upgraded, expanded plants. Effluent discharge would be other than into Grand Lake St. Marys.

The second approach (Plan A) was found to be the most cost effective, environmentally acceptable alternative. Annual equivalent costs for Plan A and Plan D were estimated at nearly $1,800,000 and $2,000,000, respectively. Total estimated capital costs of the recommended plan is $14,912,000.

However, the contribution of nutrients from 17 domestic wastewater treatment plants that currently discharge directly or indirectly to the lake is minor, being approximately 2 percent of the total load entering the lake on an annual basis. This nutrient discharge will have a negligible impact on the long-range overall water quality of the lake with respect to phosphorus load and concentration. Likewise, phosphorus input to the lake from faulty septic tank-soil absorption systems close to the lake are estimated to be contributing only small quantities of phosphorus to the lake (less than 2 percent). The implementation of a regional sewage system that encompasses the south shore is expected to reduce the existing phosphorus loading to Grand Lake by less than 10 percent and little improvement in the phosphorus concentration or trophic state of Grand Lake St. Marys would be anticipated as a result. (This may not be the critical concern, however, since the primary water quality improvement associated with the proposed sewage system is the reduction of bacterial pollution to the lake.)

Although the planned regional sewerage project (Plan A) is seen to be a positive step toward reducing pollutants to the lake and in particular bacteriological pollution emanating from human sources and would effect a lifting on the currently imposed construction ban, a major unresolved question is whether centralized collection and treatment of wastewater, as planned, is justified because of the financial burden it places on its residents. Costs would be high due to the need for extensive collecting and pumping of wastewater along the south shore where houses are scattered and topography is flat.

A third wastewater management approach involves on-lot systems for low density or small community areas. Although a thorough analysis and evaluation of this approach is beyond the scope of this study, it is worthy of mention for possible application to the Grand Lake St. Marys area. In the past, the nationwide tendency has been to provide conventional collection, conveyance, and treatment systems to meet the wastewater management needs of low density areas or smaller communities). Recently, however, attention has focused on the consideration of innovative on-lot systems as an alternative to central sewerage systems. In recent draft guidance documents, the USEPA has underscored that alternatives other than central sewerage systems must be evaluated for small communities, in terms of cost-effectiveness, as part of the Section 201 planning process. Alternative approaches include the following methods.

- Measures to improve operation and maintenance of existing septic tanks including more frequent inspections and timely pumpouts;

- New septic tank-drainfield systems;

- Holding tanks and "honey wagons";

- Various means of upgrading septic tanks, including mounds, alternate leaching fields, vacuum and pressure sewers on an individual household or a cluster of households basis; and

- Systems to serve individual households or a cluster of households such as wastewater separation, water conservation, and recycle systems where feasible.

Each of these techniques is discussed in the following pages. An overview is provided at the end of this section with respect to the potential of these various techniques for use in the Grand Lake St. Marys area.

Improved Operation and Maintenance of Existing Systems

In a properly functioning septic tank, heavier solids settle to the bottom while lighter particles, including grease and foam, rise to the surface and form a mat of floating scum. If not removed on a periodic basis, these solids will fill the tank and carry over into the drainfield, causing clogging and failure of the system. A program of regular inspection should be maintained on an annual basis for septic tanks in order to assure the timely pumpout of accumulated scum and solids from the tank. Responsibility for a regular program of inspection and pump-out could remain with the individual homeowner, or could be assumed by a local or regional management agency.

New Septic Tank-Drainfield Systems

Malfunctioning septic tank-drainfield systems often are attributable to the overloading of either the septic tank or drainfield. This condition may result from the use of more water-intensive appliances and garbage grinders in the home. Where overloading of a septic tank-drainfield system has occurred, the installation of larger tanks or more extensive drainfields may remedy the situation, provided that soils are acceptable.

Holding Tanks and Honey Wagons

Another on-lot alternative is the use of holding tanks to provide storage of wastewater from the home until the contents can be pumped out and hauled away for proper disposal. This method of handling wastewater should be considered as a temporary measure, at best. The use of holding tanks is usually considered only in cases of extreme emergency. An example case would be the frequent pump-out of failing septic tanks, until a more permanent wastewater handling method could be implemented.

A major consideration associated with the frequent pump-out of holding tanks is the proper disposal of the liquid contents at a wastewater facility, which could involve extensive distances. In addition, a treatment plant should be able to accept the pumped-out contents, without upset of its own treatment efficiency and plant performance.

Upgrading of Existing Septic Tanks

Existing malfunctioning septic tanks can be corrected by a number of various methods. The applicability of each method is dependent upon the cause of the septic tank failure, and upon whether corrections are being made for an individual household or group of households.

Aerobic Tanks. The installation of larger septic tank-drainfield systems has been previously discussed, with respect to relieving problems caused by existing, undersized systems. The use of aerobic tanks, in which diffused air is provided to promote biological activity, offers an alternative to the use of septic tanks. Normally, the effluent from an aerobic tank contains less solids than that from a septic tank. As a result, a drainfield with smaller area can be used for the disposal of the effluent into the soil. However, the aerobic tank is more costly than a septic tank.

An air blower or compressor, with an energy source, is needed to supply air to the aerobic system. As a result, more frequent owner maintenance is required. If the aerobic unit stops functioning, then the treatment process will become septic, and the tank will function as an undersized septic tank, resulting in subsequent problems. These maintenance requirements cannot be overlooked. The possibility of creating a public management agency to provide regular maintenance of aerobic units would be a logical consideration.

Elevated Sand Mounds. The use of elevated sand mounds, in conjunction with either septic or aerobic tanks, is a technique now being considered by many health agencies. The elevated sand mound is simply a mound of sandy fill material which is placed on the surface of the ground. The sandy fill serves as a physical and biological medium in which the septic or aerobic tank effluent is filtered before being absorbed by the natural soil. In cases of failing systems, an elevated sand mound would replace the existing subsurface drainfield. Use of an elevated sand mound would require that effluent from the septic or aerobic tank be pumped to the mound for disposal. Approximately 330 square feet of sand mounds are needed per bedroom for use with a septic tank; if an aerobic tank is used, the area requirements are reduced to 220 square feet.

It should be noted that, although it has promise, the elevated sand mound is not a cure-all for all failing drainfields. It cannot be used on a flood plain or any soil that is poorly drained, nor where the seasonal water table occurs within 20 inches of the soil surface.

Alternating Drainfields. The use of dual drainfields for septic tank systems is a technique that has had positive results in other areas of the country. A gate or valve is used to switch flow from one absorption area to another, thereby providing a resting period for each. This allows the establishment of aerobic conditions in the soil and the renewal of its absorptive capacity. Greater areas are necessarily required for dual drainfields. Lot size would likely pose a constraint in the case of existing systems.

Community Systems

Where failing septic tank systems exist at a number of homes within a given area, consideration should be extended to correcting these problems on an area basis, through the use of the elevated sand mound concept. The elevated sand mound design would be similar to that for the individual household, except that a dual mound might be required in the event of a malfunction of the primary site.

When converting existing septic tank-drainfield systems to a community sand mound, the use of pressure sewers should be considered. Coarse solids would continue to be removed by the septic tank, and a small effluent pump could be used to convey wastewater from the septic tank, through the pressure sewer network, to the community sand mound. New homes which might be connected to the pressure sewer network would need a grinder pump installed.

Another sewerage system which has recently emerged as a bona fide serious alternative is a pressure sewer system. This type of system effectively solves the problem of serving areas with difficult topographic features such as hilly terrain and lakeside developments. The concept consists of reducing wastewater solids by grinding and thence pumping through small diameter pipe under minimal pressure to further treatment and disposal. Each user or cluster of users discharges to an individual collection tank and grinder pump unit. Such a system eliminates most construction problems commonly encountered in installing a conventional gravity system. The network of pipe in the pressure system closely follows the contour of the land and involves shallow installation just below the frost line. For the study area, conventional interceptor sewers and pumping stations would need to be utilized in conjunction with pressure sewers, but costs of the pressure sewer system may be eligible for up to 85 percent funding by the USEPA since they are considered innovative alternatives. Vacuum systems are essentially comparable to pressure systems in concept, but operate under a negative (vacuum) rather than positive pressure.

New technology has provided the basis for consideration of alternatives involving the separate handling of toilet wastes ("blackwater") and other household water ("graywater"). Systems vary in their applicability and range from composting toilets to incinerator toilets to recycle toilets. Self-contained waste treatment and water recycling toilet systems have primarily been installed for commercial and industrial establishments.

Even though toilet wastes may be effectively handled, the "gray-water" portion of household wastes must still be treated and safely disposed, most likely by a septic tank-drainfield system where soil conditions permit.

Summary - On-lot Systems

A number of on-lot system alternatives are available for Grand Lake St. Marys area. Their use should be seriouslv considered, either on an individual household or group of households basis. The applicability of each alternative is dependent upon the precise nature of the problems in the study area and current methods of wastewater disposal. Detailed studies will be necessary to gather additional data upon which to narrow the list of on-lot alternatives down to a specific community basis.

Recent amendments to Public Law 92-500 permit the awarding to grants for construction of individual, or community on-lot systems, where a public body applies for such grant on behalf of a number of such units and will assure that proper operation and maintenance is provided. Such service must be shown to be cost-effective, compared to more conventional systems. In addition, Federal funding at the 85 percent level is also authorized for the use of "alternative and innovative" wastewater management alternatives.

Table D-7 presents a summary of the on-lot system alternatives that have been discussed in this section. Advantages, disadvantages, and other comments are provided for each.

The fourth wastewater management approach deals with existing "package" treatment plants. The basic treatment process in these plants consists of aeration, clarification, and chlorination producing an effluent phosphorus concentration of 7 to 10 mg/l, and effluent BOD_5 of approximately 20 mg/l. The addition of mixed media filtration as a tertiary treatment process prior to chlorination would result in a significant reduction in BOD_5 and suspended solids concentration to 8 mg/l but little reduction in phosphorus concentration. Probably the

TABLE D-7

SUMMARY OF AVAILABLE ON-LOT SYSTEM ALTERNATIVES

On-lot System Alternative	Description	Advantages	Disadvantages	Comments
Individual Household Basis				
Improved Operation and Maintenance of Existing Septic Tanks	Program of annual inspections with pump-out as needed.	Preventive measure against drainfield clogging.	Does not offer lasting solutions where failures occur due to soils limitations or high water table.	Could be provided by individual homeowner or public management agency. Pump-out cost approximately $50.
New Septic Tank-Drainfield System	Installation of new system to replace malfunctioning system.	Effective where problems are related to undersized tank or drainfield area.	Not effective where failures occurred due to soils limitations or high water table.	Approximate cost of $1,200.
Holding Tanks and Honeywagons	Utilize septic tank as holding tank with frequent pumpout.	May alleviate existing health situation.	Provides only temporary solution	Requires proper disposal of pumped-out liquid. May adversely affect treatment plant where transported.
Aerobic Tanks	Can be used to upgrade existing septic tank, or as new system.	Provides better effluent than septic tank. Requires smaller drainfield or sand mound.	High initial costs. Requires energy source. Frequent maintenance also required.	Approximate cost of $2,000. Service contract may be required to assure efficient operation. Service can be provided by private contractor or public management agency.

TABLE D-7 (Continued)

On-lot System Alternative	Description	Advantages	Disadvantages	Comments
Individual Household Basis				
Elevated Sand Mound	Used in conjunction with either septic tank or aerobic tank. Replaces drainfield. A pump is required for dosing the sand mound.	Can be effective remedy for alleviating existing failing systems.	Cannot be used where soil is poorly drained, nor where high seasonal water table exists.	Approximate cost of elevated sand mound and associated laterals is $2,600, including dosing tank and pump.
Alternate Drainfields	Use of dual drainfields. Flow switched from one absorption area to another by use of valve.	Provides resting period for each absorption area. Allows renewal of absorption capacity.	No guarantee that measure will provide permanent relief where severe soils limitations exist.	Lot size may pose constrain for existing dwellings.
Community Household Basis				
Elevated Sand Mound	Same as for individual household, except dual mounds required. Each home requires pumping to off-site mound system.	Can be effective remedy for alleviating failing systems which exist in cluster of homes.	Could require extensive transport system from each individual home to location of community sand mound. Use of pressure sewers a consideration.	Approximate cost of a mound system sized for 20 homes is $19,000. Allow minimum of $1,500 for pump and pressure sewer for each home.
Wastewater Separation	Involves separate handling of toilet wastes ("blackwater"). Systems vary from composting to incinerator to recycle systems.	Can effectively handle toilet wastes.	Not total solution. Kitchen, bath, and laundry wastes ("graywater") must still be treated and disposed	Application, primarily to date, has been for industrial and commercial uses.

most efficient method of phosphorus reduction is through chemical addition prior to filtration. Phosphate can be precipitated from solution by a wide variety of chemicals, although economic factors usually reduce the choice to iron salts, aluminum salts, and lime. Typical removals are in the range of 70-95% for total phosphorus, 65-90% for dissolved phosphorus, and 100% for particulate phosphorus for the combined precipitation/filtration tertiary process. Drawbacks of the process, especially for small package plants, are high equipment and chemical costs, the need for careful process control, and disposal of sludge, all of which contribute to higher operation and maintenance costs. These conditions may possibly be beyond the capabilities of these small systems.

General Summary - Treating Wastewater Inflow

Studies to re-evaluate regional sewerage needs include modifying the scope of the existing plan; alternative and innovative on-lot systems, either on an individual household or group of households basis; and upgrading or converting existing treatment plants to include tertiary treatment and chlorination to name a few, are necessary but are beyond the scope of this study. Federal funding is available to local governments through the Section 201 Construction Grants Program to facilitate such special studies.

Agricultural Land Management

Soil erosion, migration of phosphorus and other nutrients from cropland, barnyard runoff, and the application of manure on frozen ground are all problems in the Grand Lake watershed affecting water quality. To a large extent, the problems of sedimentation and eutrophication in Grand Lake are the result of intensive agricultural use of watershed lands. That agricultural activity is the predominant source of suspended solids and phosphates has been demonstrated through detailed monitoring and analytical studies in two nearby watersheds, the Honey Creek, Ohio, watershed[7] and the Black Creek, Indiana watershed.[8] These basins have much in common with the Grand Lake basin, including similarities in soil types, physiography, agricultural land-use patterns, and the types of crops produced.

Extrapolating from countywide data, approximately 81 percent of the surface area of the Grand Lake watershed is in cropland, with the remaining 19 percent distributed among pasture, woodlands, residential, commercial, etc. From the standpoint of types of crops being grown, surface susceptibility to erosion is high, with 60-70 percent of the cropland area being planted in low density row crops, mainly corn and soybeans.

To achieve maximum crop yields, farmers have been applying increasing amounts of phosphate fertilizer throughout northern Ohio. Between 1961 and 1971, both Mercer and Auglaize Counties have progressed from a "less than 30 pounds of phosphate applied per acre" classification to a "31-60 pounds of phosphate applied per acre" classification. The average rate of application, however, has been in excess of that required by the crops, and as a result available soil phosphorus levels have increased dramatically. In Mercer and Auglaize Counties, the result has been an approximate doubling of available phosphorus values for field crop soils between 1961 and 1976 (Mercer County: from 30 pounds/acre to 51 pounds/acre; Auglaize County: from 21 pounds/acre to 44 pounds/acre). Reductions in phosphate yields to streams in the Grand Lake watershed will therefore require controlling not only the loss of sediment from cultivated land, but also the rate of fertilizer applications.

Beneficial and Adverse Impacts

The use of agricultural land management has as its primary objective the abatement of soil and nutrient loss. From the standpoint of Grand Lake and its identified problems, the resultant benefits are a reduction in sediment load, a reduction in nutrient input, and improved water quality. These benefits are discussed in this section. No significant adverse impacts on Grand Lake should occur as a result of improved agricultural practice. Other beneficial and adverse impacts could be realized by the individual farmer, but these primarily have an economic basis and are discussed later.

Before proceeding with possible improvements, the present or "without" condition is discussed.

Present Soil Loss and Nutrient Loads. The universal soil loss equation (USLE) is a generally recognized tool for predicting potential soil losses from a given area. The factors that enter into the equation are rainfall intensity and duration, soil erodibility, length and steepness of slope, vegetative cover, soil management practices, and erosion control practices. A detailed inventory and quantification of these factors in Mercer and Auglaize Counties has been conducted as part of the Lake Erie Wastewater Management Study.[9] Predicted rates of soil loss using the USLE are presented on a countywide basis in Tables D-8a and D-8b. The columns correspond to cropland management scenarios, while the rows define various soil management groups. Column 1 represents present conditions for each county. The countywide averages of potential soil loss are observed to be 3.83 tons/acre/year for Mercer County and 4.47 tons/acre/year for Auglaize County.

Over 90 percent of the surface area of the Grand Lake watershed is occupied by three distinct soil types that, although morphologically similar, differ primarily as to drainage class (Table D-9). These soils, formed in gently undulating glacial ground and end moraine, are characterized by a silty surface horizon over a clayey (argillic) subsoil horizon. Restriction of percolation by the low permeability subsoil, and the ease of entrainment of the silts in the surface horizon, combine to present a potentially erodible soil condition reflected in high K-values. The Pewamo soil poses less of an erosion risk as a result of its lower slope position and heavier surface textures.

TABLE D-8a

ESTIMATED SOIL LOSS FOR VARIOUS LAND MANAGEMENT SCENARIOS: MERCER COUNTY

ARMY CORPS OF ENGINEERS
BUFFALO DISTRICT: LEWNS
ESTIMATION OF POTENTIAL
GROSS EROSION BY USLE
AND LRIS(MAIN FILE)

MAUMEE @ WATERVILLE
SAMPLING STATION NO. 1
STA. TYPE:LOWST IN BSN
CO: MERCER, O
COUNTY NUMBER: 59

	1 PRESENT CONDITION	2 CONFORM TO TFAC IF PGE GT TFAC	3 PRESENT CONDITION IF PGF LE TFAC	4 SOIL SAVED IF TFAC MET 4=1-(2+3)	5 SPRING PLOWED RESIDUE LEFT	6 FALL PLOW RESIDUE LEFT	7 WINTER COVER	8 CONSERV. TILL: MULCH	9 CONSERV. TILL: NO TILL
	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR
	C1				C2	C3	C4	C5	C6
	SCENAR 1	(SCENARIO 2=2+3)			SCENAR 3		SCENAR 6		
CROPLAND	48393.8	20104.5	0.0	28289.3	46316.8	51717.0	46732.2	21393.0	6854.0
SMG	5871.2	5871.2	0.0	5871.2	5871.2	5871.2	5871.2	5871.2	5871.2
1	8.24	3.42	0.0	4.82	7.89	8.81	7.96	3.64	1.17
CROPLAND	382467.0	165461.6	7216.7	209788.6	366052.2	408731.0	369335.2	169073.4	54169.2
SMG	58445.3	55153.9	3291.4	55153.9	58445.3	58445.3	58445.3	58445.3	58445.3
2	6.54	3.00	2.19	3.80	6.26	6.99	6.32	2.89	0.93
CROPLAND	36857.6	0.0	36857.6	0.0	35275.7	39388.5	35592.1	16293.2	5220.2
SMG	42877.7	0.0	42877.7	0.0	42877.7	42877.7	42877.7	42877.7	42877.7
4	0.86	0.0	0.86	0.0	0.82	0.92	0.83	0.38	0.12
CROPLAND	3233.8	0.0	3233.8	0.0	3095.0	3455.8	3122.7	1429.5	458.0
SMG	2312.9	0.0	2312.9	0.0	2312.9	2312.9	2312.9	2312.9	2312.9
5	1.40	0.0	1.40	0.0	1.34	1.49	1.35	0.62	0.20
CROPLAND	2929.0	0.0	2929.0	0.0	2803.3	3130.1	2828.4	1294.8	414.8
SMG	2046.0	0.0	2046.0	0.0	2046.0	2046.0	2046.0	2046.0	2046.0
8	1.43	0.0	1.43	0.0	1.37	1.53	1.38	0.63	0.20
CROPLAND	2539.3	0.0	2539.3	0.0	2430.3	2713.7	2452.1	1122.5	359.6
SMG	1690.2	0.0	1690.2	0.0	1690.2	1690.2	1690.2	1690.2	1690.2
9	1.50	0.0	1.50	0.0	1.44	1.61	1.45	0.66	0.21
SUMMARY	476420.1	185566.1	52776.3	238077.7	455973.1	509135.9	460062.6	210606.2	67475.7
CROPLAND	113243.2	61025.1	52218.3	61025.1	113243.2	113243.2	113243.2	113243.2	113243.2
SMG 1-10	4.21	3.04	1.01	3.90	4.03	4.50	4.06	1.86	0.60
GRASSLAND	194.4	0.0	194.4	0.0					
	3558.3	0.0	3558.3	0.0					
	0.055	0.0	0.055	0.0					
WOODLAND	788.4	0.0	788.4	0.0					
	7828.3	0.0	7828.3	0.0					
	0.101	0.0	0.101	0.0					
SUBTOTAL	477402.5	185566.1	53759.1	238077.3	456955.4	510118.3	461044.9	211588.6	68458.1
	124629.3	61025.1	63604.8	61025.1	124629.3	124629.3	124629.3	124629.3	124629.3
	3.83	3.04	0.85	3.90	3.67	4.09	3.70	1.70	0.55

SOURCE: Appendix I: Application of the Universal Soil Loss in the Lake Erie Basin, U.S. Army Engineer District, Buffalo

TABLE D-8b

ESTIMATED SOIL LOSS FOR VARIOUS LAND MANAGEMENT SCENARIOS: AUGLAIZE COUNTY

ARMY CORPS OF ENGINEERS BUFFALO DISTRICT: LEWIS ESTIMATION OF POTENTIAL GROSS EROSION BY USLE AND LRIS(MAIN FILE)	1 PRESENT CONDITION	2 CONFORM TO TFAC IF PGE GT TFAC	3 PRESENT CONDITION IF PGE LE TFAC	4 SOIL SAVED IF TFAC MET 4=1-(2+3)	5 SPRING PLOWED RESIDUE LEFT	6 FALL PLOW RESIDUE LEFT	7 WINTER COVER	8 CONSERV. TILL: MULCH	9 CONSERV. TILL: NO TILL
	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR	TONS/YR ACRES T/A/YR
MAUMEE @ WATERVILLE SAMPLING STATION NO. 1 STA. TYPE:LOWST IN BSN CO: AUGLAIZE, 0 COUNTY NUMBER: 60	C1				C2	C3	C4	C5	C6
	SCENAR 1	(SCENARIO 2=2+3)			SCENAR 3		SCENAR 6		
CROPLAND	137660.1	30245.7	0.0	107414.4	131568.9	146796.8	134005.4	61520.7	19491.7
SMG	10408,1	10408.1	0.0	10408.1	10408.1	10408.1	10408.1	10408.1	10408.1
1	13.23	2.91	0.0	10.32	12.64	14.10	12.88	5.91	1.87
CROPLAND	204449.1	99010.1	5890.5	99548.5	195402.7	218018.7	199021.3	91368.8	28948.6
SMG	36650.6	33003.4	3647.3	33003.4	36650.6	36650.6	36650.6	36650.6	36650.6
2	5.58	3.00	1.62	3.02	5.33	5.95	5.43	2.49	0.79
CROPLAND	1563.0	1334.4	0.0	228.7	1493.9	1666.8	1521.5	698.5	221.3
SMG	444.8	444.8	0.0	444.8	444.8	444.8	444.8	444.8	444.8
3	3.51	3.00	0.0	0.51	3.36	3.75	3.42	1.57	0.50
CROPLAND	16252.4	0.0	16252.4	0.0	15533.2	17331.0	15820.9	7263.2	2301.2
SMG	20549.3	0.0	20549.3	0.0	20549.3	20549.3	20549.3	20549.3	20549.3
4	0.79	0.0	0.79	0.0	0.76	0.84	0.77	0.35	0.11
CROPLAND	2815.4	0.0	2815.4	0.0	2690.9	3002.3	2740.7	1258.2	398.6
SMG	2135.0	0.0	2135.0	0.0	2135.0	2135.0	2135.0	2135.0	2135.0
5	1.32	0.0	1.32	0.0	1.26	1.41	1.28	0.59	0.19
CROPLAND	2066.0	0.0	2066.0	0.0	1974.6	2203.2	2011.2	923.3	292.5
SMG	1512.3	0.0	1512.3	0.0	1512.3	1512.3	1512.3	1512.3	1512.3
9	1.37	0.0	1.37	0.0	1.31	1.46	1.33	0.61	0.19
* SUMMARY *	364805.9	130590.0	27024.3	207191.6	348664.0	389018.7	355120.9	163032.7	51654.0
* CROPLAND *	71699.9	43856.2	27843.8	43856.2	71699.9	71699.9	71699.9	71699.9	71699.9
* SMG 1-10 *	5.09	2.98	0.97	4.72	4.86	5.43	4.95	2.27	0.72
GRASSLAND	166.0	0.0	166.0	0.0					
	2757.7	0.0	2757.7	0.0					
	0.060	0.0	0.060	0.0					
WOODLAND	864.9	0.0	864.9	0.0					
	7383.5	0.0	7383.5	0.0					
	0.117	0.0	0.117	0.0					
* SUBTOTAL *	365836.3	130590.0	28055.3	207191.0	349694.4	390049.1	356151.2	164063.1	52684.9
* *	81840.7	43856.2	37985.0	43856.2	81840.7	81840.7	81840.7	81840.7	81840.7
* *	4.47	2.98	0.74	4.72	4.27	4.77	4.35	2.00	0.64

SOURCE: Appendix I: Application of the Universal Soil Loss in the Lake Erie Basin, U.S. Army Engineer District, Buffalo

To designate the three predominant soil types as to Soil Management Groups, the Blount and Glynwood soils are judged to be SMG2, while the Pewamo soils are designated SMG4. These Soil Management Groups are defined as follows:

SMG 2: Somewhat poorly and very poorly drained soils which have good response to surface or subsurface drainage.

SMG 4: Very poorly drained soil with fine textured surfaces and relatively high amounts of organic matter, response to subsurface drainage is good, but mulch cover retards warming of the soil in the spring.

Based on the percentage occurrence of soil types given in Table D-9 and assuming that the remaining nine percent of the watershed has a soil potential of 0.1 ton/acre/year (see "grassland" and "woodland" in Tables D-8a,b), the average soil loss values are 4.37 tons/acre/year for that portion of the watershed in Mercer County, and 3.75 tons/acre/year in Auglaize County. Since about 85 percent of the watershed is within Mercer County, an average soil loss under current conditions in the Grand Lake watershed is 4.28 tons/acre/year.

Since most of the total phosphorus is of surficial soil origin, the amount of total phosphorus being contributed by soil loss in the Grand Lake watershed in milligrams per hectare can be estimated on the basis of gross erosion by the relationship:[10]

Total phosphorus loss (mg/ha) =
gross erosion (kg/ha) x Total
phosphorus content of surface
soil (mg/kg) x Phosphorus
enrichment ratio.

TABLE D-9

SOIL DATA: GRAND LAKE WATERSHED

Series Name	Drainage Class	% Area	Frodibility (K-Factor)	Maximum Allowable Erosion (T-Factor) Tons/Acre
Blount silt loam 0-2%	Somewhat poorly	2	Moderate to (.43)	3
Blount silt loam 2-6%	Somewhat poorly	42	High	
Glynwood silt loam 2-6%	Somewhat poorly to	17	Moderate to (.43)	3
Glynwood silt loam 6-12%	moderately well	2	High	
Pewamo silty clay loam 0-2%	Poorly drained	28	Moderate to (.24) Slight	4

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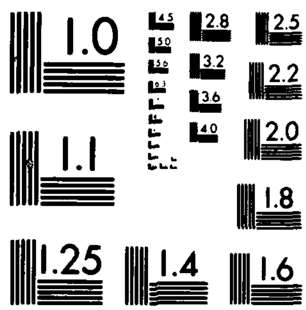

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

The phosphorus enrichment ratio reflects the selective washout of finer particles (e.g., clays and fine silts) that have a higher phosphorus content than the bulk surface soil. This ratio varies from about one to three, with lower values corresponding to high clay content and high gross erosion rates. For the Blount soil series, an enrichment ratio of 2.0 is typical, although values as high as 2.5 may be realized. The mean total phosphorus content in Blount and Blount-Pewamo soils is 455 mg/kg. Based on these values, the average phosphorus contribution due to soil loss in the Grand Lake watershed is 8.74 kg/ha (7.79 pounds/acre).

Both the soil loss and phosphorus contribution just computed represent potential values from a given plot of land. Before reaching a watercourse, much of the soil and attached nutrients are redeposited, at lower slope positions, primarily as a result of vegetative cover or topographic depressions. It is estimated that ten percent of the soil potentially lost actually reaches a watercourse. The corresponding loads to Grand Lake are, therefore, 0.428 ton of soil/acre/year, and 0.78 pound of total phosphorus/acre/year. The total annual contributions due to soil loss throughout the watershed are 26,000 tons of soil (sediment) and 47,000 pounds (21,000 kilograms) of total phosphorus.

These values compare well with earlier studies. The computed annual sediment load of 0.428 tons/acre (274 tons/mi^2) is reasonably close to the range of values (100-200 tons/mi^2) for the US Geological Survey classification of a "moderately low" sediment yield for Grand Lake. The total phosphorus load of about 21,000 kilograms is also reasonable when compared to the National Eutrophication Survey estimate of 19,170 kilograms from all nonpoint sources.

Expected Improvements. The maximum allowable erosion rates (T-factors) given in Table D-9 are upper limits of the potential gross erosion that a soil in crop production can withstand over the long-term without a reduction in crop yield. For any given soil, the T-factor is the goal in the development of conservation management plans. In order to promote this goal without an excessive economic burden on individual farm owners, the Ohio Department of Natural Resources has proposed Agricultural Sediment Pollution Abatement Rules to the Ohio Legislature. Though several types of erosion are covered, the principal impetus of the rules is that all agricultural landowners shall apply and maintain conservation practices and follow a management system such that the permissible soil loss values (T-factors) are not exceeded. To assist landowners in meeting these requirements, the State will pay 75 percent of the cost of establishing eligible practices.

The current rate of sediment yield for SMG2 soils (6.54 and 5.58 tons/acre/year for Mercer and Auglaize Counties, respectively) indicates that the Blount and Glynwood soils in cropland are significantly in excess of the T-factors given in Table D-9. In light of the possibility that farm owners may be legally bound to meet these criteria in the near future, it is interesting to evaluate the overall effect of all lands being within the T-factor limitation. With reference to Tables D-8a and D-8b, the potential gross erosion rate that would result under this compliance condition is indicated by summing Columns 2 and 3. SMG4, grassland, and woodland are currently satisfying the T-factor and do not change. The revised values for SMG2 are 2.95 tons/acre/year for Mercer County and 2.86 tons/acre/year for Auglaize County. Converting these to an average value for the Grand Lake watershed (as done previously) gives 2.05 tons/acre/year. The sediment load reduction to be realized by comprehensively satisfying the T-factor is 2.23 tons/acre/year, or 13,500 tons annually to Grand Lake.

Of more concern is the resultant reduction in nutrient loadings. Because the nutrient content of the finer, harder to manage soil fraction is higher on a unit weight basis than the coarse soil types conducive to removal by management practices, a one-to-one correspondence between percent soil loss reduction and percent phosphorus reduction cannot be substantiated. It has been assumed based on information from other studies that the phosphorus reduction factor is between 0.6 and 0.9 of the soil loss reduction factor. That is, for the

52 percent reduction in the gross erosion potential if the T-factors are satisfied, a 31-47 percent reduction in phosphorus contributed by the sediments can be expected. This corresponds to a removal of 6,500-9,900 kilograms per year, or approximately 40 percent of the current annual phosphorus loading rate to Grand Lake (relative to the USEPA loading estimate). Although this in itself will not lead to a mesotrophic lake classification, the steady-state total phosphorus concentration in the lake will be reduced by about 40 percent. This is a significant reduction and could supplement nutrient removal by other measures to reach a mesotrophic state.

The effect of other land-use scenarios and agricultural management practices are given in columns 5-9 of Tables D-8a and D-8b. The corresponding values for the Grand Lake watershed and the resultant annual reductions in sediment and nutrient loads are given in Table D-10. Leaving a fall residue cover with spring plowing or providing a winter cover crop on all cultivated lands of the watershed would only slightly reduce soil and nutrient loads over existing practices. This suggests that many areas already employ these methods. Utilizing only fall plowing will actually increase the loads to Grand Lake, although not significantly. If, however, either minimum tillage or no till planting were employed, the reduction in soil loss and nutrient loads would be dramatic. In the latter case, over half of the total phosphorus contributed by sediments can be removed, representing abou[illegible] percent reduction in the total annual phosphorus load.

A number of agricultural management alternatives exist for controlling the amount of soil loss from cultivated areas, as listed in Table D-11. Also included in this table is a qualitative ranking of these practices as to their beneficial impact on four categories: water quality, soil protection, crop production, and other conservation uses. This ranking is taken from the Black Creek Watershed Study.[8]

TABLE D-10

CHANGES IN ANNUAL SEDIMENT AND NUTRIENT LOADS FOR VARIOUS CROPLAND MANAGEMENT SCENARIOS

Scenario	Potential Soil Loss: Grand Lake Watershed (tons/acre)	Change in Annual Sediment Load to Grand Lake (tons) 1/	% Change	Change in Annual Phosphorus Load To Grand Lake (Kilograms) 1/ 2/	% Change
Retain spring plowing, Eliminate fall plowing	4.09	(1,150)	- 4.4	(710)	- 3.4
Eliminate spring plowing, Use fall plowing only	4.57	1,760	+ 6.8	1,450	+ 6.9
Winter cover crops planted in fall-tilled fields	4.13	(910)	- 3.5	(560)	- 2.9
Application of mulch tillage (Surface residue of previous crop)	1.90	(14,460)	- 55.6	(8,910)	- 42.4
No-tillage cropping management system	0.62	(22,230)	- 85.5	(13,560)	- 64.6
No action	4.28	26,000		21,000	

1/ Numbers in parentheses are negative changes or reductions.
2/ Based on a 0.75 phosphorus reduction value (range: 0.6-0.9).

TABLE '1

RANKING AND UNIT COSTS OF
AGRICULTURAL MANAGEMENT ALTERNATIVES

	Alternative	Unit	Unit Cost (1977)	Evaluation Ranking 1/ Water Quality	Soil Protection	Crop Production	Other Conservation Uses
1.	Conservation cropping system	Acre	$0.90	2	1	3	2
2.	Contour farming	Acre	2.00	1	1	3	3
3.	Critical area planting	Acre	229.38	1	1	3	2
4.	Crop residue management	Acre	1.30	1	1	2	2
5.	Diversions	Feet	1.02	2	1	3	4
6.	Farmstead windbreaks	Acre	96.59	3	2	4	1
7.	Field border	Feet	0.30	1	2	4	2
8.	Field windbreak	Feet	Not given	2	1	3	2
9.	Grade stabilization structure	Each	294.51	2	1	3	4
10.	Grassed waterway	Acre	755.19	1	1	3	3
11.	Land smoothing	Acre	Not given	4	3	1	4
12.	Minimum tillage	Acre	3.88	1	1	3	2
13.	Sediment control basins	Each	1,977.29	1	3	4	2
14.	Stream channel stabilization	Feet	7.93	2	1	3	3
15.	Stripcropping	Acre	Not given	2	1	2	2
16.	Surface drains	Feet	0.39	3	3	1	4
17.	Terraces (Perforated tile outlets)	Feet	0.75	1	1	2	2
18.	Tile drains	Feet	1.13	3	2	1	3

1/ 1 -- Primary benefit
2 -- Secondary benefit
3 -- Very little, if any, benefit
4 -- No benefit

Technical and Physical Feasibility

One of the principal tasks of the Lake Erie Wastewater Management Study was a feasibility analysis of agricultural management practices for specific watershed conditions. Of special note is that, of the 63 counties in the Lake Erie watershed, Auglaize County ranked in the top 10 and Mercer County in the top 15 in regard to the potential reduction in soil loss under maximum reduction strategies, particularly reduced tillage. That is, these counties can be considered preferred areas for agricultural management practices. While it was recognized that all aforementioned management practices would generally give favorable results, several were identified as being more cost effective and successful in sediment yield reduction.

Contour plowing and stripcropping are useful in reducing erosion up to 50 percent on slopes greater than two percent. Because they are best suited to soils with smooth, uniform slopes, their use is limited in the Grand Lake watershed where slopes are generally irregular. Manipulating the surface of sloping cropland by joining terraces and diversions, which decrease slope length and runoff velocities, is also of limited use since the slope to slope length criteria necessary for warranting these structures is generally too low.

A large number of cropping systems can be proposed, and each system will affect the generation of runoff and erosion to varying degrees. Grass crops are more protective of the surface than small grain crops, which, in turn, provide better protection than row crops. In the Grand Lake watershed agricultural production is centered primarily around raising crops to support livestock operations. The number of cropping alternatives is, therefore, limited by the acreage needed to grow those crops required for livestock feed. Within this economic constraint, there is little opportunity to further reduce soil erosion since crop rotation is widely practiced to control pest insects and vary nutrient withdrawal.

The remaining alternatives can be classified into those measures aimed at restricting sediment detachment and transport from cultivated fields, and those measures which attempt to control erosion in channels once runoff has occurred or restrict sediment movement from the farm site. Of these two groups of alternatives, it is far more preferable from the standpoint of agronomic productivity and costs of implementation to concentrate on restricting runoff in the field and thereby reduce or eliminate the need for costlier structures further down the line.

Cultivation techniques which have proven successful in reducing sediment erosion include:

Delayed Plowing and Residue Management. Fall plowing following harvesting is a widely employed practice which promotes drying of the soil in the spring. Plowing under the crop residue, however, leaves the surface exposed to the damaging effects of raindrop impact, while fostering detachment of soil particles for easy runoff removal. For this reason, spring planting should be encouraged to reduce sediment loss, particularly during early spring when the ground is saturated. The actual amount of plant debris left on the surface will also depend on the manner by which it is incorporated into the subsoil and on whether the farmer chooses to remove the residue for silage. Proper allocation of surface residue that retains maximum coverage during critical periods will help reduce yearly losses.

Cover or Green Manure Crops. The purpose of winter cover crops is to protect the soil surface from erosion during winter and spring storm. Generally a small grain crop like rye is planted soon after harvesting of the fall crops, particularly where the residue from the previous crop is insufficient to provide adequate protection. In the spring, the crop is either harvested, plowed under or chemically killed to prepare for the next crop plant. A chemically killed cover crop has the advantage of providing a good surface residue for no-till planting of row crops. The principal disadvantage is the extra costs involved, especially when the crop cannot be harvested.

No-Till Planting. No-till refers to the planting of row crops in narrow slots opened in the soil without any physical disturbance of the soil or crop residue between rows. Suitable for use on better drained soils, no till is most commonly used in growing corn and soybeans. Leaving plant residue on the surface, however, promotes greater growth opportunities to insect pests and results in nutrient accumulation on the soil surface. Otherwise soil structure, drainage, and moisture retention are enhanced. Increased infiltration of the soil may result in leaching of mobile nitrate compounds from nitrogen fertilizers.

Although most advantageous from a soil loss reduction standpoint, a major constraint of greatly reduced tillage or no-till systems is that they are not suitable for areas that have both erosion and wetness problems. When large quantities of surface residue are left on the surface, drying of the soils in the spring is reduced and warming of the soil is retarded. Significant yield reduction can result.

Minimum Tillage. This technique encompasses a wide range of tillage practices, the objective of which is to retain as much of the former crop residue on the surface for controlling soil erosion. Unlike conventional tillage utilizing the moldboard plow which plows under surface residue, minimum tillage emphasizes minimum disturbance of the soil between planted rows. As a result, weed control relies heavily on herbicides. Minimum tillage should be considered for row crops on poorly and very poorly drained soils where no till is not feasible.

Economic Feasibility

Unit Costs. Because the implementation of agricultural management alternatives is on an individual farm basis, it is difficult to define unit costs. The best available information is the unit cost actually experienced by the demonstration projects in the Black Creek Basin. These are included in Table D-10, and should be considered as representative costs for the Grand Lake watershed due to the similarities between watersheds.

Total Benefits and Costs. As with the units costs, total benefits and costs to be realized by the implementation of the various techniques cannot be specified. In general, the benefits are derived from increased crop yield due either directly to a management practice or indirectly to a long-term reduction in topsoil and nutrient losses. Some techniques designed for specific remedial purposes (e.g., water quality improvement) can actually be detrimental to crop yield, and the lost income would have to be considered a cost for these alternatives.

A detailed study on the economic impact of changing tillage practices in the Lake Erie Basin has been completed as part of that study. The impacts of reduced tillage practices on yields, costs of production, and consequent net income vary in accordance with the applicability of the technology to different soil conditions. In general, reduced tillage practices save labor and energy (fewer operations), and require lower capital investment than conventional tillage. Fertilizer inputs would be expected to decrease as sediment yields drop, but chemical costs would increase due to greater dependence on chemical weed control. Total operating costs and equipment costs for minimum tillage and no tillage average about eight to ten percent less, respectively than conventional tillage costs.

The following gives estimated percent income changes for minimum tillage and no tillage (relative to the net income using conventional tillage) for the two Soil Management Groups being considered:

	Percent Income Change With			
	Minimum Tillage		No Tillage	
	SMG2	SMG4	SMG2	SMG4
Mercer County	9.5	-1.0	10.9	Not given
Auglaize County	10.1	-0.7	11.6	Not given

The predominance of SMG2 soil in the Grand Lake watershed points to significant economic benefits if reduced tillage or no till practices are implemented.

Given the topographic and drainage characteristics of the Grand Lake watershed, it is anticipated that the costs of implementing many of the agricultural management alternatives will exceed the benefits. However, if the State of Ohio contributes 75 percent of the cost of implementation under the proposed cost sharing program, the benefit/cost ratio for the individual landowner will probably shift to favor implementation. The intent of the cost sharing program is that the general public welfare will be enhanced as a result of agricultural management, thus the actual negative difference between direct benefits and direct costs is not the governing criterion.

Livestock Waste Management

Pollution of water courses as a result of livestock operation has received increased attention in recent years. Among the identified problems are discharges from animal waste collection and storage facilities, runoff from feedlots, seepage from animal waste management facilities, and improper land application of animal wastes. These considerations are particularly critical in the Grand Lake watershed due to the widespread presence of animal feedlots.

Although such pollution is of concern to the general public and downstream water users, the cost of implementing remedial measures becomes the burden of the livestock owner. With this conflict of interest in mind, the Ohio Department of Natural Resources has proposed rules to the Ohio Legislature that would both require compliance with discharge limits and provide cost sharing to the livestock owners. In particular, the proposed rules call for zero pollutant discharge from some pollutant sources and minimizing pollution potential from others for all "concentrated animal feeding operations". (Most of the livestock operations in the Grand Lake watershed will be subject to the regulations.) The State will provide 75 percent of the cost of establishing eligible practices up to $5,000 per person.

In this section, the water quality improvements that can be expected at Grand Lake due to the full implementation of these regulations are considered. Costs and benefits will be given some consideration, although each is case dependent and of private concern. For detailed information on livestock waste management, reference is made to the Ohio Livestock Waste Management Guide.[11]

Beneficial and Adverse Impacts

Many of the beneficial and adverse impacts of implementing livestock waste management techniques have an economic basis and are restricted to the individual livestock owner. These are dealt with later. For present purposes, only the potential improvement in Grand Lake water quality is considered. The recreational benefits related to reduced nutrient loads and improved water quality have been discussed in the evaluation of other alternatives and are not repeated here.

A study on the influence of land use on stream nutrient levels[12] reports data on livestock in the Grand Lake watershed. This study reports animal unit densities (animal units/km^2) for the five major tributaries. (An animal unit is the equivalent number of cattle that would result in the same annual nutrient production as the actual livestock types.) The reported animal unit densities for phosphorus leads to a watershed value of 12,168 animal units, or 214,000 kilograms of total phosphorus production per year. Of more concern is the percentage of this nutrient production that actually reaches the tributaries to Grand Lake.

The delivery ratio of phosphorus from an animal concentration area was found to vary with distance from a watercourse. A conservative estimate is that five percent of the produced phosphorus load will be exported to a watercourse if the livestock operation is located within 3,000 feet of the receiving streams. Based on an examination of USGS topographic maps, it is estimated that 70 percent of the animal concentration areas in the Grand Lake watershed are so located. The corresponding annual phosphorus load to Grand Lake as a result of livestock operations is 7,500 kilograms, or 23 percent of the current total phosphorus load. If the reported disposal of manure on frozen ground in the Grand Lake watershed is widespread, the 23 percent contribution to the annual phosphorus load may be low.

Under the hypothesis that pollutant discharges from livestock operations can be completely eliminated, a 23 percent reduction in the annual nutrient input can be realized and the intake total phosphorus concentration can consequently be reduced to about 0.12 mg/l. Although eutrophic conditions are still indicated, a significant reduction in phosphorus concentrations is realized and can serve to supplement reductions from other nutrient reduction measures. Model studies indicate that a 60 percent reduction in phosphorus loading rates could lead to mesotrophic conditions in the lake. The elimination of nutrients from livestock operations achieves nearly half of this goal.

Technical and Physical Feasibility

A review of the Ohio Livestock Waste Management Guide leads to the conclusion that, although all management techniques may not be applicable to a particular livestock operation, some technique can be conceptualized to overcome any local topographic or operational problems. That is, the overall feasibility of the measure is not restricted by case-dependent physical constraints, and further consideration is not warranted.

Economic Feasibility

The costs to implement and operate animal waste management facilities are dependent on many factors, the primary of which are type of system and size of the herd. Table D-12 presents typical unit costs (per head of livestock) for various waste disposal and runoff control

TABLE D-12

CAPITAL INVESTMENT AND ANNUAL COSTS
FOR SELECTED LIVESTOCK WASTE DISPOSAL SYSTEMS

Housing Type	Capital Investment Per Head			Annual Costs Per Head		
	50-74[1] 100[2] 500[3]	75-99 400 1500	100+ 700 2500	50-74 100 500	75-99 400 1500	100+ 700 2500
Dairy						
1. Open Lot, Free Stall Housing Scraper Loader System, Grass Filter Runoff Control	$197	$172	$102	$65	$59	$38
2. Enclosed Cold Housing, Free Stalls, Scraper Loader System	182	146	122	62	56	46
3. Enclosed Cold Housing, Free Stalls, Liquid System	299	265	191	75	70	45
Beef						
1. Unpaved Drylot, Housing, Scraper Loader System, Grass Filter Runoff Control	$ 99	$ 46	$ 39	$28	$13	$11
2. Paved Drylot, Housing, Scraper Loader System, Grass Filter Runoff Control	104	51	42	29	14	13
3. Confined Slotted Floor, Liquid System	198	121	111	41	23	21
Swine						
1. Enclosed, Partially Slotted Floor, Liquid System	$27.70	$18.30	$16.40	$5.80	$3.90	$3.50
2. Open Front, Scraper Loaded System, Grass Filter Runoff Control	23.90	14.00	11.90	7.90	4.80	4.30

1. Dairy Herd Size (Head)
2. Beef Feedlot Capacity (Head)
3. Annual Swine Production (Head)

SOURCE: Ohio Livestock Waste Management Guide, 1975 systems for dairy, beef, and swine. Whereas actual costs are site specific, these figures indicate the magnitude of the capital investments and annual costs. (All figures reported in this section are taken from the Ohio Livestock Waste Management Guide.)

The primary economic benefits to the livestock owner are the value of the manure, an increase in feed efficiency, and reduced labor requirements. Manure has value as a substitute for commercial fertilizer, especially considering recent price increases in the latter. Approximate annual values of manure produced per head of livestock are: dairy cows, $35-$60; beef cattle, $35-$50; and swine, $5.00-$7.50. These are 1975 figures, and are probably much higher today. The range of values corresponds to different waste disposal systems, thus indicating the potential value of proper manure management.

Enclosed housing systems for livestock result in more efficient utilization of feed. For example, the average daily weight gain for feeder cattle can be increased by about 14 percent for the same feed requirement if an outside lot is converted to a 100 percent covered lot. The resultant increase in the turnover rate (ratio of one year and the time actually required for the livestock to reach a designated weight) could have significant economic benefits on an annual basis, possibly several thousands of dollars.

The savings resulting from reduced labor requirements are not expected to be significant. This is due to a concurrent need for additional managerial effort to deal with increased disease, feeding, and equipment problems of the more confined systems. In general, the benefits just discussed cannot be expected to balance the capital investments and annual costs associated with implementing livestock waste management systems. However, the 75 percent cost sharing program could shift the balance and encourage individual feedlot operators to implement recommended measures. If so, users of Grand Lake may realize a noticeable improvement in water quality.

Dredging of Lake Sediments

The in-lake dredging of bottom sediments addresses more planning objectives than any other alternative. In addition, more than any other alternative, the recommended scope of the dredging program is dependent on and an integral part of the overall lake plan. This is especially true considering that analysis has identified potential physical conflicts resulting from in-lake dredging.

Beneficial and Adverse Impacts

Water Quality. The results of modeling analysis indicate that no significant improvement in the phosphorus regime and related biologically-oriented nuisance conditions can be expected from the dredging and anticipated in-lake containment of bottom sediments at Grand Lake. In fact, a slight degradation could occur if assumed model conditions are truly representative of the prototype. The primary reason for this lack of positive impact is that any projected dredging operation can be visualized either as removing an insignificant depth of sediment over the entire lake (e.g., 1.8 million cubic yards represents an inch of sediment removal over the lake), thereby simply exposing more of the same type of sediment, or as removing all the accumulated sediment from an inconsequential portion of the lake (as is now being done). To uncover the natural bottom over the entire lake represents approximately 100 million cubic yards of sediment removal. Over 35 percent of the lake surface area would be required for dredge spoil containment in this case. Even if priority dredging zones could be identified by a quantitative and qualitative sediment survey, as for example cattail marshes, the overall reduction in lake nutrient content is expected to be only a few percent.

The potential reduction of wind-induced sediment resuspension resulting from lake dredging, and its consequential impact on water quality, was not incorporated into the model. However, the results of the analysis on the movement of sediment in Grand Lake due to wind have shown that no significant reduction of suspended sediments can be expected, even for the extreme case of 3 feet of sediment removal. The findings of the modeling study are therefore not invalidated, and no noticeable improvement in water quality can be expected as a result of the alleviation of wind-mixing effects by dredging.

A preliminary notion was held that dredging would promote aquatic plant growth by reducing lake turbidity. However, the aforementioned analytical finding that dredging will not appreciably reduce sediment resuspension does not substantiate this notion. An exception would be the potential for aquatic plant growth in dredged stillwater areas created by breakwaters or islands, but even in this case the causal reduction in resuspended sediment load would result more from the structural alternative (breakwater or island) than from a combined dredging operation to deepen the stillwater areas.

Up to this point, the anticipated beneficial and adverse impacts (or lack thereof) of dredging on lake water quality generally refer to long-term average conditions at Grand Lake. More perceptible temporary and localized adverse impacts on water quality can be expected as a result of any dredging operation. Most significant is an increased turbidity and the resulting transport of nutrients into the water column near the dredge site. In addition, decant water from the containment area could have exceptionally high concentrations of suspended solids and nutrients. Clarifier ponds for the decant water, including provisions for the addition of chemical flocculants, are often incorporated into the containment design to minimize this latter impact.

Physical Conditions, including Lakeshore Flooding. Dredging has been promoted as a potential remedial measure for several of the physical problems at Grand Lake. These include flooding, severe wave action, shoreline erosion, and fluctuating lake levels. Whereas some of the modeling results support this contention, others indicate that the contrary may be true.

Flooding of downwind shorelines due to the long-period setup of the water surface could indeed be reduced by a dredging program. For example, model results show the wind setup at the eastern embankment for a 50 mph westerly wind to be reduced from 1.35 feet to 0.90 foot in the limiting case of 3 feet of sediment removal. In conflict with this improvement is the finding that the significant wave height of the short-period wave spectrum will increase with dredging. For example, for the same 50 mph wind and 3 feet of sediment removal, the significant wave height at the eastern end of Grand Lake will increase from 2.4 feet to 2.9 feet. Conditions on the south and north shores are close to the same magnitude and follow a similar pattern for the corresponding wind events.

The objective of wave attenuation is more relevant to the short-period, high-intensity waves. Therefore, the model results indicate that the existing severe wave action is expected to be aggravated by dredging the lake bottom.

A similar conclusion is reached regarding erosion of the lake shoreline. Even though wind setup does impact on the erosive process, the greatest concern is intense wave action and the overtopping of erosion control structures. As a result, lake bottom dredging or any other alternative that intensifies short-period waves would be detrimental to shoreline erosion.

Long-term fluctuations in lake level will not be significantly influenced by dredging. If anything, the situation will be aggravated if dredge spoil containment is within the lake basin. The reason for this is that as the surface area of the lake is reduced, the change in water level resulting from a unit increase or decrease in water volume is greater.

Water-Related Recreation. The major improvements to be expected from a dredging program at Grand Lake are associated with water-based recreational activities. The most direct benefits are an increase in boater access to extended portions of the lake, and an improvement in boater safety resulting both from the actual deepening process and the potential for stump identification and removal. This advancement in boater safety is, of course, offset by the potential intensification of wave action that accompanies dredging.

Localized disturbances of fish habitat will occur during the dredging operation. However, the long-term effect of deepening Grand Lake should be an enhancement of fish habitat and the related recreational fishing activity. A decrease in lake turbidity, and its consequential effects on fishing at Grand Lake, is not expected to result from dredging.

One indirect benefit of dredging is the potential for extending the wildlife refuge through the creation of protected dredge islands near the southwest corner of Grand Lake.

Technical and Physical Feasibility

No technical or physical constraints that prohibit dredging sediments from the bottom of Grand Lake have been identified or documented. The principal concern appears to be the proper containment and disposal of the spoil material. This problem, common to all dredging operations, is aggravated at Grand Lake by the absence of suitable topography and available land for spoil disposal outside the lake boundary. On the other hand, a notable advantage at Grand Lake is that the spoil material is relatively "clean." That is, the lake sediments are typically nutrient-enriched soil displaced from the upstream watershed. Critical concentrations of toxic or hazardous materials have not been identified in the sediments. The value is that some typical containment requirements appear to be relaxed at Grand Lake (e.g., no special provisions for impermeable leachate barriers). Considering the current dredging operations at Grand Lake, care in the design, construction, operation, and maintenance of containment areas should alleviate any regulatory constraints.

A related concern is the settling characteristics and engineering properties of the sediment material. Difficulty in achieving an effective spoil settlement has been reported at Grand Lake, and this could impact on the scheduling of a large-scale dredging program. The engineering properties of the dewatered material are unknown at this time, but could impact on the future use of the created dredge islands. A positive indicator is the current use of dredge spoil land forms at Grand Lake for roadways and recreational activities.

In a sense, the mere size of Grand Lake and the present volume of bottom sediments can be considered as constraints. The reason is that they prohibit the realization of many commonly referenced benefits of a large-scale dredging program.

Economic Feasibility

Unit Cost. The unit cost analysis for dredging at Grand Lake is predicated on two assumptions: (1) hydraulic dredging is the most appropriate technique for large-scale dredging of inland lakes; and (2) as a result of physical watershed constraints (e.g., flat topography, land availability), the spoil material will be contained in areas created within the current lake basin. The unit cost for a dredging program is conveniently separated into the cost of the actual dredging operation (pumping, transport), and the cost associated with the creation of containment areas.

To develop the cost of construction for containment dikes, two typical cross sections were developed in accordance with current Corps of Engineers requirements for Grand Lake. Whether or not a dredge island (or peninsula) would be developed for commercial or residential purposes provided the differentiation in the cross sections. Containment cost for undeveloped land forms would be $0.50/cubic yard and $1.00/cubic yard for developed land forms.

The total unit cost for dredging is therefore $2.00/cubic yard if the created land form is to remain undeveloped (e.g., wildlife habitat, picnic areas), and $2.50/cubic yard if commercial or residential development is projected.

Monetary Benefits and Costs. Basic to the unit cost approach is that the total cost of a dredging operation is directly proportional to the volume of sediment removed. However, the dependence of the dredging volume on a currently undefined lake development plan prohibits the computation of a single total cost for Grand Lake. To exemplify typical costs, consider the volume of sediment that would have to be removed to achieve various minimum depths at Grand Lake (i.e., the condition that the entire lake would be at least as deep as the given value). The results and associated costs are as follows:

Minimum Depth	Required Dredging Volume	Cost ($2.00/CY)
4 feet	6,600,000 CY	$13,200,000
6 feet	18,600,000 CY	37,200,000
8 feet	44,300,000 CY	88,600,000

To remove and contain 3 feet of sediment from the lake, as represented in the various analytical models, the cost would be $135 million or $168 million, depending on the future land use.

The results of the analysis for an extreme case of 3 feet of sediment removal throughout the lake indicate little impact on water quality. Any indirect benefits derived from dredging solely on the basis of water quality improvement at Grand Lake are therefore judged to be insignificant.

The analytical findings related to physical processes signify that changes can be expected if extensive dredging occurs. However, if the results for 3 feet of sediment removal are extrapolated to a more realistic scope of dredging at Grand Lake, the physical impacts become very small. For example, changes in wind setup and wave heights would be, at most, on the order of inches. Considering the type of nuisance flooding that is prevalent at Grand Lake, any increase or decrease that might result from lake dredging will have a negligible economic impact. In addition, there is no justification for assuming that indirect benefits or costs will be realized due to such slight variations in the physical conditions at Grand Lake.

Improvement in water-based recreation as a result of dredging will provide indirect benefits from increased lake usage. In order to estimate public benefits resulting from lake visitation, a dollar value must be put on recreational activities. In 1973, the Water Resources Council established standards of $0.75 to $2.25 per visitor-day of recreation participation, depending on the type and quality of a facility. If these numbers are adjusted to reflect 1980 dollars, the value of a visitor-day may be in the range $1.50-$4.50. Water-related recreation usually corresponds to the upper end of the scale, and thus a value of $4.00 per visitor-day was selected for Grand Lake.

Table D-13 presents recorded and projected visitor-day figures for Grand Lake, and the respective revenue that could potentially result. The projections have been developed using approved forecasting methods, and appear reasonable. Nevertheless, they must be taken to represent upper limits of lake visitation if Grand Lake were free of its problems. Of more significance is the documented progressive drop in visitation since 1973, and the corresponding loss of annual revenue. For example, the cumulative loss of potential revenue since 1973 is over $22 million, an amount sufficient to cover the costs of dredging to achieve a minimum 6-foot depth throughout Grand Lake.

Three notes of qualification are necessary. First, data limitations prohibit a differentiation of resident and non-resident lake visitation. If residents account for a significant percentage of the recorded number of lake users, some reduction in the computed revenues would be in order. Second, the abnormally high visitation values reported for 1972 and 1973 could, to some degree, be an artifact of a change in lake usage estimation techniques. No documentation of such a change has been ascertained, however. Third, the information presented in Table D-13 is not meant to imply that the decline in lake visitation is attributable solely to the shallowness of Grand Lake and the lack of an extensive dredging program. Nor is it implied that the implementation of such a dredging program will, in itself, reverse the visitation trend. What is intended is to provide an economic base against which various alternatives that impact on the recreational value of Grand Lake can be compared.

A potential direct benefit of a dredging program is the value of the land created by the dredge spoil operation. To investigate this, consider that the total dredging and containment cost required to form a 100-acre, 12-foot deep, developable site is $4.75 million. To balance this cost, the land would have to be sold for $47,500 per acre, or approximately $10,500 for a 120-foot x 80-foot lot. Real estate information from the Grand Lake area indicates that this size of lake-front lot is in great demand and currently sells for $12,000-$15,000. An approximate balance therefore corresponds to a 75 percent subdivision of the area created, and the economic viability of developing dredge islands is indicated. The creation of peninsulas rather than islands would reduce the cost by approximately 12 percent. A noteworthy aspect of developing dredge islands is that any other direct or indirect benefits of lake dredging can be realized without an associated cost.

Maintenance Dredging of Tributaries and Boat Channels

If an enlarged width on the USGS quadrangle sheets is assumed to correspond to boat accessibility, approximately 7 miles of water are

TABLE D-13

POTENTIAL REVENUE FROM GRAND LAND VISITATION

Year	Lake Visitation (Visitor-Days)	Potential Revenue 1/	Net Revenue Relative to 1973 Visitation
1970	1,711,800	$ 6,847,200	
1971	1,636,200	6,544,800	
1972	2,106,100	8,424,400	
1973	2,448,500	9,794,000	
1974	1,725,200	6,900,800	- $ 2,893,200
1975	1,658,800	6,635,200	- 3,158,800
1976	1,489,900	5,959,600	- 3,834,400
1977	1,474,950 2/	5,899,800	- 3,894,200
1978	1,479,018 2/	5,912,100	- 3,881,900
1979	1,219,637 2/	4,878,500	- 4,915,500
2000	3,000,000 3/	12,000,000	+ 2,206,000
2020	3,600,000 3/	14,400,000	+ 4,406,000

1/ Based on $4.00 per visitor-day.
2/ Visitation figures are for fiscal year, not calendar year (Source: ODNR).
3/ Projected.

accessible on the tributaries to Grand Lake. In addition, about an equal length of boat access channels to private dwellings exists along the south shore. To guarantee that these channels satisfy their principal recreational purpose, periodic dredging must be performed. According to the State of Ohio major access areas are dredged approximately every 3 years.

Table D-14 presents estimated costs of maintenance dredging. These values are based on a unit cost of $2.00/cubic yard, a 25-foot channel width, and 2 feet of sediment removal. The corresponding cost per 50 feet of channel length is $185, or about $60 per year. This latter figure is illustrative of a channel along a typical residential frontage, and provides input to the issue of cost sharing for maintenance dredging of private boat access channels.

TABLE D-14

COST OF MAINTENANCE DREDGING:
TRIBUTARIES AND BOAT ACCESS CHANNELS

Channel	Length (feet)	Cost to Dredge Every 3 Years	Dredging Cost per Year
Coldwater Creek	9,000	$ 33,000	$ 11,000
Chickasaw Creek	7,500	28,000	9,300
Little Chickasaw Creek	3,000	11,000	3,700
Prairie Creek	4,500	17,000	5,600
Beaver Creek	7,500	28,000	9,300
Barnes Creek	3,000	11,000	3,700
Monroe Creek	2,000	7,500	2,500
Boat Access Channels	36,000	133,000	44,000

The major concern with this type of dredging is the proper disposal of the spoil material. The current method of placing the spoil on the channel banks is technically deficient due to the susceptibility of the material to erode back into the channel. The proper containment of the waste along the channel banks is prohibited by the low containment volume to dike length ratio, and the transfer of the spoil material to in-lake containment areas is cost prohibitive. One alternative is to form containment areas at the mouths of the tributaries. These areas have a multiple purpose, and are presented in more detail in the section on shoreline protection. A second alternative is the availability of equipment for "spraying" hydraulic-dredged material on the watershed. The feasibility of this technique for Grand Lake is enhanced by the lack of any toxic or hazardous spoil contaminants. The return of the nutrient enriched sediment to the watershed could actually prove beneficial. The availability of suitable land (particularly agricultural land) and the cooperation of the landowners are necessary for the successful implementation of this technique.

Other Non-Point Source Phosphorus Controls

Precipitation Phosphorus Control

Precipitation contributes an estimated 780 kilograms of phosphorus or approximately 2 percent of the annual load to Grand Lake St. Marys. This loading originates principally outside the lake basin from such sources as wind-induced soil erosion, industrial ash, smoke, and certain mining activities, and the addition of organic phosphates to gasoline. It takes the form of particulate phosphorus carried by wind and other unit processes which is later removed by rainfall or other precipitation. In general, it can be said that the phosphorus content of direct precipitation on the lake surface, besides being small as compared to other sources, is not manageable or controllable by man.

Goose Population Reduction

In recent years, Grand Lake has accommodated increased numbers of migrating Canadian geese. Estimates indicate total phosphorus loadings from geese to Grand Lake to be approximately 210 kilograms or less than one percent of the total annual phosphorus loading. The orthophosphorus loading, that form which would be immediately available to the biological system, is only 43 kilograms or less than one percent of the total annual orthophosphorus loading to the lake. The fact that geese utilize Grand Lake during the fall and early winter when biological activity is at a minimum lessens the impact of these nutrients on the lake.

Approximately one percent of the total annual phosphorus load is attributed to migrating geese, but the amount that is available to the biological system is insignificant. Therefore, any program recommending a reduction in goose population on Grand Lake by hazing or hunting would have little impact on water quality.

Suburban Runoff Control

Suburban runoff in areas directly adjacent to the lake contributes approximately 3 percent of the total phosphorus loading to Grand Lake. This runoff, especially after a first flush during a heavy rain, may carry a wide range of pollutants in high concentrations. Fertilizers, pesticides, detergents, oil grease, salts, lead, domestic animal wastes, and street litter are all carried through ditches or directly to the lake.

Property owners can have a positive effect on water quality by reducing the amount of pollutants in stormwater runoff. Fertilizers could be applied to lawns and gardens if a soil test indicates a nutrient deficiency. Then, fertilizers should be applied only when and where runoff would not present problems. An effort can also be made to prevent leaves, lawn clippings, and other yard debris from being carried to the lake in runoff. Composting may be an effective measure to control pollutant loadings from this source. Frequent street cleaning in paved areas is also helpful in preventing nutrients from reaching surface waters. Lake residents could make additional efforts to use low phosphate detergents to reduce phosphorus seepage to the lake from septic systems. Management methods could be employed in the following areas:

(1) minimum fertilizer and pesticide application -- lake shore residents, areas adjacent to drainageways to the lake.

(2) composting yard debris -- lake shore residents, areas adjacent to drainageways to the lake.

(3) frequent street sweepings -- developed areas adjacent to lake (Celina, north shore, south shore).

(4) use of low phosphate detergents -- Grand Lake north shore from Harbor Point to Lakeland Beach, and Northwood and Sandy Beach; south shore from Montezuma to Southmoor Shores.

Erosion and Sedimentation Control Alternatives

Shoreline and Streambank Protection

For purposes of this study, four specific types of shoreline and streambank erosion control measures representative of the range of available alternatives were investigated: (1) riprap, the most commonly utilized and often the least expensive method for streambank protection; (2) gabions, a more stable method than riprap that requires similar materials; (3) aluminum bulkheads, selected to represent the many types of bulkheading available; and (4) concrete fabriform mats, one of the many applications of synthetic fabrics for streambank erosion control.

Four types of erosion problems at Grand Lake were considered including tributary streambank erosion, boat channel erosion, lakeshore erosion, and island shoreline erosion. No documented data exists on past or present rates of erosion, although the often observed movement of sediment plumes away from shorelines could lead to a preliminary judgment of excessively high rates. What remains unclear is whether the current erosion patterns will continue once the dredge spoil previously deposited on the banks is eroded and the natural streambanks are re-exposed.

Beneficial and Adverse Impacts. Tributary Streambanks. The streambanks of the tributaries to Grand Lake have the lowest percentage of protected length among the four categories under consideration. The protection is limited to several areas where individuals have implemented various bank protection measures, including primarily makeshift wooden bulkheads and tie-back walls. In addition, it is the streambanks that appear to be most susceptible to the disposal of highly erodible dredge material at the water's edge.

The retardation or prevention of streambank erosion has two direct benefits. First, the land bordering the tributary will be stabilized. This latter benefit should not be overestimated since, even though a relative contribution is due to the existence of dredge spoil on the banks, the general conclusion is that the dominant sediment source is watershed soil loss.

One important planning aspect of streambank protection is the progressive development and urbanization of the watershed. Due to increases in peak discharge rates in the tributaries, current erosion rates could be significantly increased over the next few decades. Of particular concern is Coldwater Creek due to the high current and projected rates of development around the municipality of Coldwater. Noticeable widening of downstream reaches of Coldwater Creek has reportedly occurred in the recent past as a result of intensified erosion.

Lake Access Channels. Property protection and sediment load reduction are also the primary benefits to be realized from protecting boat access channels. For three reasons, however, this aspect of shoreline protection was not given further consideration. First, access channels are not subjected to the erosive forces of streamflow and waves. The potential effects of boat wake must be locally dealt with. Second, the protection of access channel banks is very similar to streambank protection. And third, a large percentage of channel length has already been protected.

Lake Shoreline. The boat and shore reconnaissance surveys have provided valuable insight to lake shoreline protection. In general, the north, east, and west shores of Grand Lake currently have adequate bank protection. A few exceptions were noted along inlet channels and embayments, and some existing protection measures are seriously deteriorated as a result of improper installation and/or excessive wave and ice action. Nevertheless, it has been shown that the investigation of shoreline erosion problems can be limited to the south shore. Conditions on the south shore are reasonably summarized by the statement that developed shoreline is protected and undeveloped shoreline is not. Bank erosion along the undeveloped areas of the south shore is the most dramatic in the Grand Lake study area, with approximately 5-foot vertical drops and uprooted trees observed in several reaches. The State of Ohio has initiated an extensive riprapping program for these areas. However, the success of any such program is limited by access problems. In addition, the irregular nature of the shoreline and the existence of islands and peninsulas magnifies the scope of work involved.

The formulation and implementation of plans that address this problem are aided by the fact that much of the undeveloped and unprotected land is State-owned. An alternative is now formulated for which shoreline protection of large portion of the problem area is but one of many benefits. The alternative is conceptualized for Chickasaw and Little Chickasaw Creeks in Plate D-6, and involves the contruction of a protected dike to isolate or enclose the existing embayment areas near the mouth of each major tributary. Although not necessary for this illustrated presentation, similar diked areas could be depicted near the mouths of Coldwater, Prairie, Monroe, and Grassy Creeks. The prevalence of private residences near the embayment areas of Beaver (Upper) and Barnes Creek will probably restrict the implementation of this alternative at these sites.

The direct benefits of this alternative are complete shore protection incorporated into the design and construction of the dike, a reduction in the irregularity of the shoreline, and the development of multipurpose containment areas. For example, the areas could serve as disposal sites for spoil material during maintenance dredging of the tributaries and access channels, with subsequent conversion to a wooded wildlife habitat and shore buffer zone. Another potential use is as a sedimentation pond, but the feasibility of this use would require data on the settleability of the sediment load. It is noted that no private property or tributary access is directly impacted by the alternative.

An adverse impact is the loss of the embayment areas. From a recreational standpoint, however, the areas are not in current use due to the prevalence of aquatic growth and the impact will be small. A more critical impact is the potential elimination of viable fish habitats. At this time, the overall importance of these embayments to aquatic species cannot be judged.

Dredge Islands. The problems associated with erosion from future dredge islands should be alleviated by more stringent containment requirements. In the case of existing islands, the alternatives are: (1) retrofit shore protection; (2) simply allow the natural loss of the islands to proceed; and (3) develop a larger scale plan that indirectly provides shoreline protection.

A constraint to implementation of bank protection on the islands is economics. The "do nothing" alternative can be somewhat justified by the small contribution of dredge islands to both the annual sediment load to the lake and the overall recreational usage of the lake. The third alternative is related to the creation of large containment areas that could include the existing islands within protected dikes.

The aforementioned containment areas near the mouths of tributaries would of necessity include some existing dredge islands. However, other containment zones constructed for dredge spoil disposal could likewise be positioned near islands. One particular alternative is to create a relatively large dredge island that would encompass several of the currently unprotected islands between Coldwater Creek and Montezuma Bay. The created land form could serve as a well-defined water-based extension of the State's goose and wildlife refuge. The progressive and dispersive movement of the waterfowl and wildlife into developed areas would be relieved.

Given the apparent lack of current usage, the adverse impacts of island modification on recreational activities at Grand Lake are expected to be insignificant. On the other hand, carefully planned islands would enhance the recreational value of Grand Lake by augmenting the wildlife sanctuaries available by boat. Land-based access could also be easily implemented. One adverse impact would be a potential increase in the nutrient load to Grand Lake due to the concentrating of waterfowl and wildlife on these islands. However, proper runoff control and a good vegetative cover should be sufficient to preclude any serious problems. The native fish population will be disrupted during the period of implementation, but the long-term effect will be an enhancement of fish habitat near the shorelines and within any embayments created by the islands.

Technical and Physical Feasibility. As evidenced by the current level of shoreline and streambank protection at Grand Lake, there are no technical constraints to implementing protective measures. Most of the constraints have a physical basis, but even those can be overcome at additional expense.

In the case of streambanks, limited access due to private land ownership or wooded areas prohibits the use of recommended transport and placement or construction techniques. Each of the four types of protection can be installed from a water-based vehicle. Of the four, aluminum bulkheads appear to be the most conducive to installation from a small barge. A second constraint on the use of riprap, gabions, and concrete fabriform mats is the recommended 1.5:1-3:1 bank slopes for stability purposes. Given the existing vertical nature of the banks, this implies an extensive cut into the bank (and most likely into private property). On the other hand, aluminum bulkheads are installed vertically, with no major modification of the shoreline. A constraint that impacts primarily on bulkheads and mats is the need to maintain subsurface drainage from the watershed, especially considering the widespread use of tile drains. The same two protective measures would be a problem in areas where private or public access to the water must be preserved.

The protection of lake and island shoreline is for the most part constrained by the same factors. Installation and operational problems will be alleviated if the diked containment areas are used for shoreline protection. The reason is that proper grading and other necessary preparation of the shoreline can be controlled during the contruction sequence.

Economic Feasibility. Unit Costs. Based on unit labor, material, and equipment costs, the unit cost for placed riprap is $20.00/cubic yard. To account for access problems and possibly water-based installation, the labor and equipment costs are doubled and the total cost becomes $31.00/cubic yard. Assuming that adequate protection requires riprap protection between 3 feet below and 5 feet above the mean water level, and a 2:1 slope, a 1-foot typical thickness converts to almost 0.7 cubic yard of riprap per lineal foot of protection. The resultant cost is $21.70/lineal foot. To account for the use of filter cloth or other filter material, use $27.00/lineal foot.

The 1978 unit cost for 12-inch deep, stone-filled gabions is $18.60/square yard. If the installation cost is doubled to account for access and installation difficulties, and a 10 percent inflation factor is imposed, the 1979 unit cost becomes $26.35/square yard. To convert this to a linear footage basis, the gabions are assumed to be placed at the recommended 1.5:1 slope and to be required between 3 feet below and 5 feet above the mean water level. The resultant unit cost is approximately $42.00/lineal foot.

The material costs for the aluminum bulkheads depend on the gage of the metal, the size and spacing of the anchor plates and rods, and the need for stiffening beams. For the type of installation at Grand Lake, material costs would be $30.00-$35.00/lineal foot, and the total unit installed cost would be approximately $60.00/lineal foot.

The recommendation for concrete fabriform mats is a 4-inch thick mat at a 3:1 slope. For 10 feet of vertical protection, this converts to 31.2 SF/LF, or $62.40/LF of shoreline.

The unit cost for containment dikes to implement either of the specific alternatives formulated in this section is $100/LF.

Total Benefits and Costs. Table D-15 presents the costs associated with complete protection of various reaches of shoreline and streambank. The tributary lengths correspond approximately to currently accessible portions, as indicated by an expanded width on the USGS topographic maps. The value for the south shore is a rough estimate for currently unprotected shoreline, including Montezuma Bay, but not accounting for the shorelines of access channels and dredge islands. The impact of the irregular shape of the south shoreline is indicated by the fact that over 11 miles of shoreline still need protection, even though the total length of the lake is only 8 miles.

The results presented in Tables D-5 and D-15 provide an interesting comparison. Under the assumption that shore protection measures and a nearshore breakwater will provide the same level of erosion protection, it is observed that shoreline protection is the most cost effective of the two alternatives. An exception is floating tire breakwaters, but this alternative is technically infeasible for such a large installation. It can be argued that the benefits derived from a breakwater would be greater due to its multi-use potential, but on the other hand shoreline protection would have fewer and less severe adverse impacts. One noteworthy feature is that the total costs of the alternatives to protect the south shore are not proportional to the respective unit costs. The reason is that shoreline protection measures must span the actual footage of the shoreline, whereas a breakwater need only be aligned along an east-west axis.

TABLE D-15

COST OF COMPLETE SHORELINE
AND STREAMBANK PROTECTION

Reach	Length Requiring Protection (feet)	Riprap ($27/LF)	Gabions ($43/LF)	Aluminum Bulkheads ($62.40/LF)	Concrete Mats ($62.40/LF)
Coldwater Creek	18,000	$ 486,000	$ 756,000	$1,080,000	$1,120,000
Chickasaw Creek	15,000	405,000	630,000	900,000	936,000
Little Chickasaw Creek	6,000	162,000	252,000	360,000	374,000
Prairie Creek	9,000	243,000	378,000	540,000	562,000
Beaver Creek	15,000	405,000	630,000	900,000	936,000
Barnes Creek	6,000	162,000	252,000	360,000	374,000
Monroe Creek	4,000	108,000	168,000	240,000	250,000
South Shore (unprotected)	60,000	1,620,000	2,520,000	3,600,000	3,740,000

The principal direct benefit of bank protection measures is the value of land that is preserved from erosion. If the typical selling price of a lakeshore lot is converted to a square-footage basis, the cost of shoreline protection in most cases far exceeds the value of the land saved. Of course, such a strict economic criterion is often outweighed by other factors when personal property loss is at stake, and shoreline protection is recommended.

Sedimentation Ponds

Sedimentation ponds are structures considered to reduce the amount of sediment and nutrients entering the lake.

Beneficial and Adverse Impacts. Primary objective of sedimentation ponds is to provide a quiescent zone in an otherwise flowing watercourse for settling suspended and settleable particulate matter. This controlled sedimentation in designated areas reduces the sediment load to downstream water bodies and provides for ease of removal of the collected matter. Because of the shallowness of Grand Lake, the upstream removal of settleable solids is an especially beneficial mechanism. An equally important benefit of sedimentation ponds to Grand Lake is the removal of any nutrients bound to the captured sediments, especially considering the extensive agricultural usage of the watershed. A long-term effect of sedimentation ponds is the improvement of the water quality of Grand Lake. Many secondary benefits, primarily of a recreational nature, can be realized as a consequence of water quality improvements.

Several negative aspects of sedimentation ponds can also be identified. First, localized nuisance conditions are created. The ponds can be compared to stagnant water ponds with their attendant high rates of algal growth, unpleasant odors, and conditions conducive to insect breeding. A second adverse impact is that severe storm events could "washout" the ponds and result in a pulse injection of sediment to Grand Lake. Benthic organisms in downstream channels and in the immediate receiving areas within Grand Lake would be subject to sediment burial, the severity of which would be very dependent on antecedent conditions in the sedimentation ponds and receiving waters. Of even more concern is a possible accompanying pulse injection of nutrients and the possibility of triggering serious water quality impacts. The third negative impact is that currently productive land would be required for the ponds. Depending on the settling characteristics of the sediment load, this land requirement could be significant. A final problem associated with sedimentation ponds is that the alternative represents a long-term operation and maintenance commitment. Periodic cleaning of the ponds must be carried out to minimize the potential of the previously mentioned "washout" and to prevent flooding as a result of channel alternations.

Technical and Physical Feasibility. The siting of sedimentation ponds in the Grand Lake watershed is the most significant constraint to their implementation. Several siting alternatives are available, with advantages and disadvantages specific to each. From a land availability standpoint, the most feasible alternative is to site ponds within the lake at the mouths of the major tributaries. This alternative is primarily limited by the need to maintain boat access and fish passage to the tributaries. A previously mentioned possibility to eliminate this constraint is to create containment areas near the mouths (but offset from the main channels) and to use these for sedimentation purposes. The disadvantage is the need for facilties to convey the tributary flow to these ponds in a controlled manner. The access constraint can also be overriden if the sedimentation ponds are placed on the major tributaries upstream of the currently accessible reaches. The acreage of currently productive private land needed for this alternative is the principal constraint, as illustrated below. So as not to require a large single parcel of land, small sedimentation ponds could be located on the feeder streams to the major tributaries. The economy of scale associated with both construction and maintenance costs is a detriment to replacing one large pond by several smaller basins. A final alternative is to locate a sedimentation pond on individual farms, but this is limited by cost and institutional constraints.

The requirements for a sediment basin to serve the entire drainage basin of Chickasaw Creek are used to exemplify the siting constraint. Ordinarily, the grain-size distribution and the corresponding settling rates of the sediment load are used to establish the residence time required to achieve the desired removal efficiency. However, the procedure to be used in this analysis was to size the pond as a function of the residence time. The important design parameter, therefore, becomes the flow rate, for the required lake volume is directly available once the flow rate and residence time are known.

The acreage of land required to implement the sediment basin alternative for the two flow rates is plotted against residence time in Figure D-13. A mean depth of 10 feet was assumed on the basis that this will provide sufficient depth for settling and storage without an excessively deep excavation. It is often found that a significant percentage of the suspended load is removed within the first several hours, whereas only a small percentage increase in removal occurs over the next several hours (or days). If this condition is satisfied at Grand Lake, sedimentation basins may prove feasible. For example, a 4-hour settling period would require only about 15 acres of surface area. Three notes of qualification are necessary. First, the percentage reduction in nutrient load will be less than the reduction in sediment load, since the finer sediment fraction not being retained will have a higher nutrient content than the settled course material. Second, if rock is encountered within 10 feet of the ground surface, the mean depth must be reduced and the required acreage of land will be increased. Third, the requirements given in Figure D-13 are for Chickasaw Creek only.

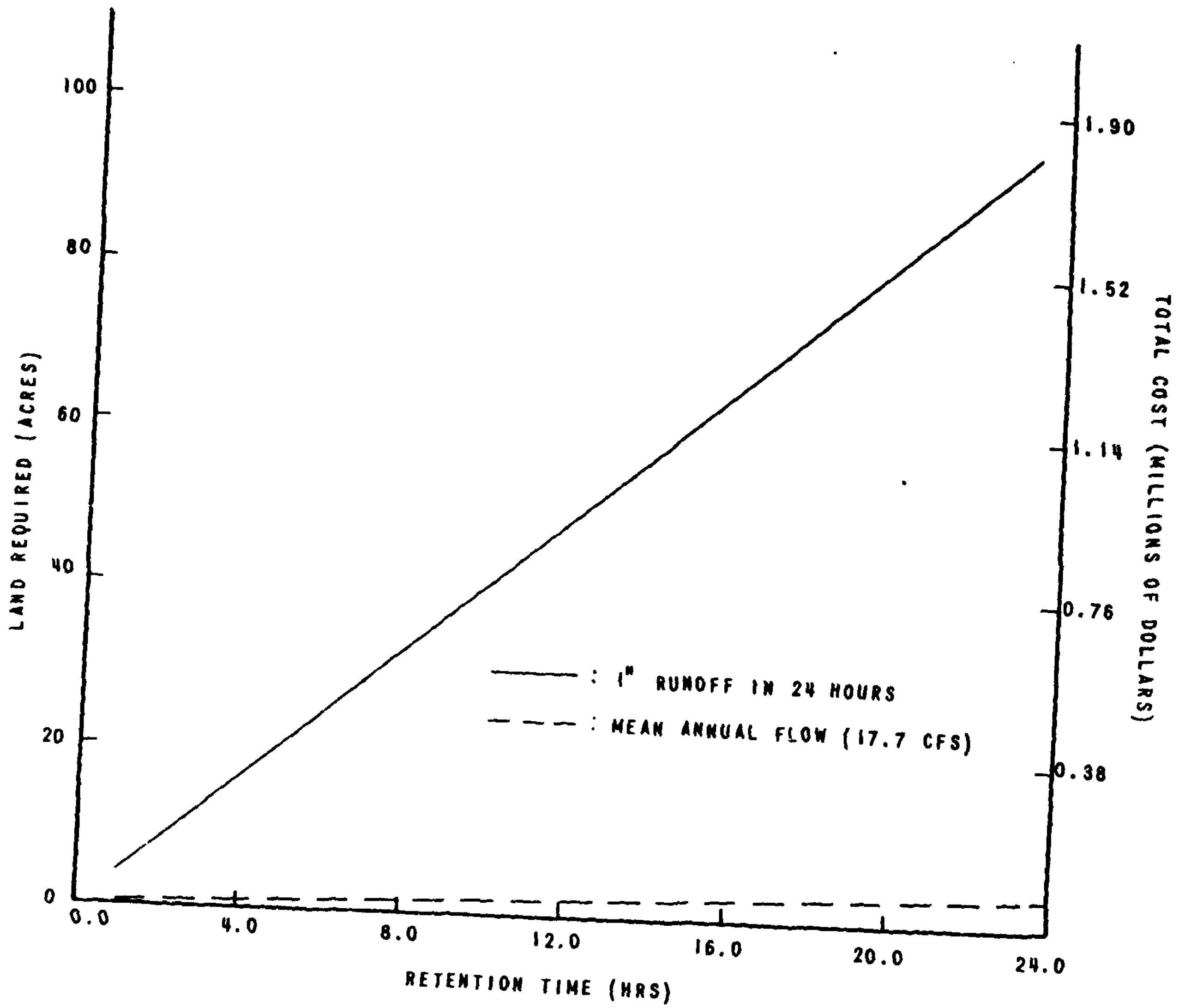

FIGURE D-13. Land Requirement and Cost for a Sediment Basin on Chickasaw Creek

Economic Feasibility. Unit Costs. The two major cost items for sediment basin construction are the land purchase and the excavation. Real estate information indicates that agricultural land in the Grand Lake watershed is currently selling for \$2,000-\$3,000 per acre. The \$3,000 per acre figure is selected to reflect the trend toward increasing property values. An excavation cost of \$1.00/cubic yard has been selected, in accordance with typical unit prices for excavation by scrapers and front-end loaders. The cost to dispose of the excavated soil has not been included since the method of disposal or possible utilization of the material is unknown at this time.

Total Benefits and Costs. Based on the selected unit prices, the total cost to construct sediment ponds is computed and plotted as a function of retention time in Figure D-13. An important observation from the plot is the sensitivity of the cost to the residence time, and therefore to the settling characteristics of the sediment load. For example, the cost associated with a 20-hour residence time is over \$1.5 million, whereas the cost for a 4-hour detention is \$300,000. In a sense, 4-hour detention basins can be constructed on all major tributaries for the same cost as constructing one 20-hour detention basin on Chickasaw Creek. Based on the selected unit price and the two ranges of residence time, estimated capital cost to construct sediment ponds on each main tributary to the lake is given in Table D-16.

Sedimentation ponds also require maintenance and "clean out" for their effective application. The clean-out period will depend on the yet to be determined design trap efficiency, so no specific cost can be quoted. As a rough estimate, consider that the estimated sediment load to Grand Lake is 100 to 200 tons/mile^2/year, or about 13 acre-feet per year from the entire watershed.(13) At a removal cost of \$2.00/CY, and assuming a 50 percent trap efficiency, the annual cost of pond clean-out is about \$21,000. This corresponds closely to the alternative approach of considering that a two-man crew working for a 6-month period each year should be able to maintain all the ponds in the watershed.

TABLE D-16

DATA AND COSTS OF SEDIMENTATION BASIN ALTERNATIVE

Tributary	Drainage Area (sq. mi.)	Area Required for Sediment Basin (ac)		Estimated Capital Cost of Sediment Basin		Estimated Annual O&M Costs	
		4 hr	20 hr	4 hr	20 hr	4 hr	20 hr
Coldwater Creek	19.2	17.5	85.5	$ 323,000	$1,624,000	1,800	8,600
Beaver Creek (Upper)	20.4	18.5	91.0	352,000	1,729,000	1,900	9,100
Prairie Creek	5.2	5.0	23.0	95,000	437,000	500	2,300
Chickasaw Creek	18.4	16.5	81.5	314,000	1,549,000	1,700	8,200
Little Chickasaw Creek	6.9	6.5	30.5	124,000	580,000	700	3,200
Barnes Creek	3.6	3.5	16.0	67,000	304,000	400	1,600
Total Watershed	73.7	67.5	327.5	$1,275,000	$6,223,000	7.000	33,000

From an economic standpoint, the most direct benefit of sedimentatin ponds in the consequent sediment reduction is maintenance dredging of tributaries. With reference to Table D-16, if the annual costs of maintenance dredging of the tributaries are reduced by a factor of one-half (50 percent trap efficiency), the net annual savings are $22,500. This is very close to balancing the cost of maintaining the sedimentation ponds. A similar decrease in maintenance dredging of access channels and the lake bottom is not expected in the short term. This is due to the current volume of sediment in the lake and its ease of transport as a result of wind mixing. Note that the annual sediment load is equivalent to only about one-hundredth of an inch of sediment over the lake bottom.

Sedimentation ponds can be expected to improve lake water quality, but no direct economic benefits can be identified as a result. The possibility of indirect revenue gains due to increased recreational lake usage has been discussed in previous sections.

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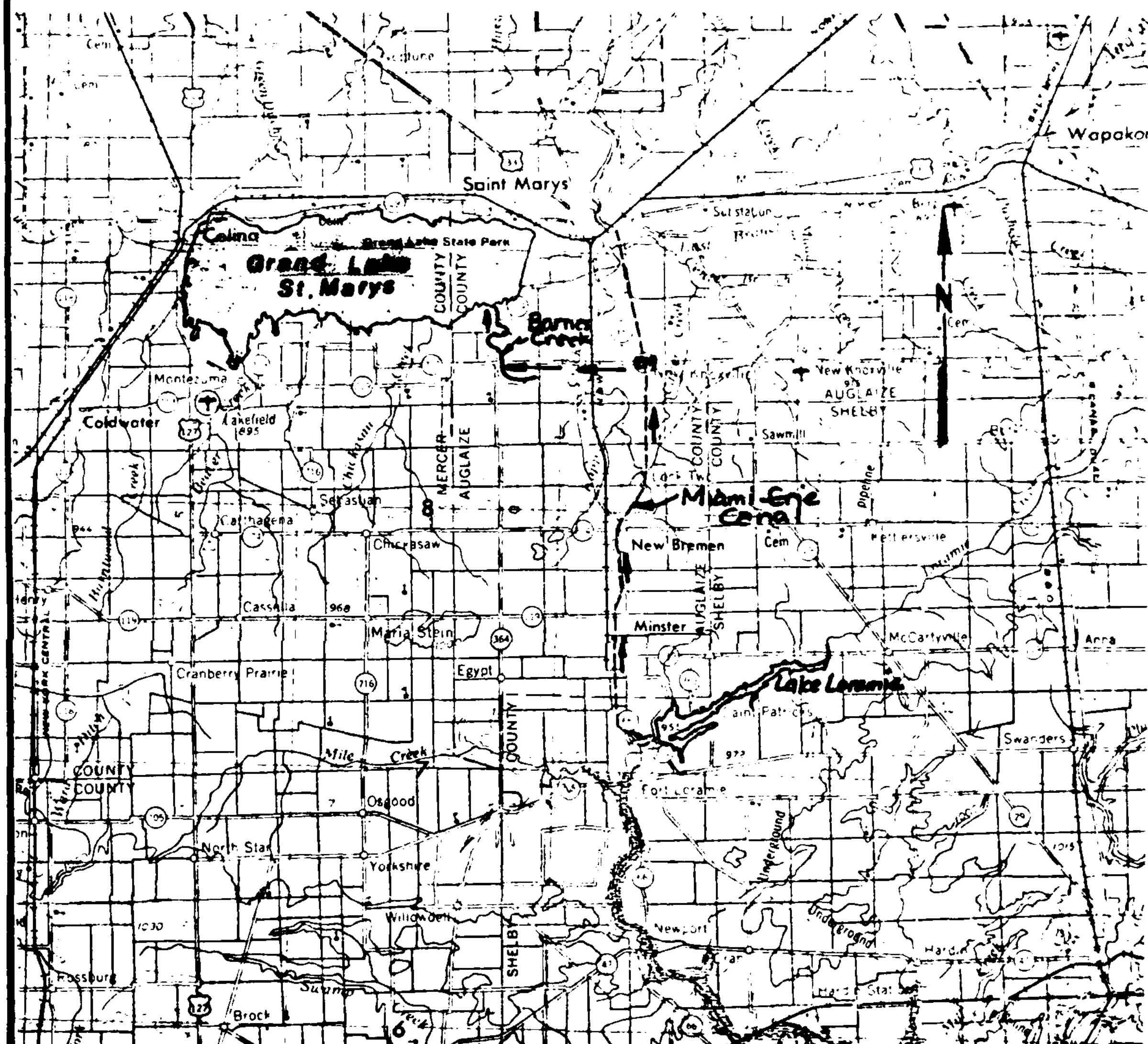
SECTION D

PLATES



SCALE IN MILES

4 0 4

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

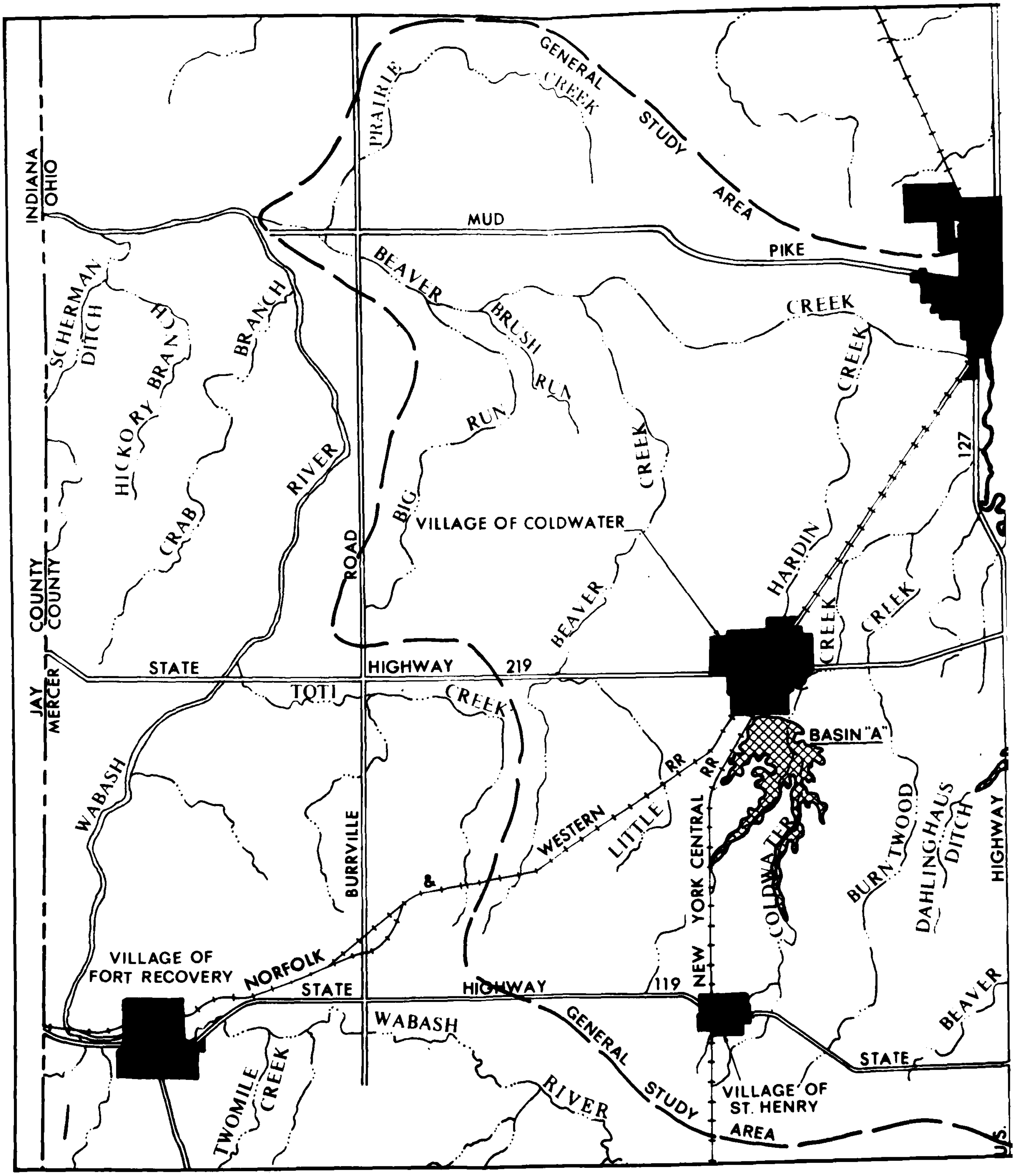
GRAND LAKE ST. MARYS

LAKE LORAMIE FEEDER CONCEPT

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLPD-P AUGUST 1981

PLATE D - 1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MERCER COUNTY
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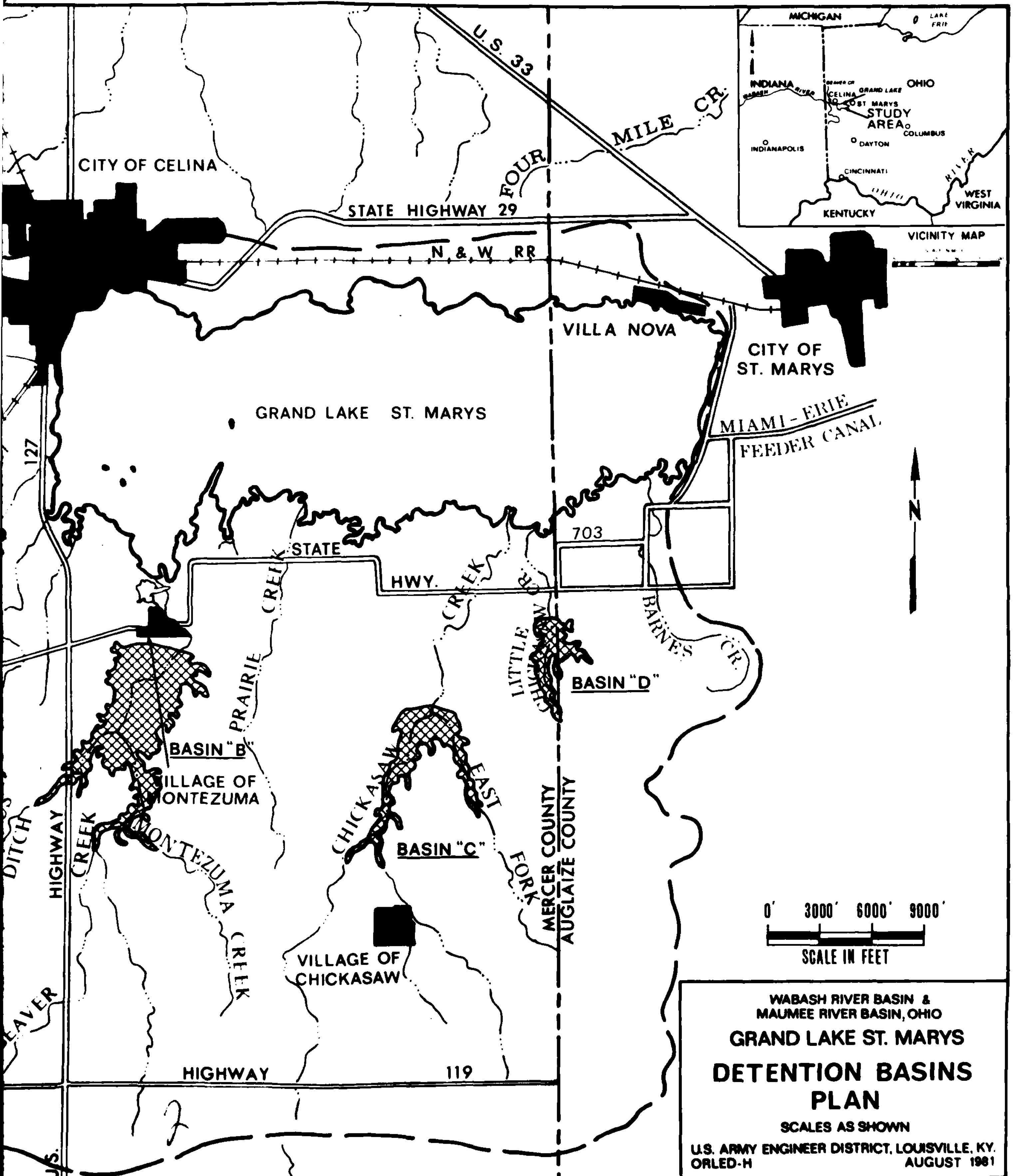
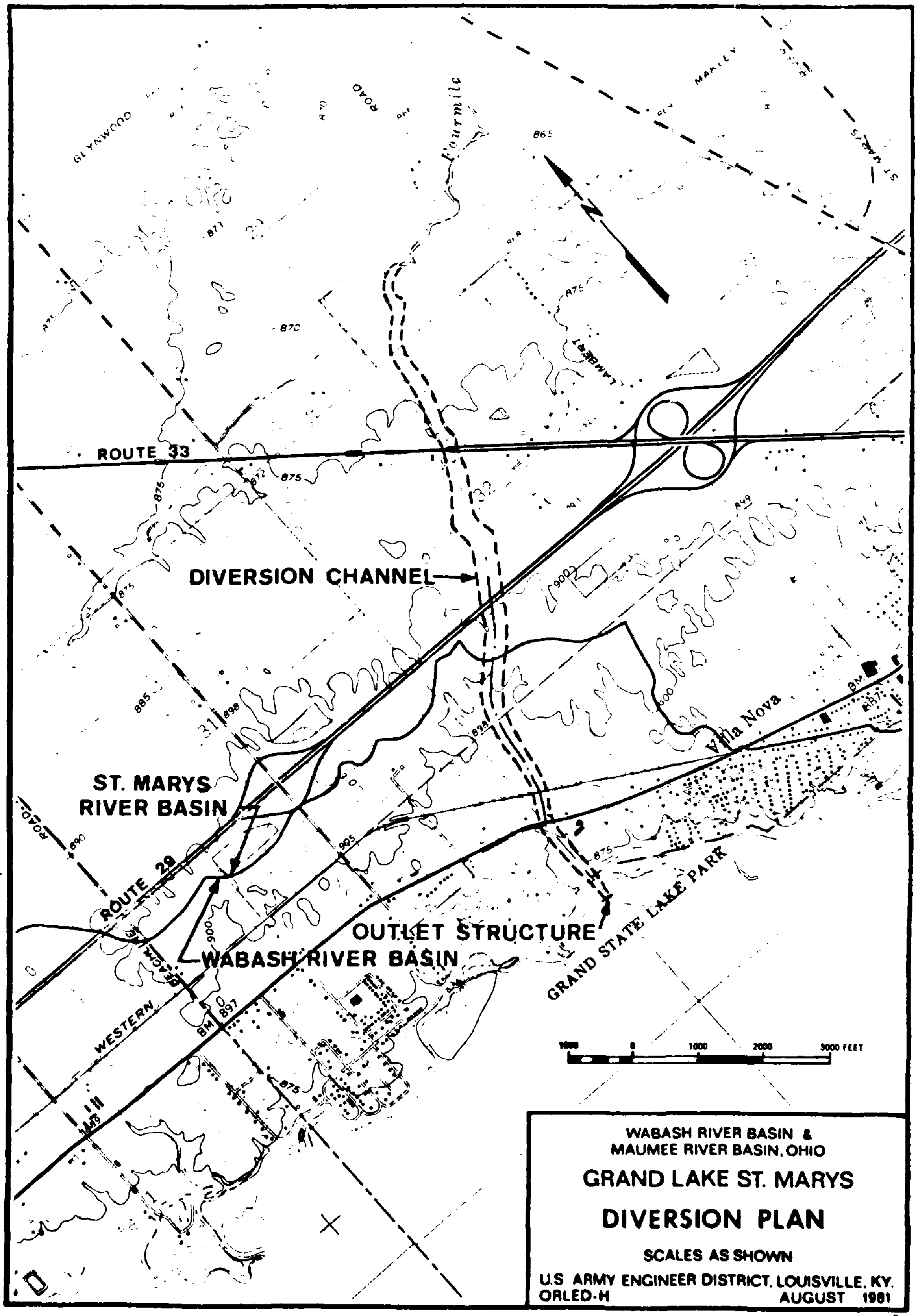
PRAIRIE
CREEK
MUD PIKE
BEAVER CREEK
SCHERMAN DITCH
HICKORY BRANCH
BRANCH
BRUSH RUN
CRAB
RIVER
RUN
BIG
CREEK
VILLAGE OF COLDWATER
HARDIN
CREEK
127
ROAD
BEAVER
STATE HIGHWAY 219
TOTI CREEK
BASIN "A"
WABASH
RR
NEW YORK CENTRAL RR
LITTLE
WESTERN
&
NORFOLK
BURRVILLE
COLDWATER
BURNTWOOD
DAHLINGHAUS DITCH
HIGHWAY
VILLAGE OF FORT RECOVERY
STATE HIGHWAY 119
WABASH RIVER
TWOMILE CREEK
VILLAGE OF ST. HENRY
STATE
BEAVER
US


MICHIGAN
INDIANA
OHIO
CELINA
GRAND LAKE
ST MARYS
STUDY AREA
INDIANAPOLIS
DAYTON
COLUMBUS
CINCINNATI
KENTUCKY
WEST VIRGINIA
VICINITY MAP
U.S. 33
FOUR MILE CR.
CITY OF CELINA
STATE HIGHWAY 29
N & W RR
VILLA NOVA
CITY OF ST. MARYS
GRAND LAKE ST. MARYS
MIAMI - ERIE FEEDER CANAL
127
STATE HWY. 703
PRAIRIE CREEK
CREEK
LITTLE CR.
BARNES CR.
BASIN "D"
BASIN "B"
VILLAGE OF MONTEZUMA
MONTEZUMA CREEK
CREEK
HIGHWAY
DITCH
BEAVER
CHICKASAW
EAST FORK
BASIN "C"
VILLAGE OF CHICKASAW
MERCER COUNTY
AUGLAIZE COUNTY
N
0' 3000' 6000' 9000'
SCALE IN FEET
HIGHWAY 119
WABASH RIVER BASIN & MAUMEE RIVER BASIN, OHIO
GRAND LAKE ST. MARYS
DETENTION BASINS PLAN
SCALES AS SHOWN
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLED-H
AUGUST 1981

CORPS OF ENGINEERS U S ARMY



WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

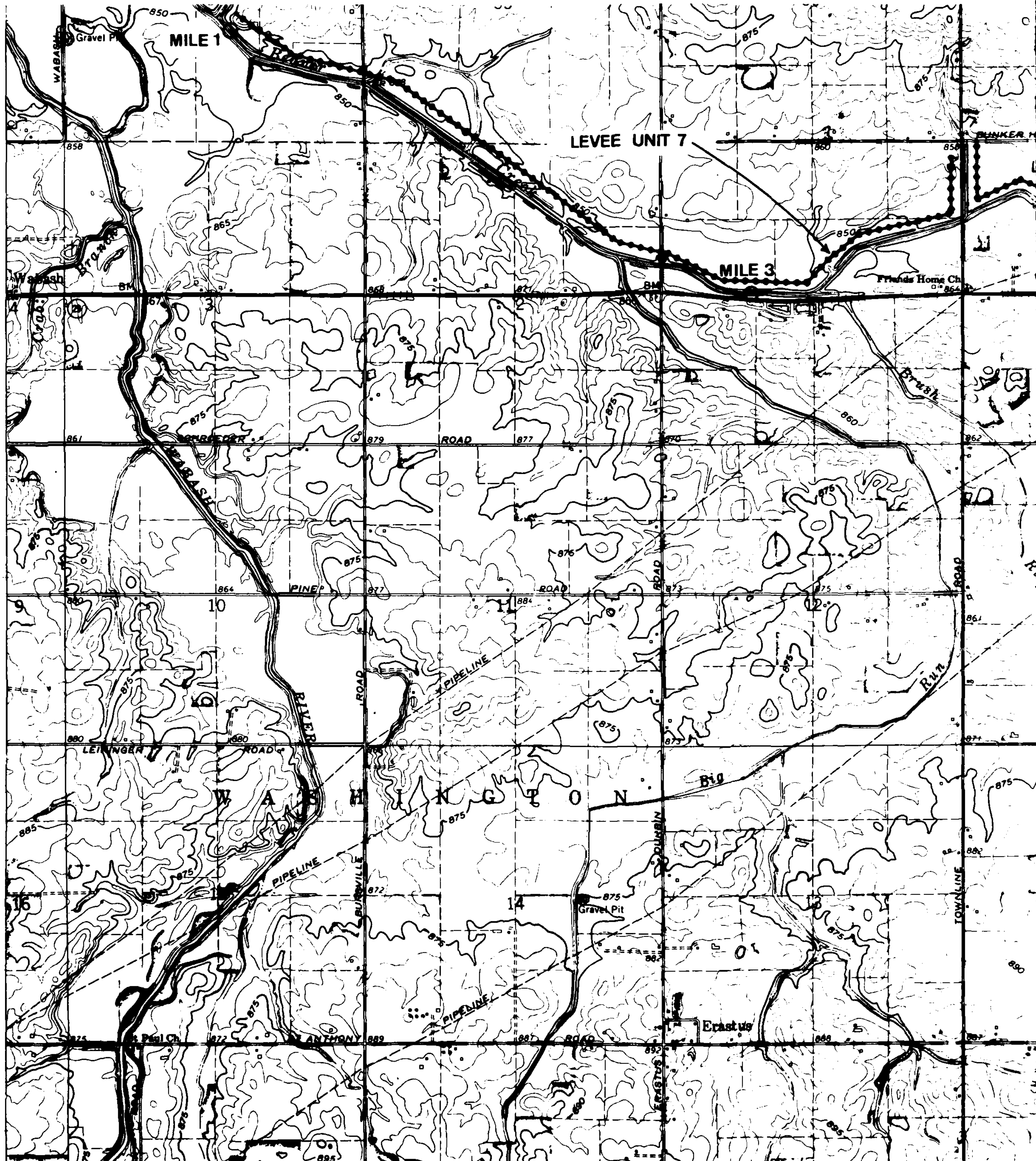
GRAND LAKE ST. MARYS

DIVERSION PLAN

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLED-H AUGUST 1981

PLATE D-3



MILE 1
Gravel Pit
LEVEE UNIT 7
MILE 3
Friends Home Ch
Wabash
WABASH
RIVER
SCHROEDER
ROAD
PINE
ROAD
LEININGER
ROAD
PIPELINE
W A S H I N G T O N
Big
Run
Brush
Gravel Pit
Erastus
St Paul Ch
ANTHONY
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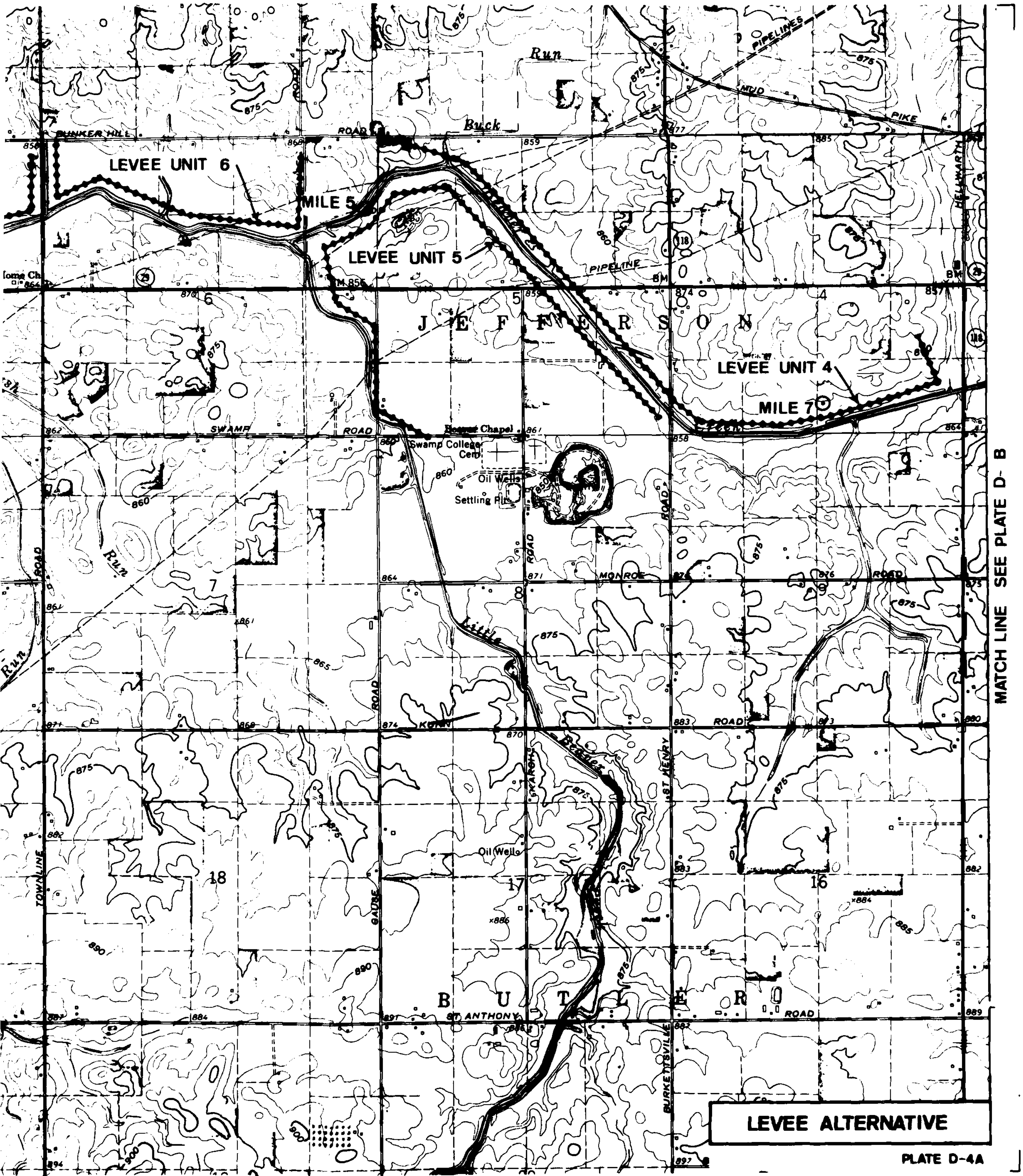
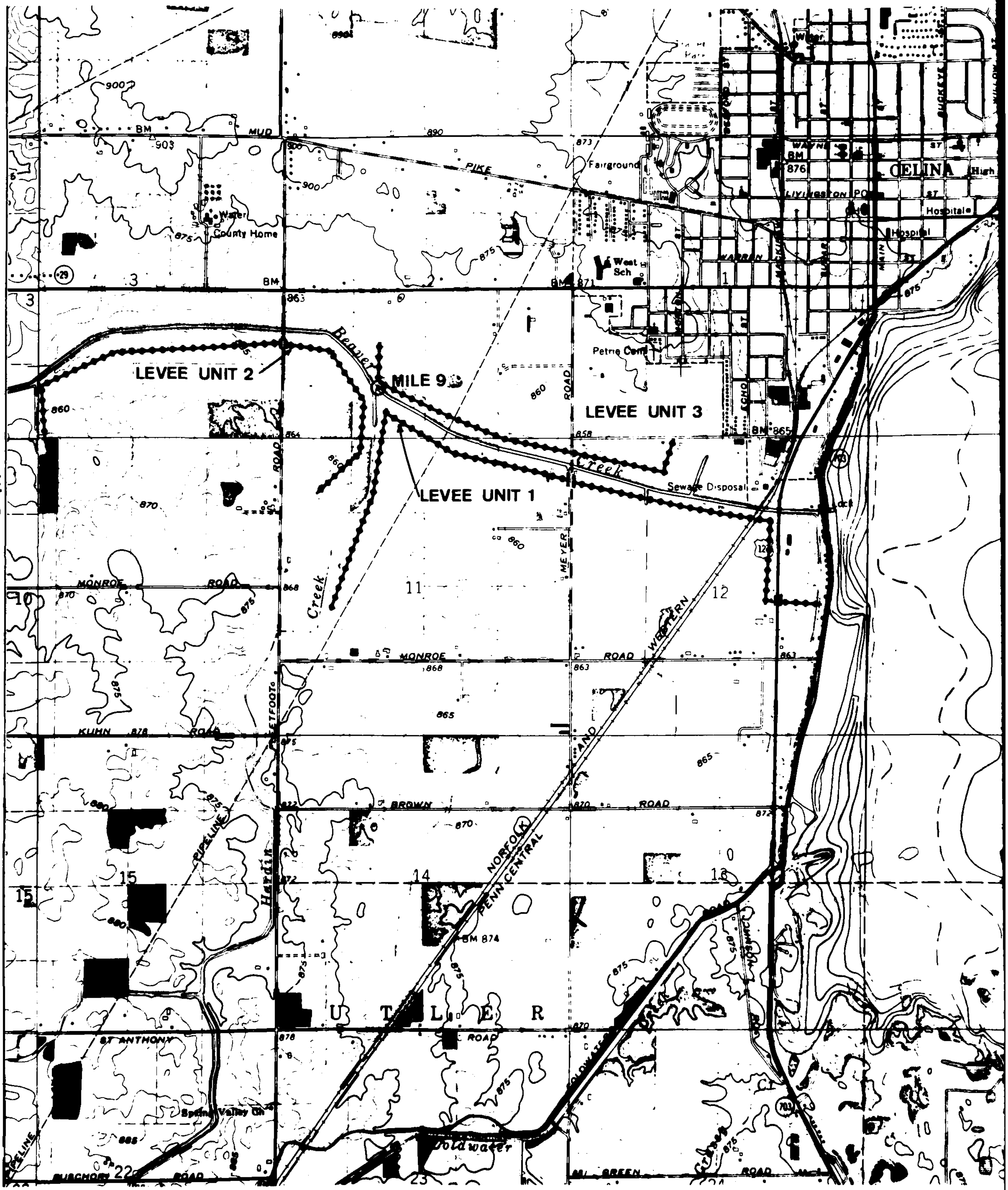
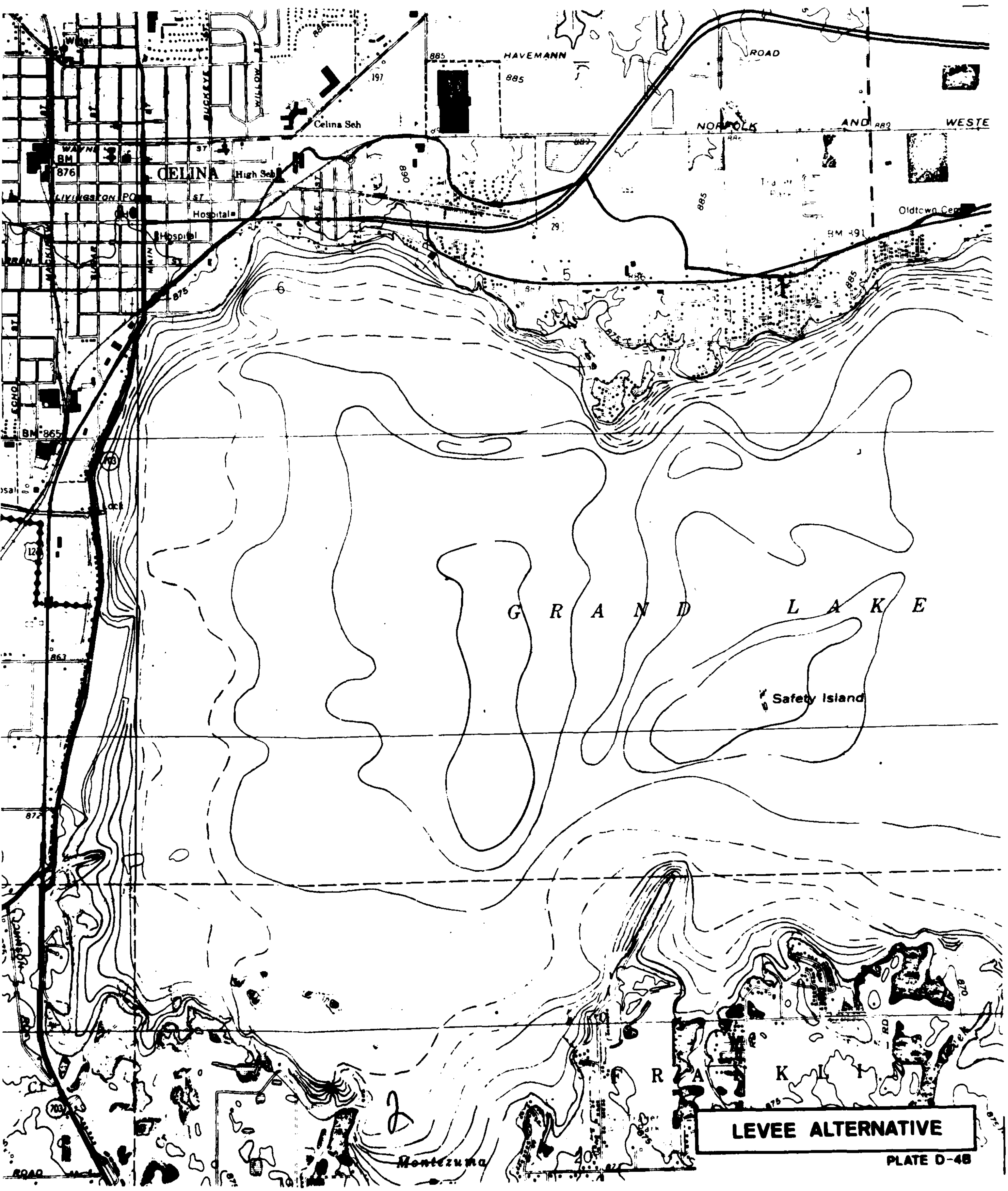


LEVEE ALTERNATIVE

PLATE D-4A



MATCH LINE SEE PLATE D-4A

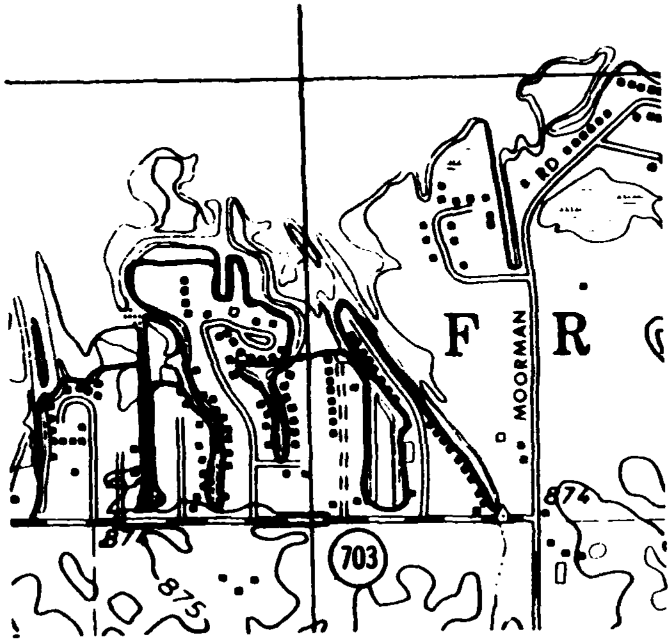


LEVEE ALTERNATIVE

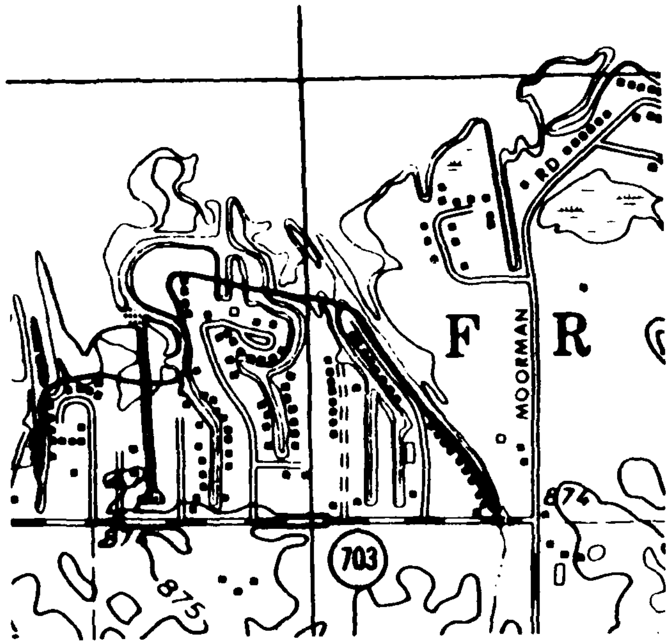
PLATE D-48

LEGEND

LEVEE



ACCESS CHANNELS MAINTAINED



LEVEES ACROSS ACCESS CHANNELS

TYPICAL LEVEE REQUIREMENT (WEST OF MOORMAN ROAD)

SCALE : 1" = 1000'

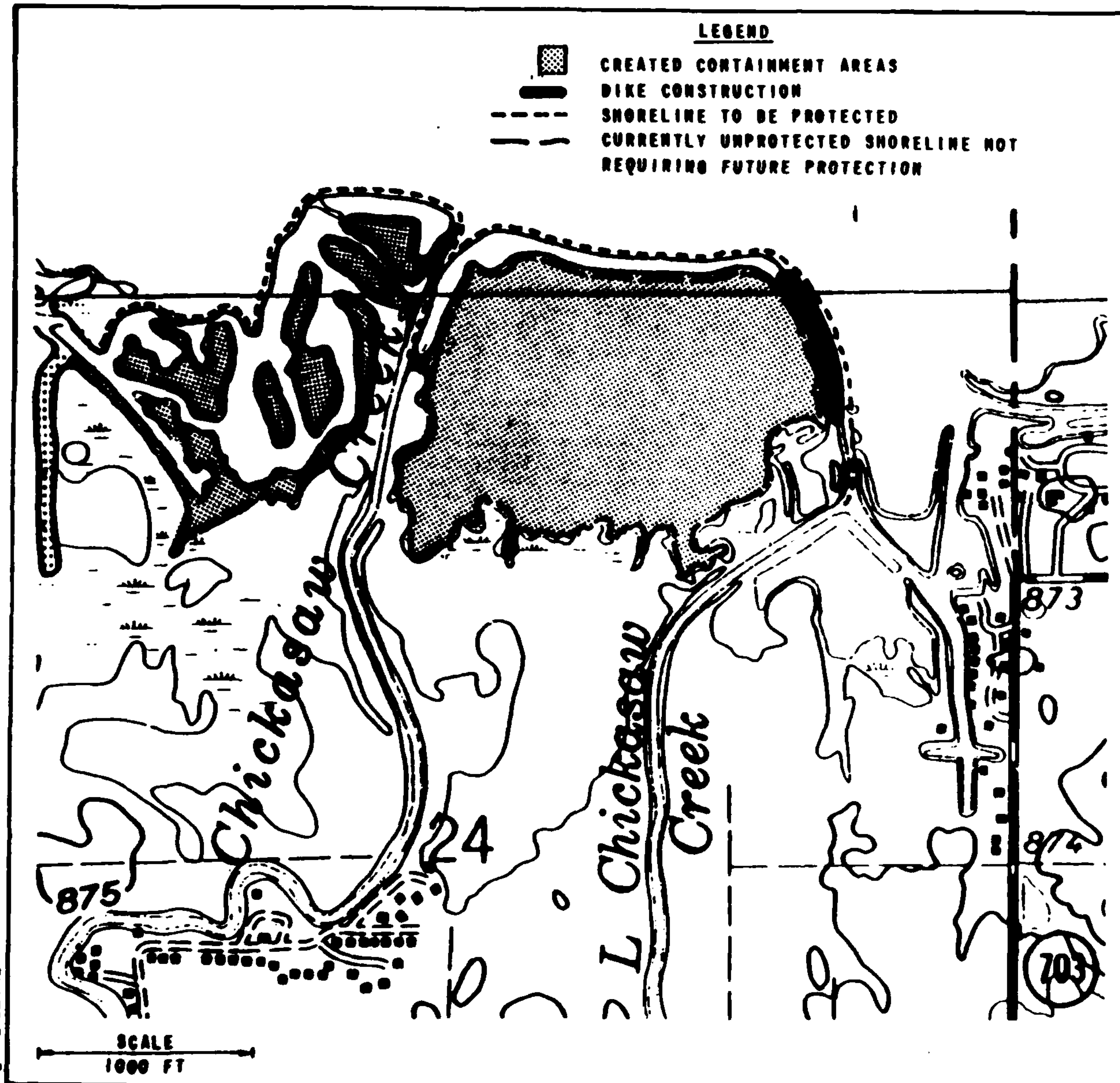
WABASH RIVER BASIN &
MAUMEE RIVER BASIN OHIO

GRAND LAKE ST. MARYS

SHORELINE LEVEE PLAN

SCALES AS SHOWN

US ARMY ENGINEER DISTRICT LOUISVILLE KY
ORLED-H AUGUST 1981



WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

CONTAINMENT AREA CONCEPT

CHICKASAW &
LITTLE CHICKASAW CR.

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY
ORLPD-F AUGUST 1981

PLATE D – 8

SECTION E

HYDROLOGY AND HYDRAULICS

SECTION E

HYDROLOGY AND HYDRAULICS

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SECTION E

HYDROLOGY AND HYDRAULICS

INTRODUCTION

This section provides methodology and assumptions used in establishing the hydrologic and hydraulic conditions of the Grand Lake St. Marys study area. Data were developed from which the extent of flooding and flood damages could be developed. Information is provided on the development of flood related alternatives.

LOCATION AND DESCRIPTION

The Grand Lake St. Marys Basin, as shown on Plate E-1, is situated in Mercer and Auglaize Counties in west-central Ohio on the drainage divide between the Wabash and St. Marys Rivers. The lake is formed by two earth dams, constructed from 1837 to 1845, over Beaver Creek on the west and Chickasaw Creek to the east. The impoundment inundates the low watershed divide forming a lake with an approximate surface area of 21 square miles at pool elevation 870. The lake is approximately 8 miles in length, east to west, and averages over two miles in width north and south. Average lake depth is 6 to 8 feet.

The total Grand Lake drainage area, as published in "Drainage Areas of Ohio Streams," prepared by the U. S. Geological Survey in cooperation with the Ohio Department of Natural Resources, is 112.1 square miles. The report further states, "the portion of Grand Lake drainage area assumed tributary to Beaver Creek is 66.2 square miles," or approximately 59 percent of the total. The remaining area, or the "eastern portion of Grand Lake area assumed tributary to St. Marys River is 45.9 square miles," or approximately 41 percent of the total. Nearly all of Grand Lake's drainage area lies to the south of the impoundment.

Beaver Creek, apparently the major outflow exit for Grand Lake, flows westwardly 10.6 miles to the Wabash River. The average streambed slope for Beaver Creek is approximately 1-foot per mile and average channel depth is 10 to 12 feet. Total drainage area below Grand Lake is 58.8 square miles.

The land surrounding Grand Lake is predominantly agricultural except for those areas immediately adjacent to the lake and the residential communities of Celina and St. Marys. The gently sloping terrain, within the study area, is classified as prime farmland with soil types and a reported high water table, which are conducive to slow permeability. The top of basin location, gently sloping terrain and general lack of topographic relief subjects Grand Lake to periodic extreme wind conditions.

CLIMATOLOGY

Since its organization in 1891, the National Oceanic and Atmosphetic Administration (NOAA - Weather Bureau) has been the principal agency for collection and dissemination of climatological data. There are 12 weather stations lying within a 30-mile radius of the subject lake site. Two stations, Celina and St. Marys, are immediately adjacent to the Grand Lake watershed. Temperature and precipitation data in excess of 20 years are available for the station near Celina. Precipitation data in excess of 40 years are available for the recording station near St. Marys. Only one short-term (9 years) evaporation station is within close proximity (60 miles) to Grand Lake. There are no first order weather stations nearer than Cincinnati, Ohio.

From records published in the "Climatological Data--Annual Summary" for data through 1978, the following normal precipitation data is furnished for the St. Marys station:

January	2.27"	May	3.84"	September	2.85"
February	1.84"	June	3.96"	October	2.39"
March	2.79"	July	3.31"	November	2.41"
April	3.63"	August	2.89"	December	1.99"

Normal Annual Total - 34.17"

Based on snowfall monitoring stations at Van Wert and Greenville (located approximately 30 miles north and south, respectively, of Grand Lake), the average annual snowfall for the basin is about 23 inches. January is the month of maximum snowfall with an average of about six inches. Approximately, 85 percent of the average annual snowfall occurs during the period December through March. The basin is seldom covered with snow for an extended period of time, and snow melt is only a minor contributing factor to floods.

Based on records for the "West Central Division of Ohio, the normal annual temperature for the Grand Lake area is 51 degrees F. During the months of December, January and February average temperatures are below freezing with January as the coldest month having an average of 27 degrees. July is the warmest with an average of 73 degrees.

Southern and central Ohio is affected by frequent temperature changes, high humidity and intense precipitation caused by the passage of storms originating in southwestern United States and the Gulf of Mexico, and moving north-eastwardly toward the north Atlantic coast. The Grand Lake area is on the northern edge of this storm path. The cyclonic storm contributes the most frequent excessive runoff for the various types of meteorological disturbances which produce precipitation. Storms of this type generally occur during the period from mid-winter to late spring when conditions are conducive to high rates of runoff. Convective storms which produce rainfalls of high intensity generally occur during the summer months, when transpiration and infiltration losses are the highest, therefore, seldom cause significant flooding. Topography of the basin is such that orographic rainfall does not occur.

STREAMFLOW RECORDS

The U. S. Geological Survey and the Corps of Engineers are the principal agencies operating stream gaging stations with additional cooperation, in recent years, from other Federal and State agencies. No streamflow gaging stations exist within the Grand Lake, Beaver Creek or upper St. Marys River watersheds. Published streamflow records are limited to the gaging stations for the Wabash River near New Corydon, Indiana, and St. Marys River at Decatur, Indiana within the general study area. The New Corydon station monitors streamflow from a 262 square mile drainage area, while the Decatur station records data from its 621 square mile area. Neither of these stations proved to be representative of the Grand Lake or Beaver Creek drainage basins. Therefore, from preliminary regional investigations the gaging station for Greenville Creek near Bradford, Ohio was selected as most representative of the natural (without Grand Lake) Beaver Creek Basin. Once daily lake water surface elevations are observed and recorded by State Parks personnel. The 24-hour pool difference, together with estimated Grand Lake outflows, were utilized to determine lake inflows.

HISTORICAL FLOODS

Limited data prohibits detailed commentary and analysis of past flood events. However, the storms which occurred in March 1913, and were centered near Bellefontaine, Ohio, produced the flood of record for a majority of long-term gaging stations in both northeastern Indiana and southwestern Ohio. The 5-day rainfall total was 11.1" at Bellefontaine, approximately 40 miles southeast of Grand Lake.

Available water surface elevation records for the Grand Lake pool begin in March 1927 and provide an indication of additional flood periods. The maximum pool level of recorded data occurred on 15 January 1930 at elevation 872.83. The Ohio Division of Parks and Recreation records also note an absence of gate operations during this high water period. This lack of outlet openings produced the maximum attainable pool structurally possible from available inflows. The peak lake inflow, during the period of recorded data, was estimated to be near 12,000 c.f.s. This event occurred on 18 May 1927 and was the result of a high intensity storm of short duration and low volume. This storm produced a peak pool elevation of 871.75. Additional peak pool elevations in descending order of magnitude are presented in Table E-1 for comparative data:

TABLE E-1

OBSERVED PEAK POOL ELEVATIONS

Date	Pool Elevation	Date	Pool Elevation
15 January 1930	872.83	7 April 1978	872.17
21 May 1943	872.67	30 January 1949	872.08
25 April 1972	872.67	10 April 1957	872.08
9 April 1938	872.42	21 June 1958	871.92
16 February 1950	872.42	6 July 1957	871.92

Local residents and farmers along Beaver Creek were interviewed and subsequently reported significant flood events during Janury 1949, December 1957 thru January 1958, March thru April 1964, May 1972 and March 1965. Several lesser floods were reported during the June through November months when crop losses are the greatest. No gaged data of historical floods are available for Beaver Creek.

DESCRIPTION OF DAM AND APPURTENANCES

The western embankment is an earth embankment carrying State Route 703. The embankment is approximately 5,540 feet in length. A curved uncontrolled spillway (37.2 foot chord) with a concrete ogee overflow section discharges under a single span highway bridge. The spillway crest elevation of 870.75 and top of dam elevation of 877.0 were previously determined. Four 30-inch diameter gated outlet conduits are provided through the spillway section. The gates are manually operated from within a gate house located over the spillway at the upstream side of the embankment. Plates E-2 and E-3 present preliminary discharge rating curves for the spillway and outlet gates.

The eastern embankment consists of an earth embankment carrying the roadway of State Route 364. The embankment is about 2,380 feet in length and has a top of dam elevation of 877.9. A 20-foot wide uncontrolled spillway is formed by two concrete walls across the lock chamber of the feeder canal to St. Marys River. The downstream wall at elevation 872.1 acts as a straight drop spillway. In addition, a 4-foot high by 5-foot wide leaf gate controls flow through a 42-inch conduit which outlets into the feeder canal. The gate is manually operated from the upstream end of the conduit.

Available mapping is limited to the USGS quadrangle sheets with a scale of 1"=2,000' and a contour interval of 5-feet. Area-capacity data were developed by Burgess and Niple for above spillway crest (870.75 feet) and are presented in this report on Plate E-4. Limited data prohibits extending area-capacity curves below spillway crest; however, estimations were made to facilitate studies presented in this report.

GRAND LAKE WAVE HEIGHT

The draft "Alternative Development Report" prepared by GAI Consultants, Inc., for Grand Lake stated "the preliminary objective was to illustrate the effect of dredging on wave generation," in the wave characteristic portion of their report. This analysis considered two cases, a mean lake depth of 8 feet and a mean lake depth of 11 feet. The GAI report states that "an increase in wave height will be observed with an increase in average pool depth." Furthermore, Figure 7 of their report shows only a 10 to 15 percent (approximately 0.6 foot) increase in the significant wave height with a 3-foot additional pool depth. The GAI methods, analysis and curve presentations are considered satisfactory to evaluate various wave situations. Therefore, the significant wave height associated with a 60 mile per hour wind and the pool at west spillway crest would be approximately 2.8 feet. It should be noted that wind setup, seiche effect and wave runup on various wall or bank slope conditions must be added to derive the effective wave condition.

STANDARD PROJECT FLOOD -- GRAND LAKE

The "Phase 1 Inspection Report, National Dam Safety Program" prepared by Burgess and Niple, Limited and dated December 1978 contains an analysis of a flood produced by the probable maximum precipitation (PMP) for Grand Lake. Synthetic 6-hour unit hydrographs were developed for the four major tributaries and local contributing areas. The HEC-1 computer program performed flood routing computations which indicated that the western dam would be overtopped by 0.7 foot. A flood produced by the 1/2 PMP would not overtop either dam. Outflow from spillways only were evaluated in their studies. Although the Burgess and Niple procedures did not strictly adhere to the latest Chief of Engineers guidelines, their results are believed to be satisfactory for this report.

SOIL SURVEY -- BEAVER CREEK

The soil survey of Mercer County, Ohio, was made by the Division of Lands and Soil, Ohio Department of Natural Resources, in cooperation with the Soil Conservation Service, United States Department of Agriculture; Ohio Agricultural Research and Development Center; Ohio Cooperative Extension Service; Ohio State University; Mercer County Commissioners; and the Mercer Soil and Water Conservation District. Their report, dated 1975, contains descriptions, characteristics and tables indicating soil limitations for selected land uses and some estimated properties for Mercer County soils. The following statements were determined from data contained within their report: The predominate land adjacent to Beaver Creek is classified as Wabasha silty clay loam which is very poorly drained soil that occupies low lying, level and depressional positions on flood plains. The representative soil sample was expressed as very dark grayish-brown, friable silty clay loam from 0 to 8 inches; 8 to 54 inches was dark gray mottled with dark yellowish-brown, neutral changing to mildly alkaline in the lower part, and firm silty clay. Wabasha silty clay loam has slow permeability in the clayey subsoil and substratum, and a high available water capacity. Drainage is difficult to establish due to the lack of suitable outlets on the nearly level topography. This soil is subject to streambank erosion and ponding of water for long periods following flooding. Depth to the seasonal high water table was estimated to be from 0 to 6 inches.

AVAILABLE DATA -- BEAVER CREEK

As previously discussed, no stream gaging stations exist on Beaver Creek. Historic high water profiles are limited to the January 1959 flood, developed by the State of Ohio, Department of Natural Resources, Division of Water. Although this profile depicts water surface elevations attained during the 1959 flood, it is not considered representative of a natural high water profile produced by the excessive flows. Through interviews with local residents and a search of the January 1959 flood history, several accounts were reported where excessive flows were retarded by ice jams and associated debris.

HISTORY -- BEAVER CREEK

The Beaver Creek Improvement Association, no longer in existence, promoted an extensive channel improvement project during 1950 and 1951 with the assistance of matching state funds. The channel improvement included Beaver Creek from Grand Lake to its mouth and the Wabash River from their confluence to the Indiana state line. This improvement reportedly proved effective in eliminating most of the flood problems for "several years." However, it must be noted that a below average rainfall period existed after the channel improvement for "several years." According to members of the association, no local funding was provided for maintenance after the 1950's. As a result, uncontrolled vegetation, tree growth and associated obstructions have gradually diminished the flow capacity along much of Beaver Creek. The Mercer County Engineer's Office in Celina, Ohio, has completed the new design/cost plan for rechannelization of Beaver Creek. Their studies included the existing and proposed modified channel cross sections utilized in this report. Also included were the outlet invert elevation of field tiles located during their survey.

LAKE REGULATION

Observed lake pool elevations provided by the Ohio Department of Natural Resources, Division of Parks and Recreation, for a 51-year period (1928-1978) were studied. These data are presented on Plates E-5 through E-21 for general familarization and reference. A regulation schedule or plan of operation was apparently non-existent during the early years. However, an increasing emphasis on lake regulation is noted during the last 15 to 20 years, with a corresponding emphasis for recreation and agricultural considerations. The existing "rule curve" includes a 1-foot drawdown from recreation pool elevation 870.75 beginning the first of November. However, after the 1-foot of flood storage is attained, minimal effort is exercised to maintain elevation 869.75 through the winter months. A practice of impounding some excess runoff early in the year, to aid in attaining recreation pool by late March or early April, appears to prevail.

Through discussions with the Grand Lake St. Marys State Park Office Manager, a maximum west bank conduit release of 200 c.f.s. was estimated. (The 200 c.f.s. was estimated from a HEC-2 backwater computation for Beaver Creek and the reference mark established by the Park Manager on Meyer Road Bridge.) This west bank outflow, when combined with baseflows is considered near bank full flow at low bank locations along Beaver Creek. During flood periods producing pool elevations in excess of elevation 870.75, uncontrolled outflows pass over the west bank spillway (200 c.f.s. at pool elevation 872.45) and would require a reduced conduit discharge in order to maintain a maximum 200 c.f.s. outflow. East bank outflows, during flood periods, are limited to spillway flows with a crest elevation of 872.1 feet. The east bank conduit is not utilized during flood periods.

A pool elevation-frequency curve (Plate E-22) was developed from observed data. This computation included all annual peak pool elevations during a 51-year period of record (1928-1978). These peak pool elevations resulted from a wide variety of initial pool elevation, inflows and outflow conditions. Outflows for these annual events ranged from spillway flow only (January 1930) to an estimated total west bank outflow (conduit plus spillway) of 550 c.f.s. in April 1938.

Plate E-23 presents observed pool elevations on a percent of time basis. For example, pool elevation 871.75 was equaled or exceeded 272 days during a 51-year period (1928-1978) or 1.46 percent of the total time (18,628 days). Several time periods, year-round (January through December) and recreation season (April through October) were studied and the results presented. An improvement, through lake regulation efforts is noted during the last 20 years (1959-1978).

LAKE RE-REGULATION INVESTIGATION

Re-regulation of Grand Lake, for annual flood events, was undertaken by "paper routing" methods with complete forecasting capability. East bank channel capacity, without modifications to the retreat channel and St. Marys River, is minimal. Therefore, only existing spillway (crest elevation 872.1) flows entered this evaluation (an estimated 50 cfs at elevation 873.0). West bank downstream control is limited to the previously discussed Meyer Road Bridge over Beaver Creek. A maximum conduit outflow rate (west bank only) of 200 cfs for above rule curve conditions was selected for this study. Starting at pool elevation 870.75 (west spillway crest), uncontrolled spillway flows require gradually reduced conduit flows to maintain a maximum 200 cfs release. Upon attaining pool elevation 872.45 the conduit is closed, and uncontrolled west bank spillway flows will exceed 200 cfs with an additional rise in pool elevation. Also considered was an outflow condition with a constant 200 cfs conduit release plus uncontrolled spillway flows.

The time required to deplete recreation pool storage will vary with the extent of total drawdown and inflow during the depletion period. Based on preliminary lake capacity data, zero inflow and a maximum 200 cfs release rate, drawdowns from recreation pool of 1-foot, 2-foot and 4-foot were considered. Minimum time periods were estimated to be 32 days, 60 days and 107 days, respectively. The probability of increased inflow periods begins in December, which emphasizes the necessity of maximum available storage during the "flood prone months" (December through March). Therefore, if a completion of drawdown date of

1 December is adopted, the initial drawdown date can be readily determined for the zero inflow and 200 cfs maximum release criteria previously set forth. For the three drawdown plans considered, initial drawdown dates of 30 October, 1 October or 16 August would be required. Loss of pool storage through evaporation, water supply withdrawal, and leakage would be considered as a "head start" toward the drawdown goal. This loss condition must be evaluated each year, resulting in an adjusted initial drawdown date. Once achieved, the winter pool elevation should be maintained through the "flood prone months." This available flood storage will reduce excessive outflows and the peak pool elevation during high inflow periods.

Based on preliminary lake capacity data the drawdown plans considered (1-foot, 2-foot and 4-foot) would require sufficient inflow to recover 6,330 day second feet (dsf), 11,900 dsf or 21,500 dsf, respectively, for the return to recreation pool. Average daily inflows were evaluated occurring during a 10-year period (1969-1978), for the months of March through April. The resulting mass inflow curve (Plate E-24) is considered a valuable tool when evaluating the return to recreation pool. The start of the recreation season is considered to be in late March or early April. The mass inflow curve presents various time periods that will return the lake to recreation pool for the 1-foot drawdown plan. However, the 2-foot drawdown plan would require approximately the full two month period, while the 4-foot drawdown would not be recovered during the time period studied. It must be realized this evaluation is based on average inflow conditions (10-year period) and not on an individual year basis. This mass inflow curve examination indicates the necessity of an early March initial filling date (for two of the three drawdown plans) to recover recreation pool by a desirable date (late March or early April).

Two winter pool elevations were selected (869.75 and 868.75) representing a 1-foot and a 2-foot drawdown from recreation pool, for additional studies. The practicality of a 4-foot drawdown was considered in the depletion and filling discussion of this report, and consequently omitted from further studies. Two filling periods (1 March and 1 April) were considered, both allowing one day filling conditions, which permits restoration of recreation pool with all available inflows. Table E-2 presents observed peak pool elevations, in descending order, the number of consecutive days above pool elevation 871.75, and the estimated maximum mean daily outflows in cubic feet per second (cfs).

Lake pool elevation 871.75 is reportedly identifiable as the water surface elevation, together with wind wave action, where "severe lake shore flooding begins." Table E-2 presents 11 of the 12 observed annual events, for 51 years of record, which exceed elevation 871.75. Furthermore, note that 7 of these 12 events occur during recreation season, minimizing the beneficial effects of various drawdown plans especially when coupled with an early filling date (1 March). Also peak mean daily outflows in both observed conditions and "paper routed" plans exceed the suggested 200 cfs maximum release; in addition, the duration in day above elevation 871.75 has a wide variance.

Based on observed data, recreation pool was obtained during 37 years of the 51 years studied, or expressed as an exceedence frequency of 72 times per 100 years. The observed 10-year exceedence frequency elevation was 872.3 (Plate E-22). Through an attempt to reproduce the present plan of lake regulation, Curve A was developed. Curve A represents a maximum controlled outflow of 200 cfs, a 1-foot drawdown and the 1 March filling date. Curve B presents reductions derived form increased outflows (200 cfs conduit plus spillway flows) with a 1-foot drawdown and the 1 March filling date. Curve C was developed from the 2-foot drawdown, 1 April filling date and a 200 cfs conduit plus spillway outflow plan. Curves A and C provide an envelope for the plans considered. The resultant exceedence frequencies, at elevation 870.75 are 67 times and 46 times per 100 years for the plans represented by Curves A and C. Also, regulation plans (A and C) produced 10-year exceedence frequency pool elevations of 872.46 and 871.75, respectively. Additional comparative data may be obtained from Plate E-22.

TABLE E-2

RE-REGULATION OF HISTORIC POOL ELEVATIONS
PEAK POOL ELEVATIONS

	Observed Data			Filling Date - 1 March Conduit plus Spillway = 200 cfs Winter Pool - 869.75			Filling Date - 1 April 200 cfs conduit plus Spillway Winter Pool - 868.75		
Date	Peak Pool Elevation	Consecutive Days Above Elevation 871.75	Peak Mean Daily Outflow (cfs)	Peak Pool Elevation (ft)	Consecutive Days Above Elevation 871.75	Peak Mean Daily Outflow (cfs)	Peak Pool Elevation (ft)	Consecutive Days Above Elevation 871.75	Peak Mean Daily Outflow (cfs)
Jan 30	872.83	18	300	872.24	40	210	871.46	0	250
May 43	872.67	24	330	872.22	20	210	871.72	0	280
Apr 72	872.67	32	310	872.56	58	230	871.54	0	260
Apr 38	872.42	19	550	872.44	58	220	871.55	0	260
Feb 50	872.42	24	520	872.85	138	315	872.07	19	330
Apr 78	871.17	37	380	872.32	69	210	871.38	0	240
Jan 49	872.08	19	260	871.16	0	205	870.33	0	200
Apr 57	872.08	23	550	872.74	71	285	871.97	8	315
Jun 58	871.92	11	380	872.39	64	215	872.22	33	355
May 33	871.92	5	490	871.88	12	210	871.38	0	240
Nov 72	871.92	9	510	872.69	104	270	872.20	35	350

It becomes apparent, through study of Table E-2 and the pool elevation-frequency curves, Plate E-22, an "optimum rule curve" alone will not alleviate excessive pool elevation problems. An increase in outflow capacity (west bank and/or east bank) and/or a reduction of natural inflows must be achieved to obtain the optimum control of Grand Lake pool fluctuations.

INCREASED GRAND LAKE OUTFLOWS

The 51 years (1928-1978) of available pool elevations are the sole data source for Grand Lake inflow evaluations. A study of these records indicates two severe inflow periods occurring at critical times. These inflows were experienced during a 6-day period in mid-May 1943, producing approximately 11,750 day second feet (dsf), and a 6-day period in early June 1958, resulting in approximately 11,300 dsf. Both events occurred during prime crop and recreation seasons. Also, for this evaluation, it was assumed that the initial Grand Lake pool was elevation 870.75 (west bank spillway crest). To limit the Grand Lake pool elevation to a maximum 1-foot rise above west spillway crest would require a total mean daily outflow of approximately 818 cfs and 743 cfs, respectively. These flows would be required through the selected severe inflow periods (mid-May 1943 and early June 1958) disregarding downstream conditions. Any reduced outflow period would proportionately increase the required subsequent discharges to meet a maximum 871.75 pool elevation criteria.

A drainage area proportion ("the portion of Grand Lake drainage area assumed tributary to Beaver Creek is approximately 59 percent of the total") of the previously stated outflows would require west bank outflows of 480 cfs and 440 cfs for the two inflow periods studied. The estimated capacity of the four west bank gates, assumed fully operational, and at pool elevation 870.75 is 450 cfs. Therefore, a combination of fully open gates and spillway flows would be required to pass these proportioned flows.

The "eastern portion of Grand Lake area assumed tributary to St. Marys River is approximately 41 percent of the total." Forty-one percent of the required total outflows (818 cfs and 745 cfs), as previously discussed, equals 333 cfs and 300 cfs for the two periods studied. East bank outflow capacity, without modifications to the retreat channel and St. Marys River is reportedly minimal. Therefore, a suggested Fourmile Creek diversion channel was considered to carry this 41 percent of total inflows as east bank outflows.

DIVERSION CHANNEL

Available mapping is limited to the USGS quadrangle Sheet (St. Marys, Ohio) with a scale of 1"= 2,000' and a contour interval of 5 feet. Selection of a diversion channel route was predicated on a "best fit" to existing topography as presented on Plate E-25. This route connects the Grand Lake pool, through a portion of the Grand Lake State Park area, to the extreme headwater area of Fourmile Creek, near State Route 29. This selected route crosses the drainage divide and has an estimated rim of basin elevation of 904 feet. A stream profile, Plate E-26, presents stream mileage from the mouth of Fourmile Creek and thalweg elevations a. derived from the USGS quadrangle sheet. Also noted is an approximate diversion channel slope used in discharge capacity computations.

Plate E-27 presents water depth vs. discharge curves for four trapezoidal channels. The two bottom widths considered were 10 feet and 15 feet. Side slopes were 1 vertical to 2 or 3 horizontal for each bottom width. From the discharge rating curves a water depth of approximately 4-1/2 feet should be expected for the range of discharge considered and the various channel configurations. A mean water velocity of approximately 2.8 feet per second would be observed. It must be noted that this preliminary investigation does not include modifications to existing bridges, St. Marys River or Fourmile Creek from its mouth to mile 3.75. Also, a gated structure must be added at the Grand Lake origin of this diversion channel for total costing purposes.

MODIFIED EAST EMBANKMENT DISCHARGE CAPACITY

This subject was addressed by Burgess and Niple in their "Grand Lake St. Marys, Miami and Erie Canal, Improvement Study" dated August 1979. The Burgess and Niple studies included discharge rating curves (Plate E-2) for the existing east and west bank spillways in their "Phase 1 Inspection Report, National Dam Safety Program," dated December 1978. Their analysis and proposed improvement to the east spillway appear to be satisfactory to provide the proportional east/west split of spillway discharges. Conduit discharge potential for both the east and west bank was neglected. The west embankment structure contains four gated 30-inch diameter conduits with an estimated total capacity of 450 cfs at pool elevation 870.75 (from Plate E-3). The east embankment structure contains one gated 42-inch diameter conduit with an estimated capacity of 145 cfs at pool elevation 870.75 (Plate E-28). Discharge rating curves were developed from available information and are considered satisfactory for this report. Through inspection of the conduit discharge rating curves, the 41/59 percent proportional discharge split cannot be met for total discharge capacity.

Plate E-29 is a combined conduit plus spillway discharge rating for existing and modified conditions. The existing west embankment discharge rating curve includes four fully open gates plus spillway flow. The existing and modified east embankment discharge capacities are also presented. To satisfy the proportional discharge split, for total outflow capacity, an additional 42-inch conduit or equivalent must be added to the proposed Burgess and Niple east embankment spillway modification. Limited data prohibits retreat channel and St. Marys River channel modifications investigation for an increased discharge capacity.

REDUCTION OF NATURAL LAKE INFLOWS

Grand Lake pool fluctuations are influenced by the rainfall-runoff patterns of each storm, the allowable outflow rates through existing structures or various outflow alternatives and the Grand Lake pool elevation based on seasonal regulation alternatives. The storage volume between Grand Lake pool elevation 870.75 (west bank spillway crest) and elevation 872.83 (the maximum pool of record), is approximately 29,530 acre-feet and is considered as a feasible storage volume for this flood control alternative. Potential inflow retarding basins, one each on the four major tributaries were selected. Damsite locations were based on maximum drainage area controlled and maximum storage available versus structural, residential and topography limitations (Plate E-30).

Damsite "A"" is located on Coldwater Creek approximately 0.35 mile downstream of Siegrest Jutte Road and only a short distance upstream from the corporate limits of Coldwater, Ohio. The damsite drainage area is 9.3 square miles controlling only 48 percent of the Coldwater Creek Basin. Length of the dam would be approximately 0.6 mile with a top of dam elevation of 915 feet.

Damsite "B" is located on Beaver Creek approximately 0.2 mile downstream of Guadalupe Road and approximately 0.5 mile upstream from the corporate limits of Montezuma, Ohio. Drainage area at this damsite is 18.9 square miles or 93 percent of the Beaver Creek Basin tributary to Grand Lake. With a top of dam elevation of 890 feet, the dam would be approximately 0.65 mile in length.

Damsite "C" is located on Chickasaw Creek approximately 0.5 stream mile upstream of Guadalupe Road and no apparent urban development nearby. The damsite drainage area is 15.3 square miles or 83 percent of the Chickasaw Creek Basin. With a top of dam elevation of 900 feet, the dam would be approximately 0.55 mile in length.

Damsite "D" is located on Little Chickasaw Creek approximately 0.4 stream mile upstream from State Route 703 with no apparent urban development nearby. The damsite drainage area is 6.6 square miles or more than 85 percent of the Little Chickasaw Creek Basin. Length of the dam would be approximately 0.3 mile with a top of dam elevation of 890 feet.

Area-capacity and drainage area data are based on USGS quadrangle sheets with a scale of 1" = 2,000' and a contour interval of 5 feet.

Top of dam area and capacities are presented as follows:

	Drainage Area (Sq Mi)	Top of Dam Elevation (Feet msl)	Area (Acres)	Storage Capacity (Acre-Feet)	Storage Capacity (Inches on Drainage Area
Damsite "A"	9.3	915	427	2,500	5.0
Damsite "B"	18.9	890	749	6,340	6.3
Damsite "C"	15.3	900	239	1,360	1.7
Damsite "D"	6.6	890	130	628	1.8
Totals	50.1		1,545	10,828	

The total capacity of 10,828 acre-feet, for the four damsites considered, is lacking approximately 18,700 acre-feet of the selected goal capacity of 29,530 acre-feet for this study. This maximum flood control storage, of 10,828 acre-feet, is limited at each of the four sites by rim of basin elevations. These top of dam capacities, as stated, could not be realized in actual operation because of over-topping and freeboard considerations. Additional locations would only provide a capacity of 300 to 500 acre-feet maximum storage based on topographic limitations.

For this study several basic assumptions were made to determine the reduction of observed peak pool elevation for Grand Lake; first, that a full 10,828 acre-feet is available for flood storage; second, assuming a general basin wide storm pattern producing a sufficient runoff intensity to fill each retarding basin to its capacity regardless of their outflows; third, a starting pool elevation the same as the observed conditions prior to the storm; and fourth, the observed outflows for Grand Lake, for each storm event, up to the time of the observed peak pool elevation. These stated assumptions will, in effect, produce the maximum Grand Lake pool reductions possible. In the following table are historical flood events, in descending order of magnitude, and their computed reductions.

Observed Data		Estimated Modification	
Date	Pool Elevation	Pool Elevation	Reduction in Feet
15 Jan 30	872.83	872.11	0.72
21-22 May 43	872.67	871.94	0.73
25 Apr 72	872.67	871.94	0.73
9-10 Apr 38	872.42	871.67	0.75
7-8 Apr 78	872.17	871.40	0.77

Based on the preliminary pool elevation frequency analysis, the Grand Lake pool elevation of 871.75 (one foot above west bank spillway crest) is equaled or exceeded once every 4 to 5 years. Through the above estimated retarding basin reductions, the modified exceedence interval, for elevation 871.75, would be once every 14 to 16 years.

A dual purpose can be realized through duty as sedimentation ponds. The trap efficiency of a sedimentation pond is increased by a permanent pool having a quiescent zone for the settlement of suspended particulate matter. However, this will further decrease the flood storage capacity of each retarding basin. Negative aspects of sedimentation ponds, with a permanent pool, include high rates of algal growth, displeasing odors and conditions conducive to insect breeding. Additionally, an adverse impact could be realized from a "flushing out" effect by a severe storm and result in a pulse injection of nutrient loaded sediment into Grand Lake. These negative aspects of a dry bed retarding basin would not be of the same magnitude.

A guideline outflow rate of 5 cfs per square mile would total 250 cfs outflow from the four retarding basins. This inflow into Grand Lake plus inflows from the remaining uncontrolled area is considered a substantial west bank outflow rate in order to maintain a stationary lake pool. However, it should be noted that even higher outflows would exist if the pool were allowed to rise to its original elevation. Outflows of greater magnitude would be observed at Damsites "C" and "D" through spillway flows produced by storms having greater than 1.7 inch and 1.8 inch of runoff, respectively.

HYPOTHETICAL EXISTING STREAM PROFILES -- BEAVER CREEK

The discharge-frequency analysis, from preliminary investigations, for the gaging station Greenville Creek near Bradford, Ohio, was selected as most representative of the natural (without Grand Lake) Beaver Creek basin. The Mercer County Engineer's Office provided the existing and proposed modified channel cross-sections. Manning's friction loss coefficients were estimated from topographic maps, aerial photographs and field investigations. With the above discussed input data the HEC-2 computer program was utilized to develop a range of hypothetical stream profiles as presented on Plate E-31. Plate E-31 includes the existing streambed elevation (average slope of 1-foot per mile); the estimated top of low bank elevation (average channel depth of 10 to 12 feet); basic bridge data (stream mile, top of road and low chord); and field tiles (stream mile and outlet invert elevation). These stream profiles representing existing channel conditions, and without Grand Lake contributing, extend from the Indiana state line on the Wabash River up Beaver Creek to the west bank Grand Lake outlet structure.

HYPOTHETICAL EXISTING AND MODIFIED FREQUENCY CURVES

Elevation frequency curves were developed for representative locations at river miles 0.34, 2.67 and 7.50 along Beaver Creek (Plates E-32, E-33 and D-34). Curve "A" presents the existing Beaver Creek conditions, without Grand Lake contributing. Curve "A_1" combines existing Beaver Creek conditions with coincident flood flows, of equal exceedance frequency from the Grand Lake west bank spillway. Curves "C" and "D" are the results of additional HEC-2 computer runs representing channel modifications similar to the Mercer County Engineer's Office proposal (Curve "B"). Their proposal is basically a removal of undesirable vegetation, trees and tree stumps with a minimum of channel excavation. Also, comparative data were developed to reflect various Grand Lake re-regulation schemes in combination with Beaver Creek channel modifications.

SECTION E

PLATES

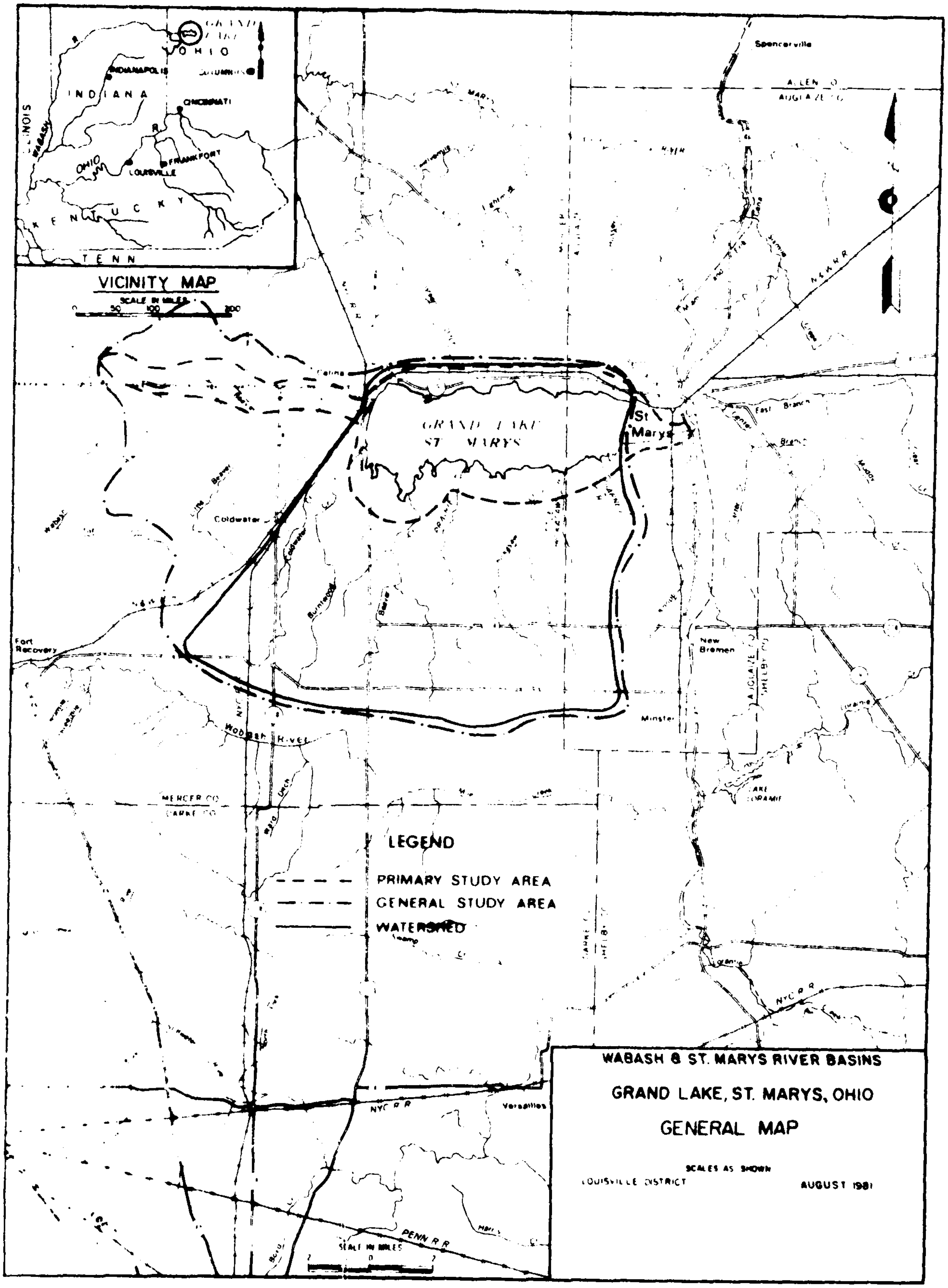
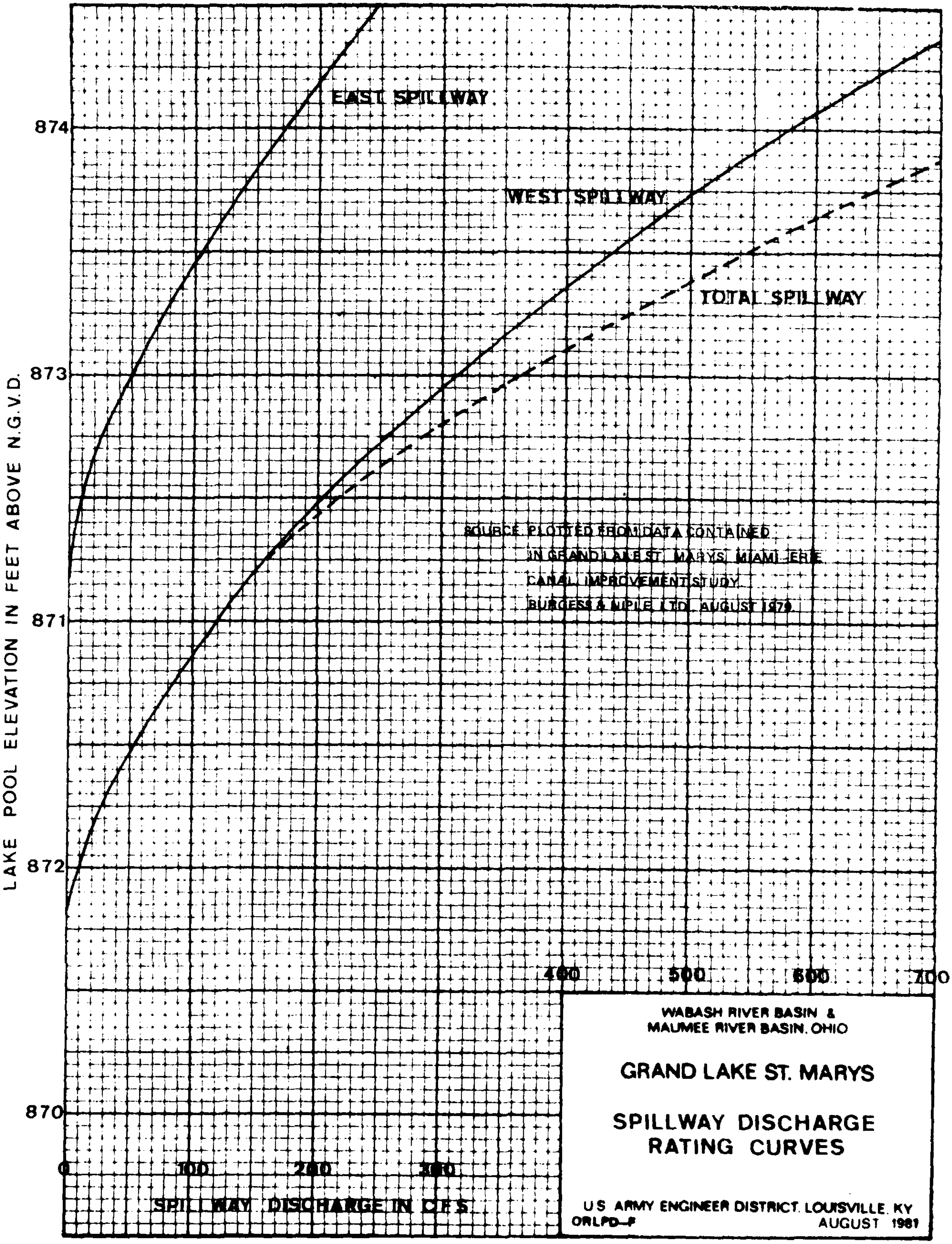

VICINITY MAP
SCALE IN MILES
0 50 100 200
OHIO
INDIANA
INDIANAPOLIS
CINCINNATI
FRANKFORT
LOUISVILLE
KENTUCKY
TENN
GRAND LAKE ST. MARYS
St Marys
Celina
Coldwater
Fort Recovery
New Bremen
Minster
Versailles
Spencerville
Wabash River
MERCER CO
DARKE CO
NYC R R
PENN R R
LEGEND
PRIMARY STUDY AREA
GENERAL STUDY AREA
WATERSHED
WABASH & ST. MARYS RIVER BASINS
GRAND LAKE, ST. MARYS, OHIO
GENERAL MAP
SCALES AS SHOWN
LOUISVILLE DISTRICT
AUGUST 1981
SCALE IN MILES

PLATE E-1



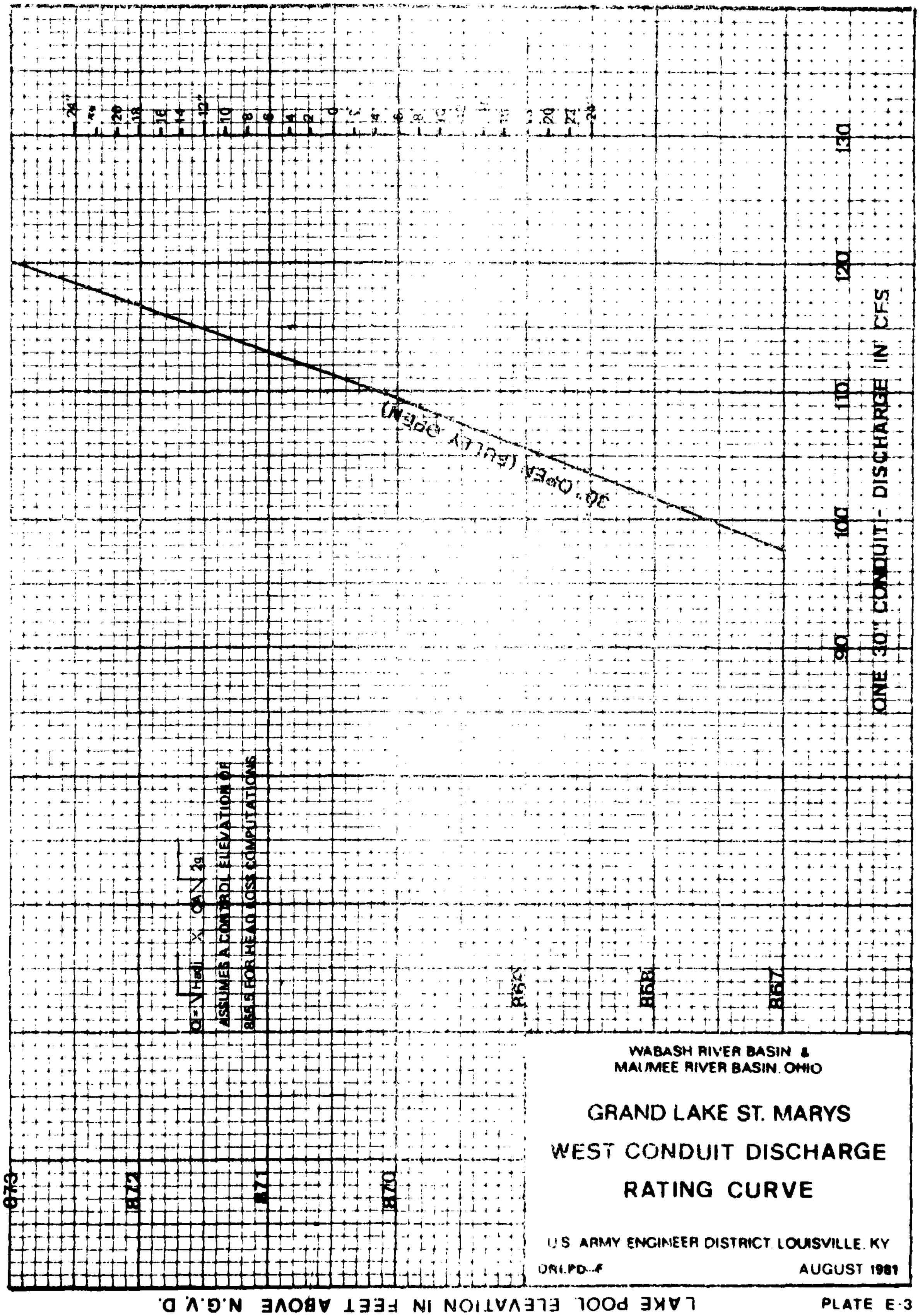
WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

SPILLWAY DISCHARGE
RATING CURVES

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY
ORLPD-F AUGUST 1981

PLATE E-2

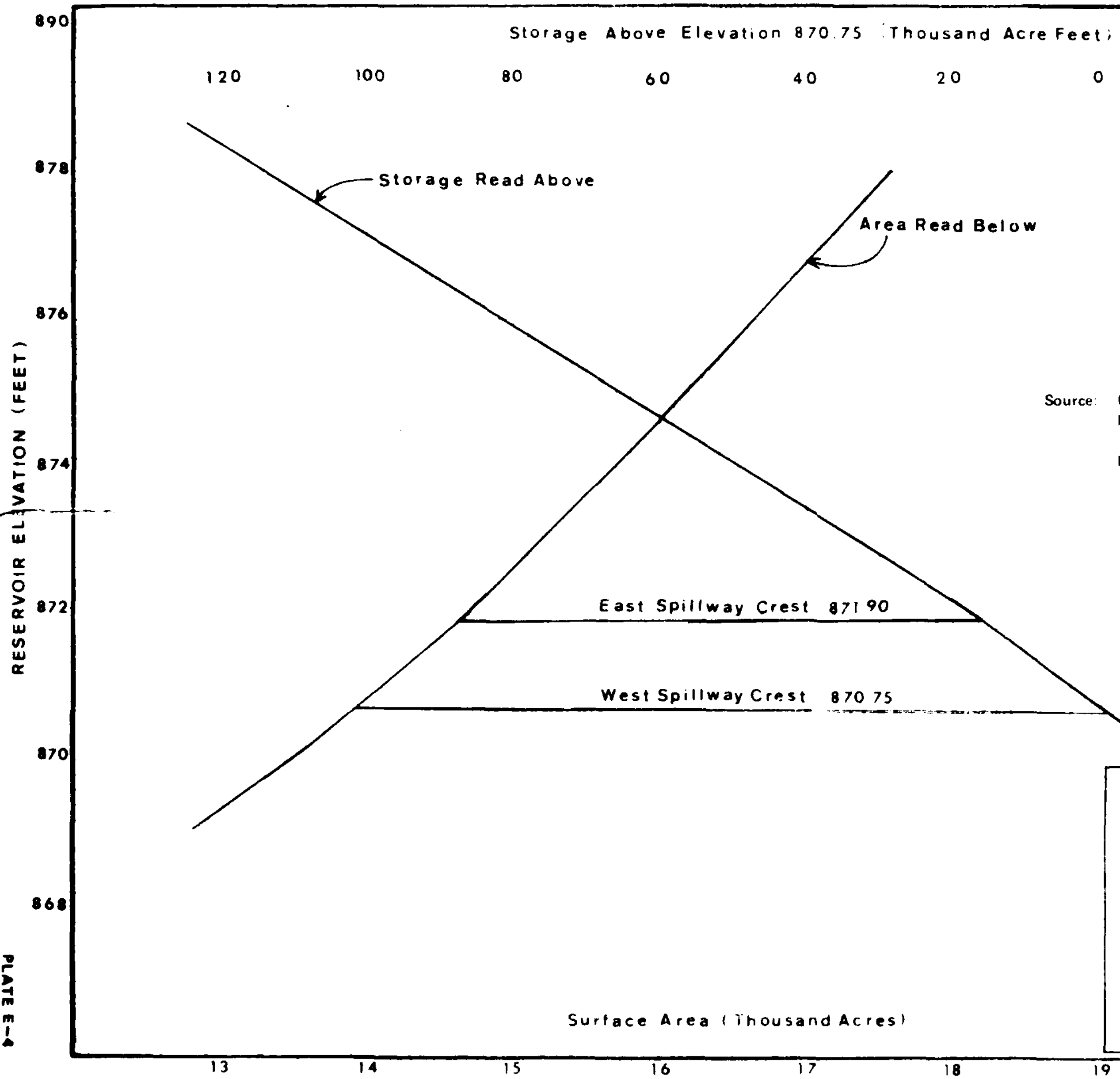


WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS
WEST CONDUIT DISCHARGE
RATING CURVE

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY

ORLPD-F AUGUST 1981



Source: U. S. Army Engineer District, Pittsburgh, Phase 1 Inspection Report: Grand Lake St. Marys, National Dam Safety Program, Prepared by Burgess & Niple, Ltd. (Dec. 1978)

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

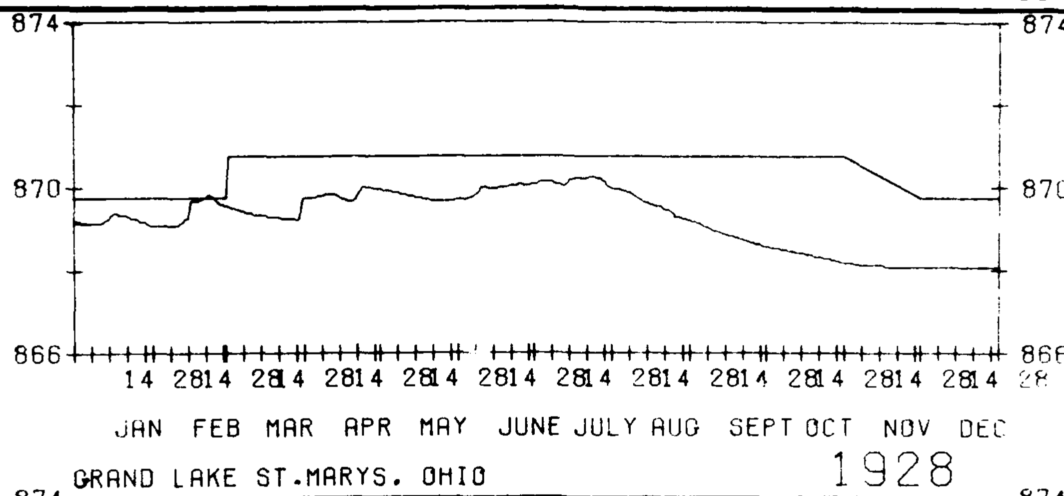
AREA-CAPACITY CURVES

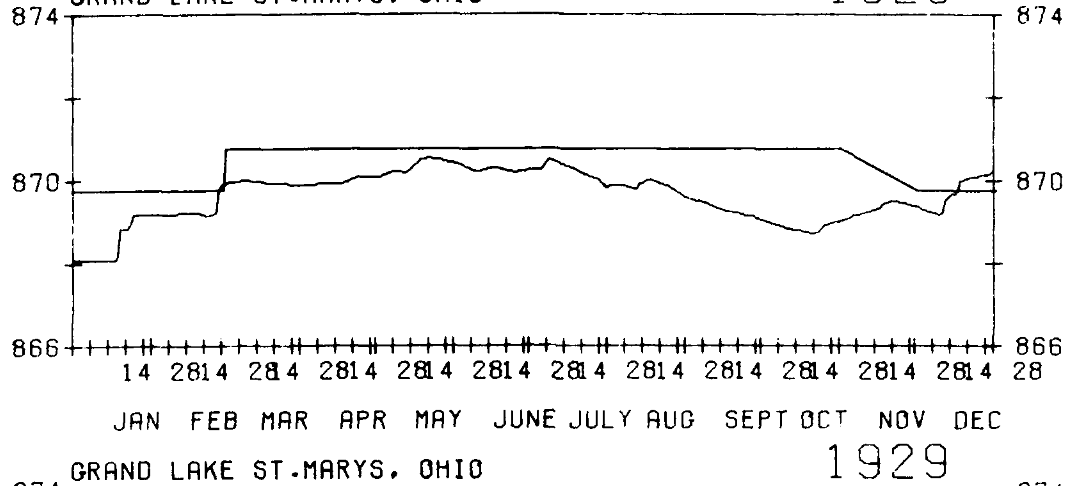
SCALES AS SHOWN

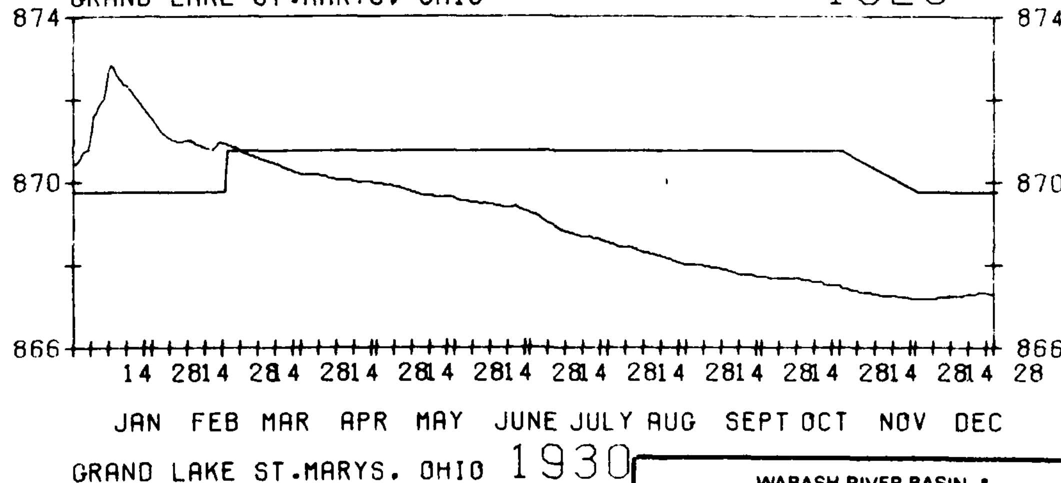
US ARMY ENGINEER DISTRICT, LOUISVILLE KY
ORLPD-F AUGUST 1981

CORPS OF ENGINEERS U. S. ARMY

CORPS OF ENGINEERS US ARMY







WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

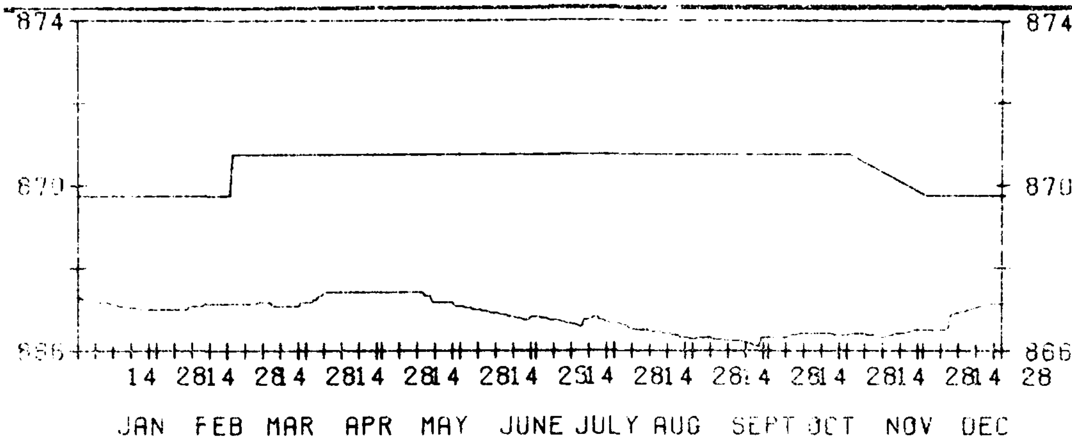
GRAND LAKE ST. MARYS

POOL HYDROGRAPHS

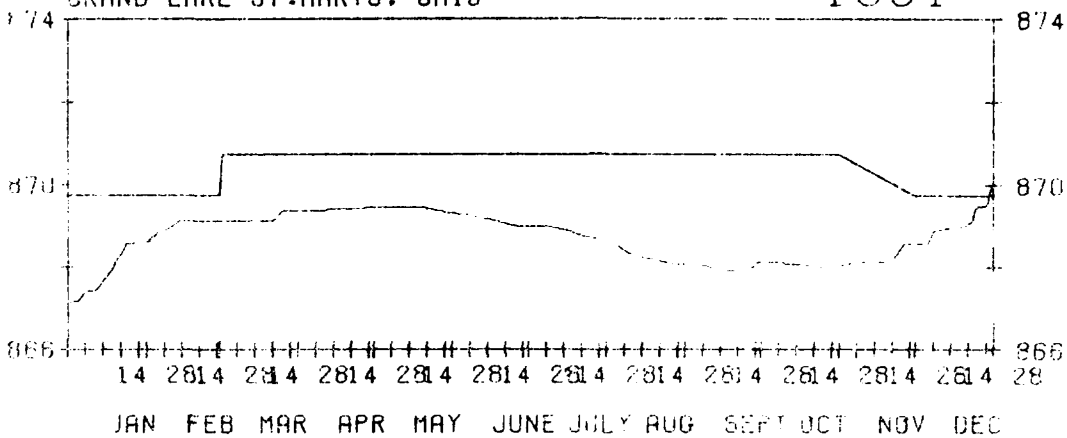
SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLED-H AUGUST 1981

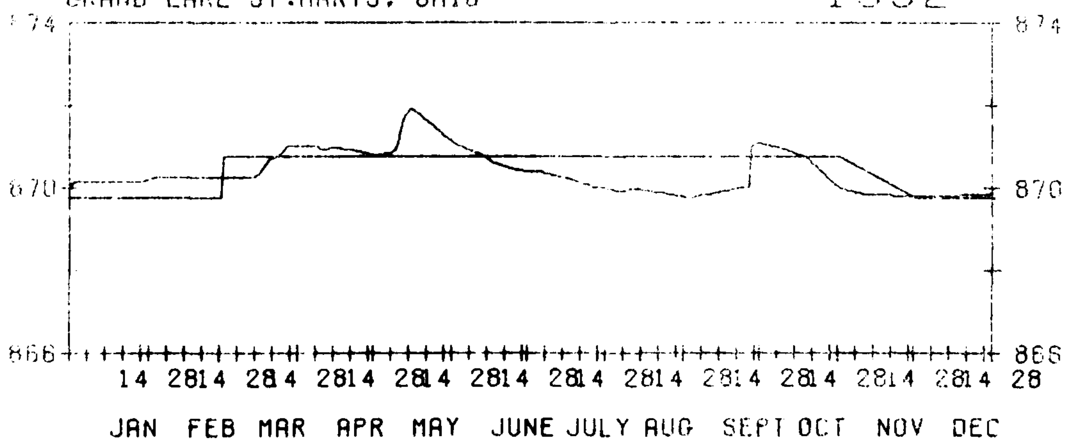
PLATE E-5



GRAND LAKE ST.MARYS. OHIO 1931



GRAND LAKE ST.MARYS. OHIO 1932



GRAND LAKE ST.MARYS. OHIO 1933

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

POOL HYDROGRAPHS

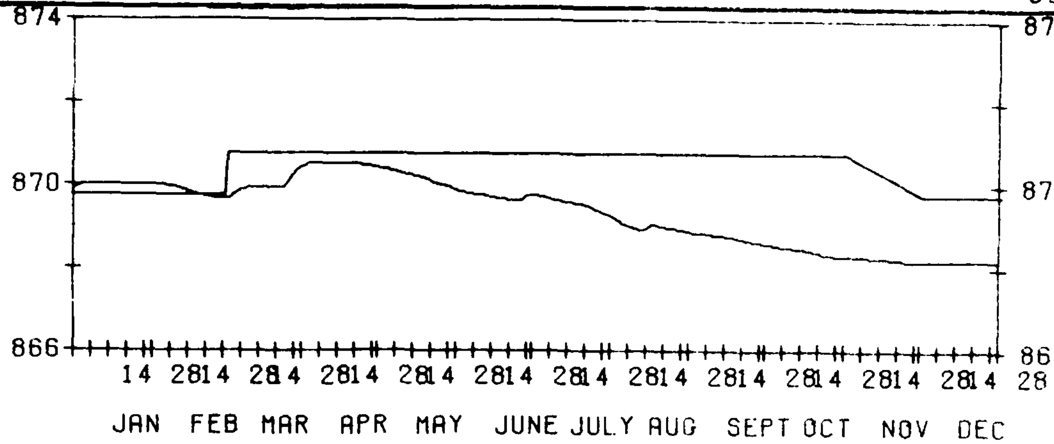
SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT LOUISVILLE, KY
ORLED-H AUGUST 1981

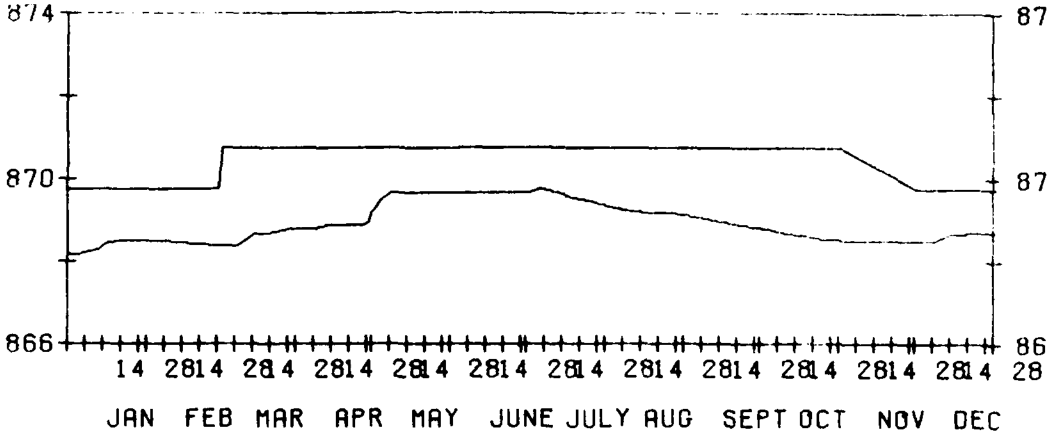
PLATE E-6

CORPS OF ENGINEERS

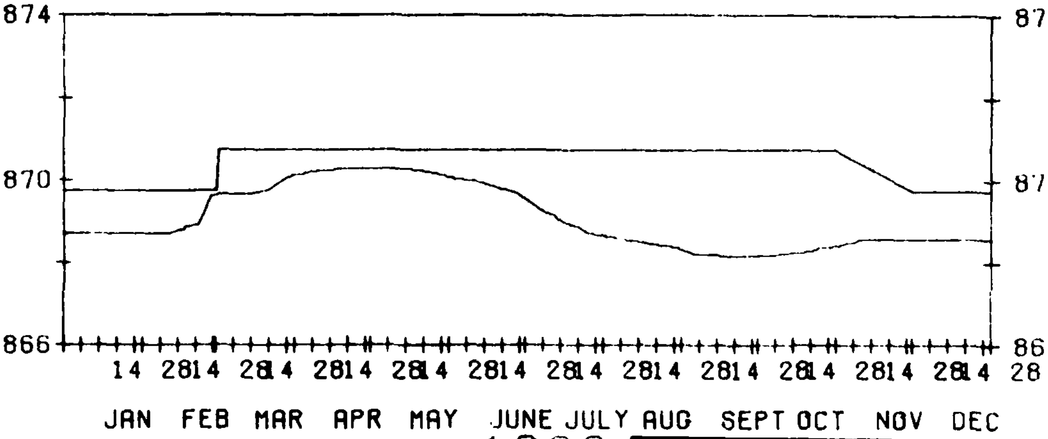
U.S. ARMY



GRAND LAKE ST.MARYS, OHIO 1934



GRAND LAKE ST.MARYS, OHIO 1935



GRAND LAKE ST.MARYS, OHIO 1936

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

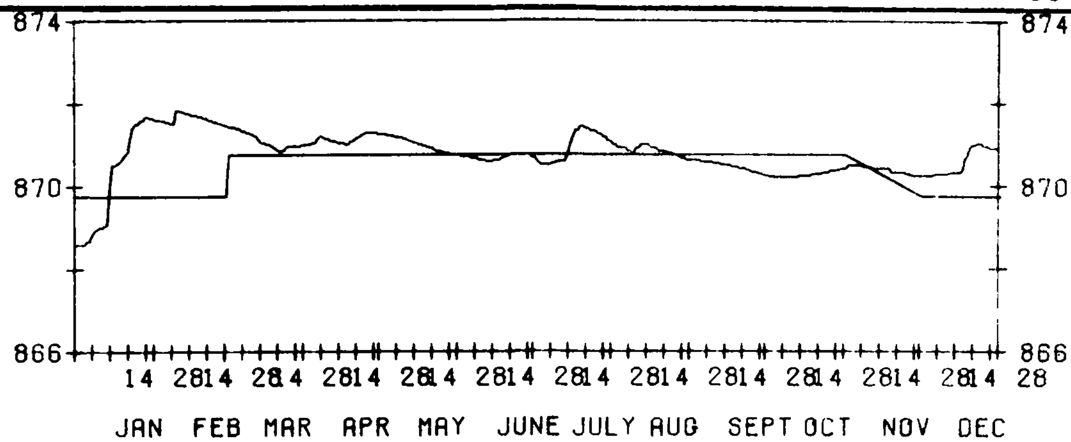
POOL HYDROGRAPHS

SCALES AS SHOWN

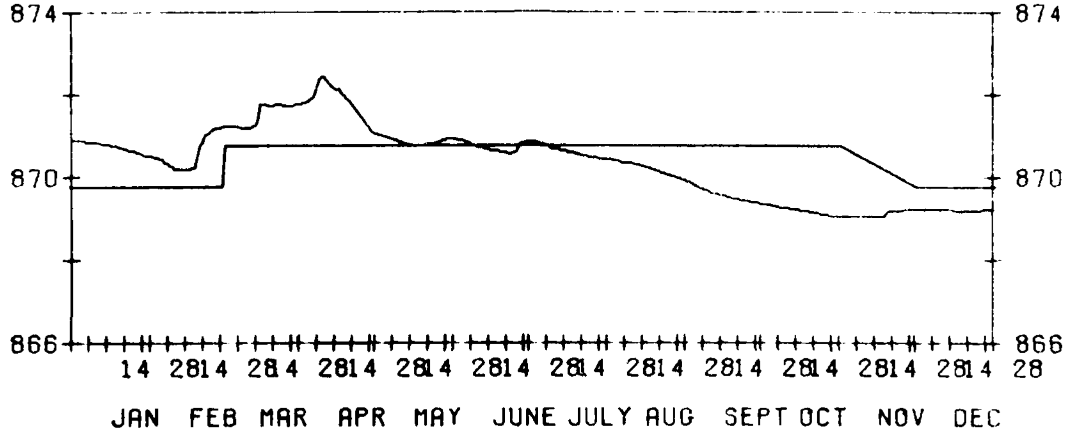
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY
ORLED-H AUGUST 1981

PLATE E-7

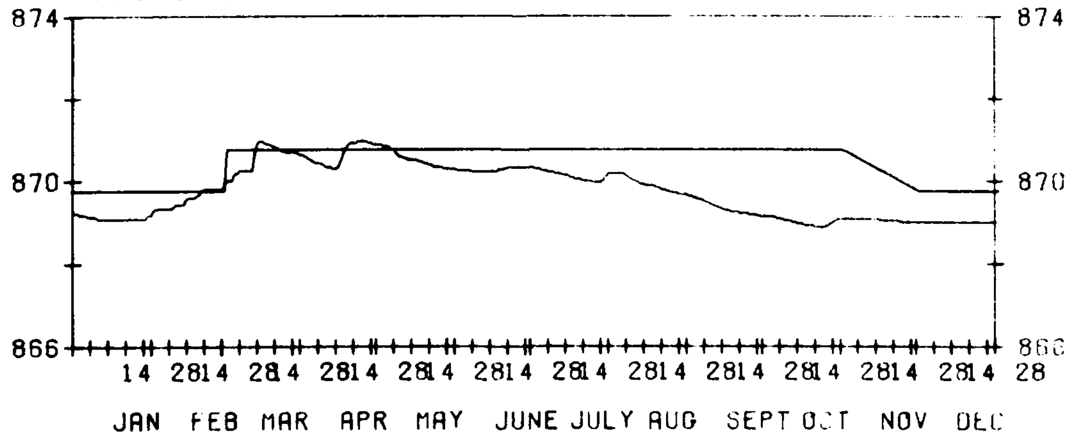
CORPS OF ENGINEERS U S ARMY



GRAND LAKE ST.MARYS. OHIO 1937



GRAND LAKE ST.MARYS. OHIO 1938



GRAND LAKE ST.MARYS. OHIO 1939

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

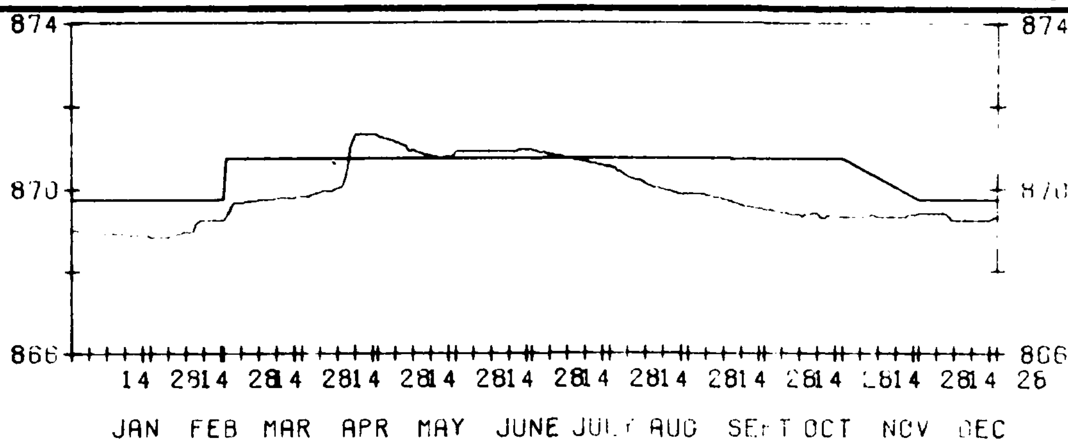
POOL HYDROGRAPHS

SCALES AS SHOWN

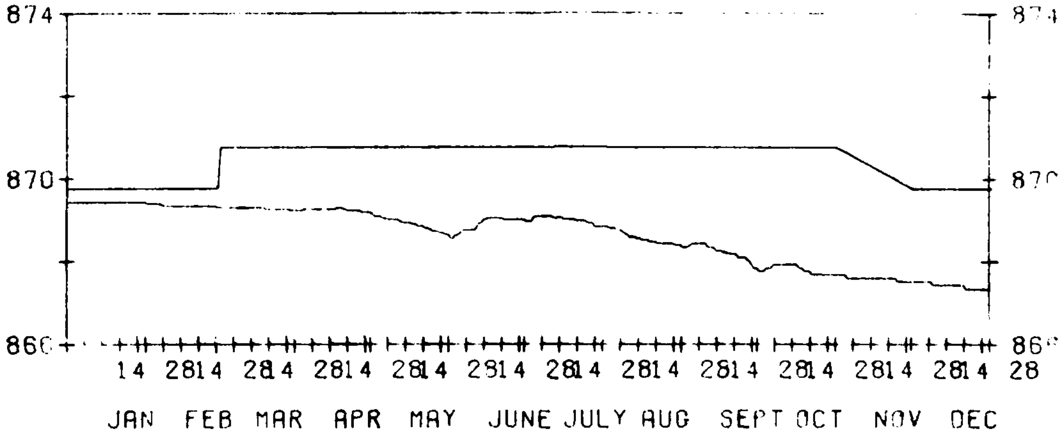
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY
ORLED-H AUGUST 1981

PLATE E-8

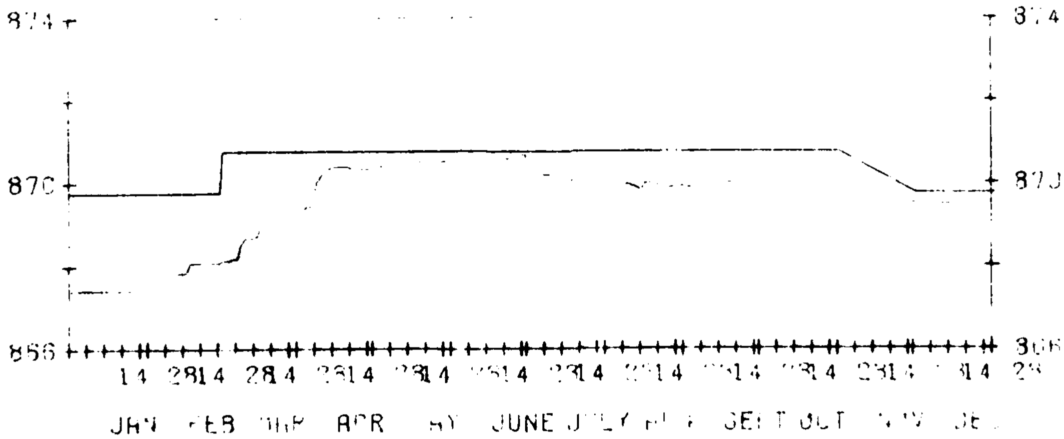
CORPS OF ENGINEERS U.S. ARMY



GRAND LAKE ST.MARYS. OHIO 1940



GRAND LAKE ST.MARYS. OHIO 1941



GRAND LAKE ST.MARYS. OHIO 1942

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

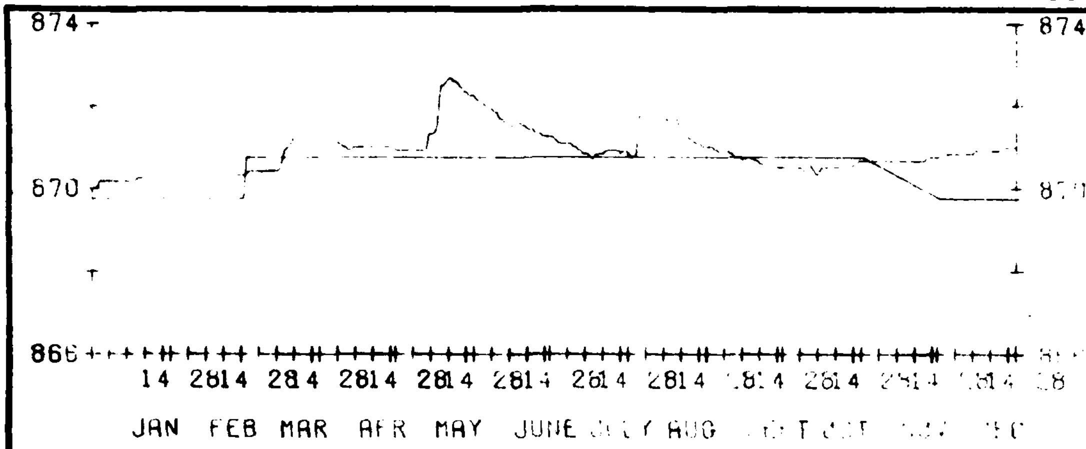
POOL HYDROGRAPHS

SCALES AS SHOWN

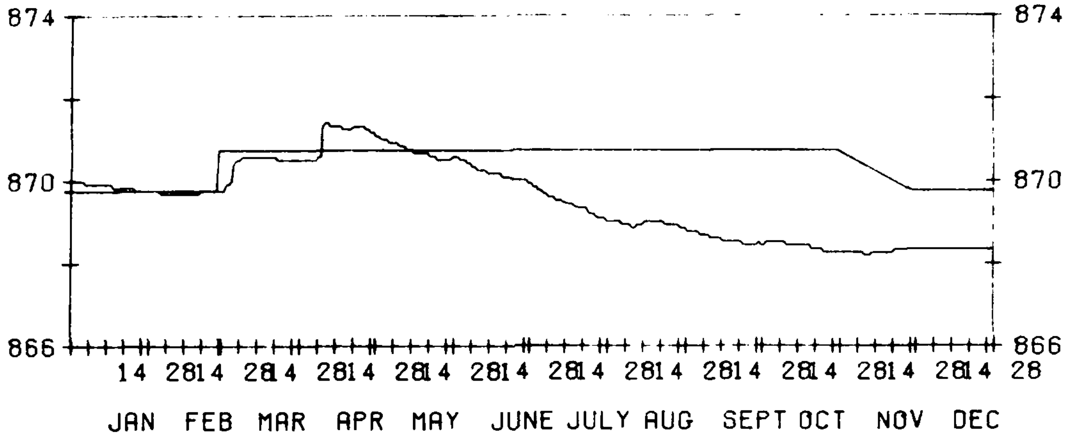
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLED-H AUGUST 1981

PLATE E-9

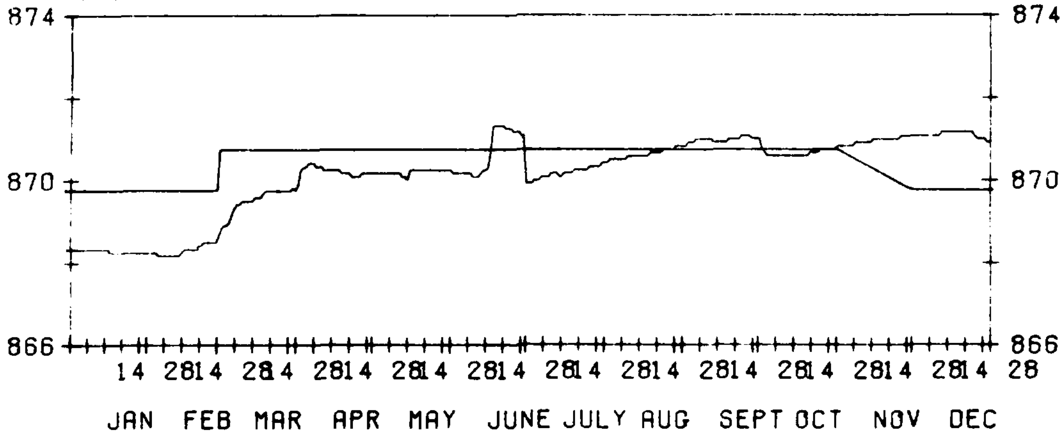
CORPS OF ENGINEERS U.S. ARMY



GRAND LAKE ST.MARYS, OHIO 1943



GRAND LAKE ST.MARYS, OHIO 1944



GRAND LAKE ST.MARYS, OHIO 1945

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

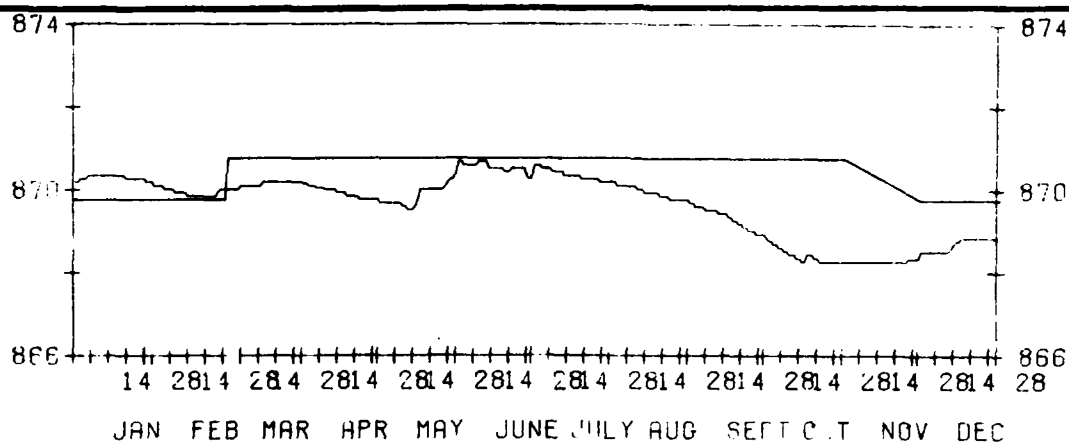
POOL HYDROGRAPHS

SCALES AS SHOWN

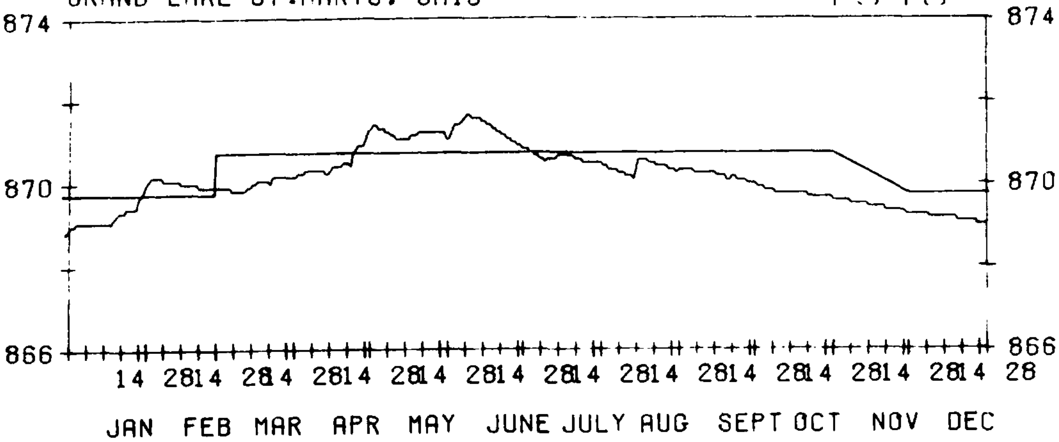
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY
ORLED-H AUGUST 1981

PLATE E-10

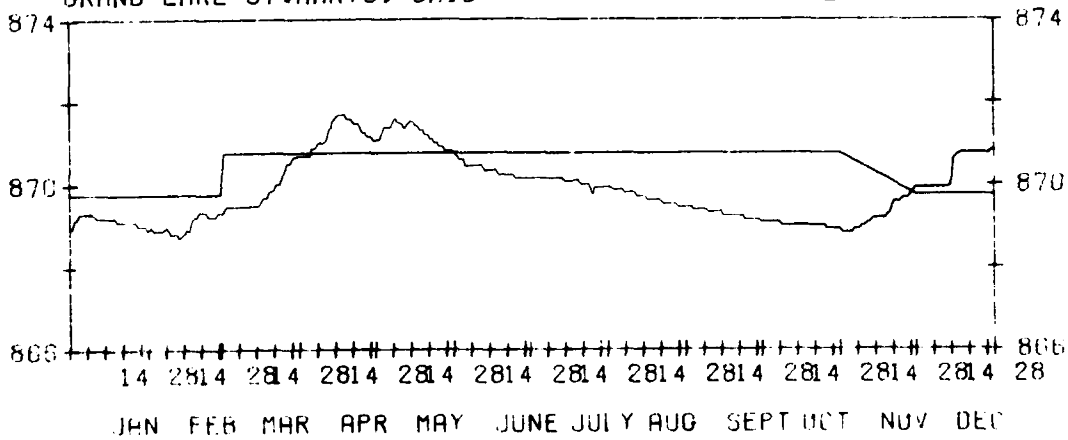
CORPS OF ENGINEERS U.S. ARMY



GRAND LAKE ST.MARYS, OHIO 1946



GRAND LAKE ST.MARYS, OHIO 1947



GRAND LAKE ST.MARYS, OHIO 1948

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

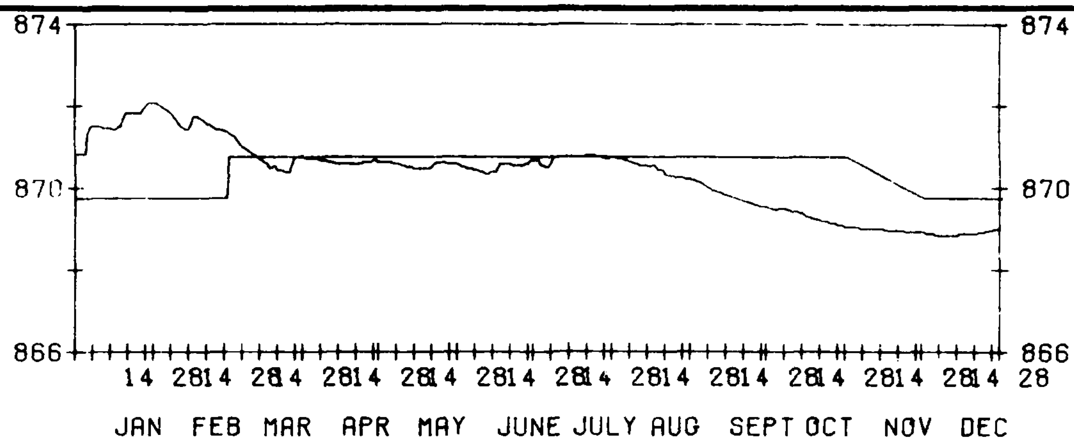
GRAND LAKE ST. MARYS

POOL HYDROGRAPHS

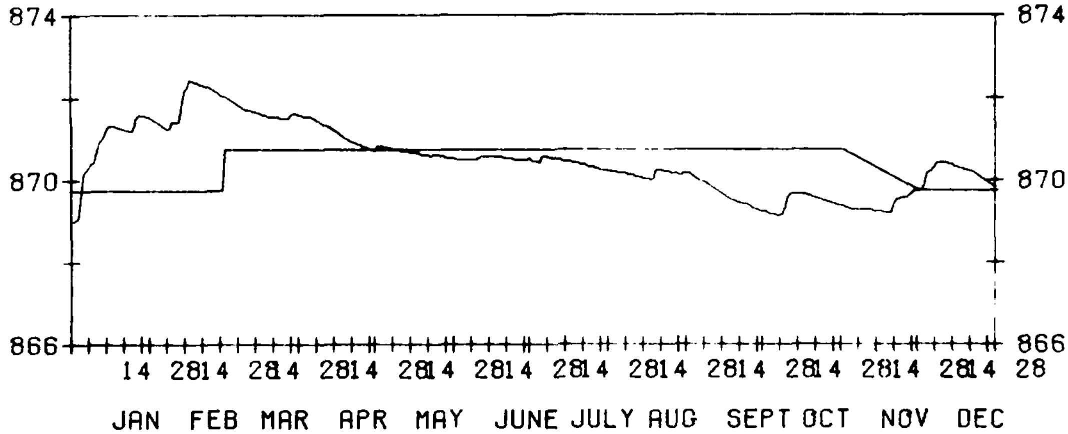
SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLED-H AUGUST 1981

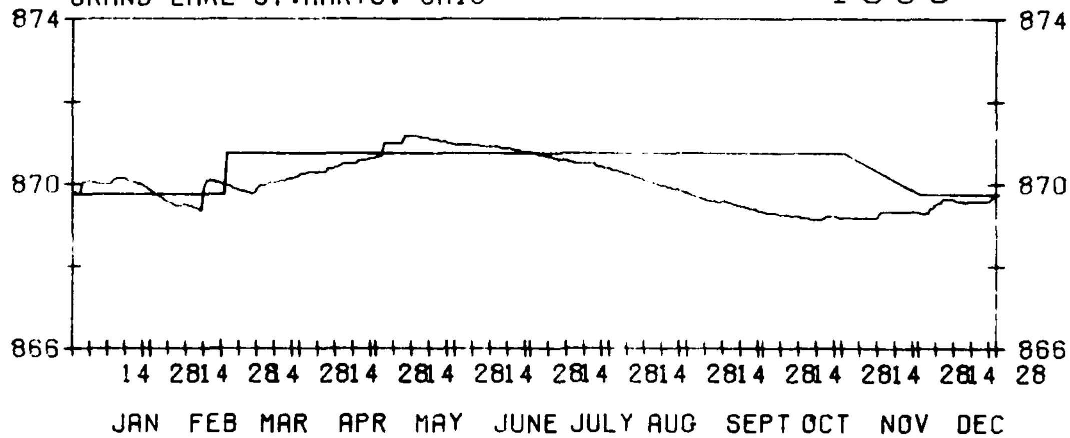
PLATE E-11



GRAND LAKE ST.MARYS. OHIO 1949



GRAND LAKE ST.MARYS. OHIO 1950



GRAND LAKE ST.MARYS. OHIO 1951

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

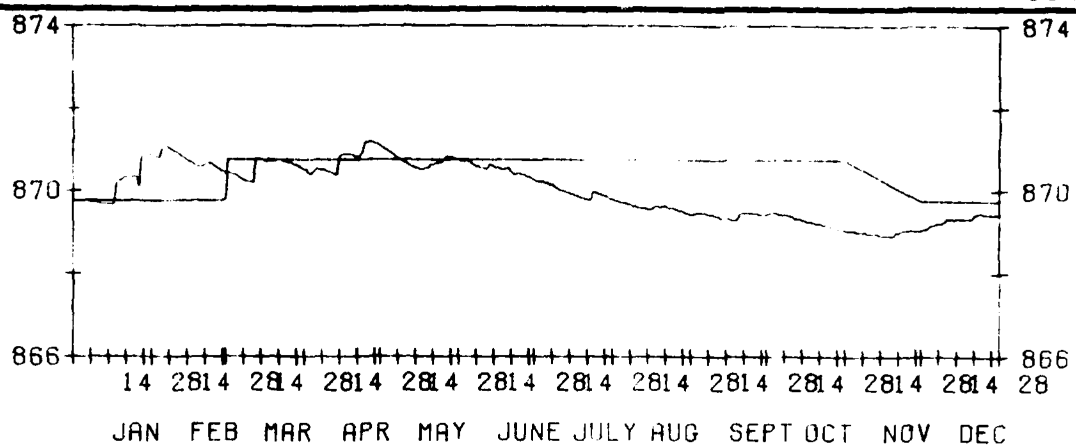
GRAND LAKE ST. MARYS

POOL HYDROGRAPHS

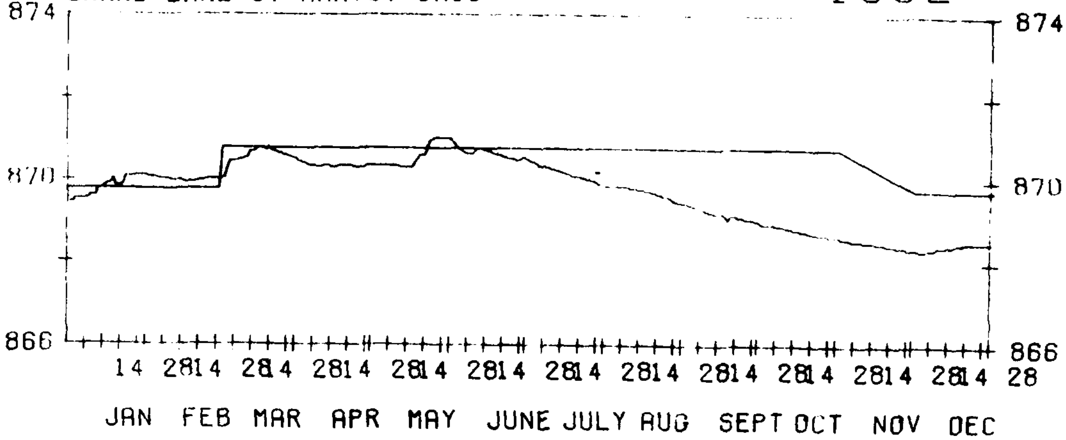
SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLED-H AUGUST 1981

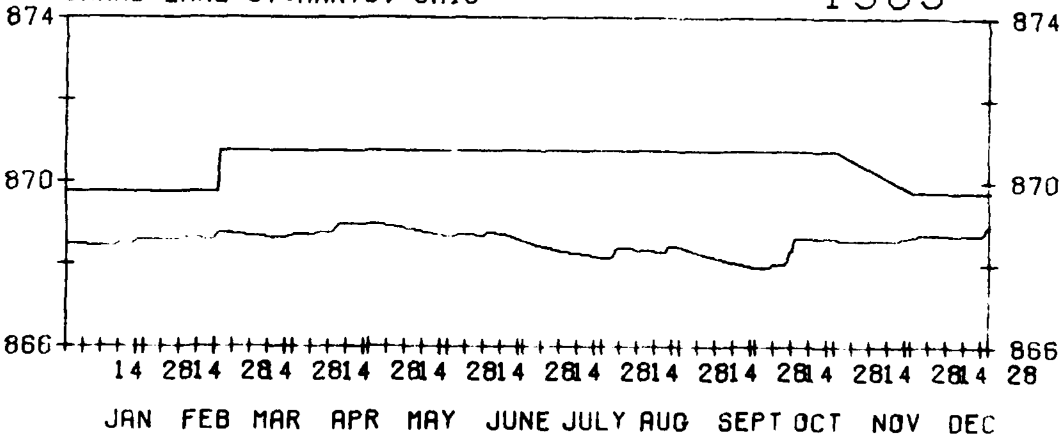
CORPS OF ENGINEERS U.S. ARMY



GRAND LAKE ST.MARYS, OHIO 1952



GRAND LAKE ST.MARYS, OHIO 1953



GRAND LAKE ST.MARYS, OHIO 1954

WABASH RIVER BASIN & MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

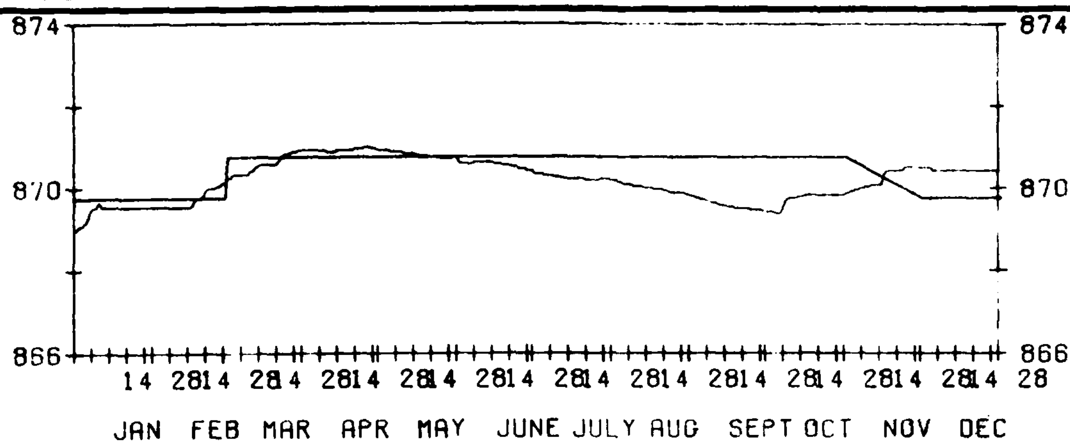
POOL HYDROGRAPHS

SCALES AS SHOWN

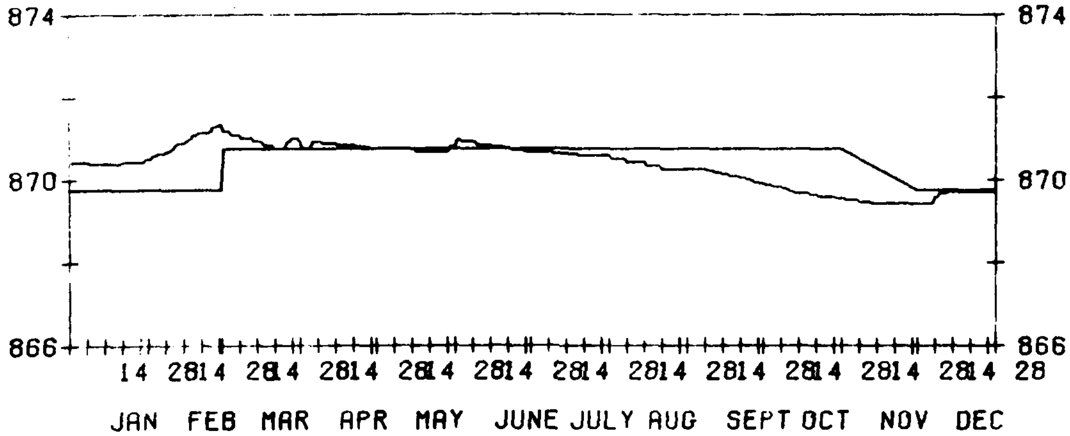
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLED-H AUGUST 1981

PLATE E-13

CORPS OF ENGINEERS U.S. ARMY



GRAND LAKE ST.MARYS, OHIO 1955



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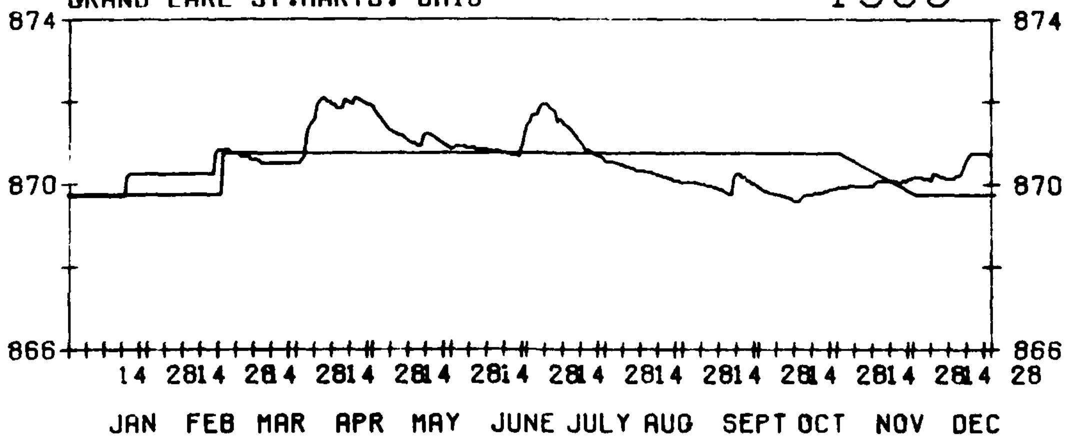


GRAND LAKE ST.MARYS. OHIO 1957

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

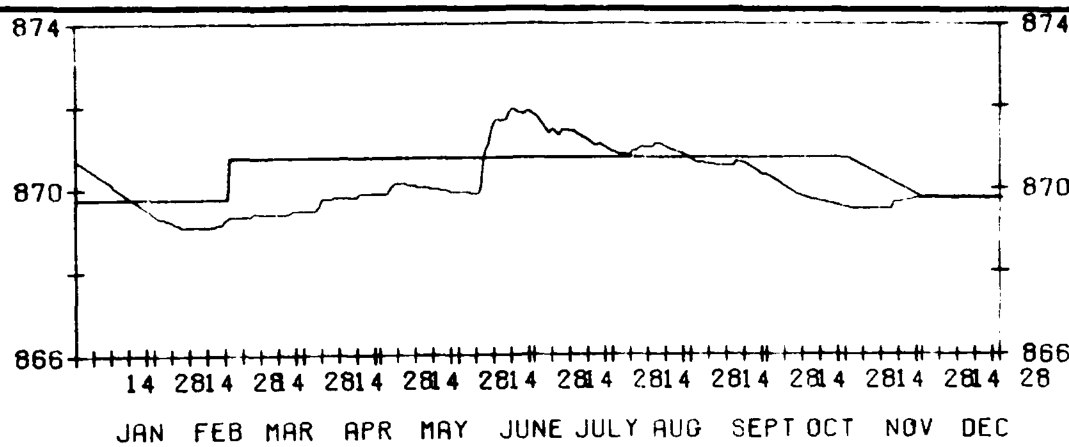
GRAND LAKE ST. MARYS

POOL HYDROGRAPHS

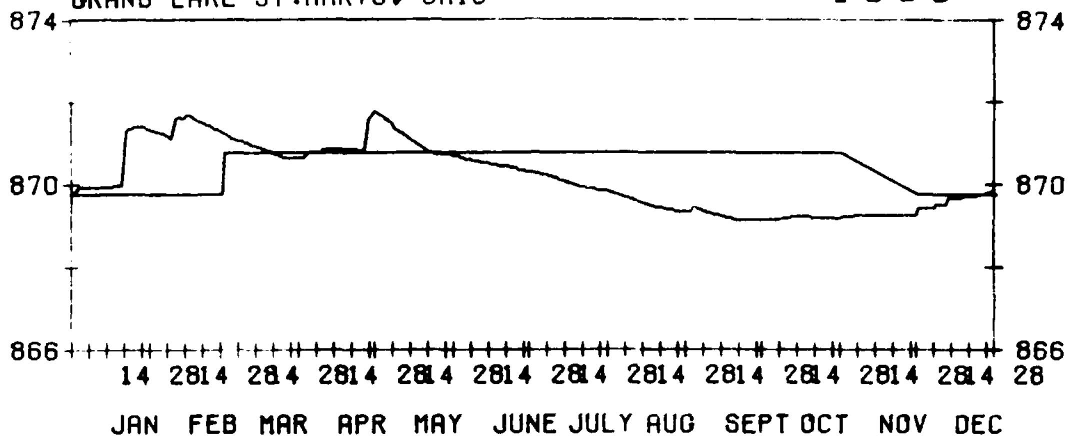
SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLED-H AUGUST 1981

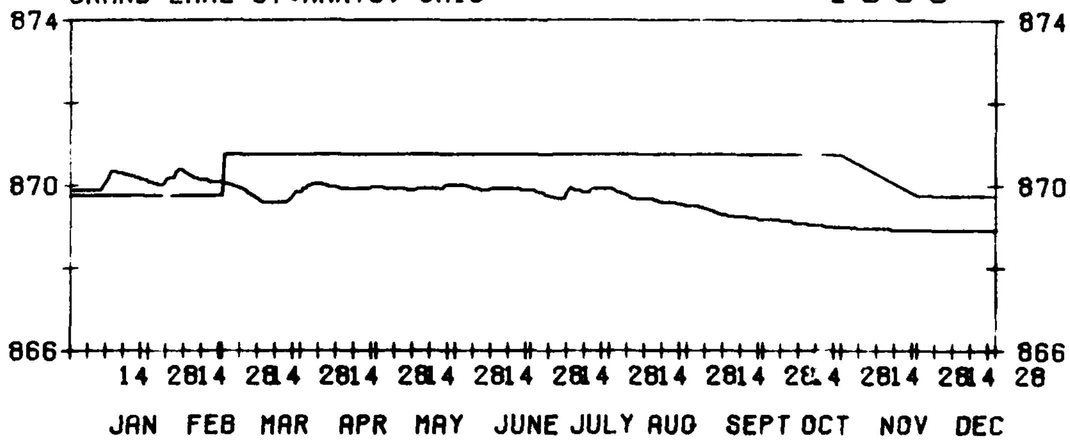
CORPS OF ENGINEERS U.S. ARMY



GRAND LAKE ST.MARYS, OHIO 1958



GRAND LAKE ST.MARYS. OHIO 1959



GRAND LAKE ST.MARYS. OHIO 1960

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

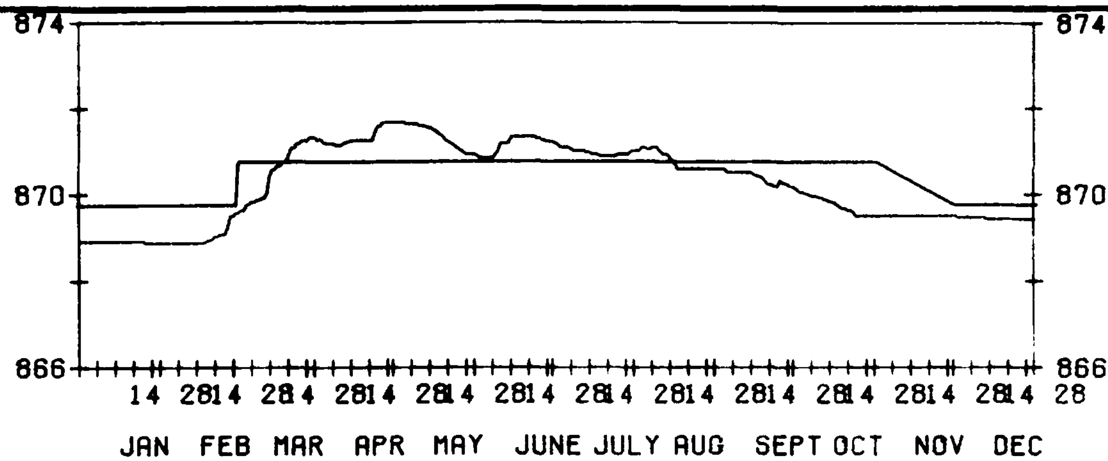
POOL HYDROGRAPHS

SCALES AS SHOWN

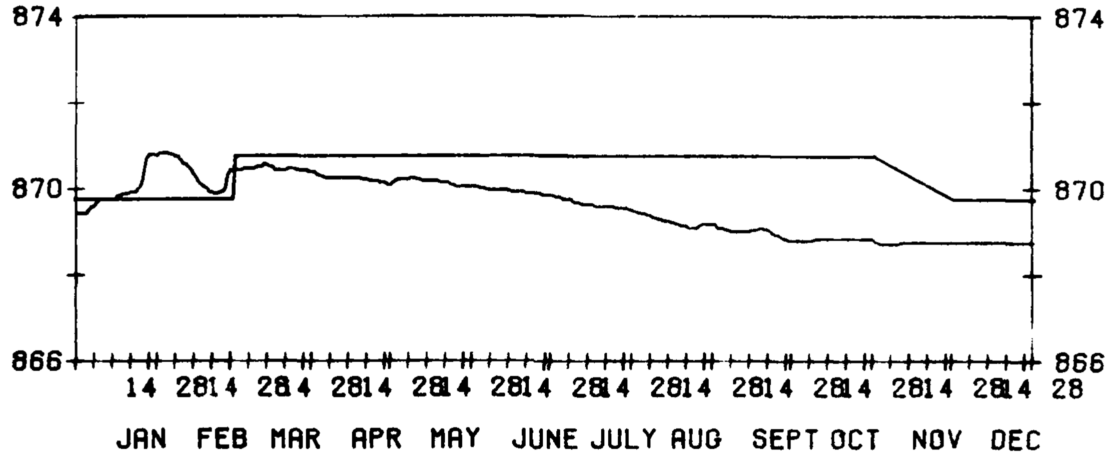
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLED-H AUGUST 1981

PLATE E-15

CORPS OF ENGINEERS U.S. ARMY



GRAND LAKE ST.MARYS, OHIO 1961



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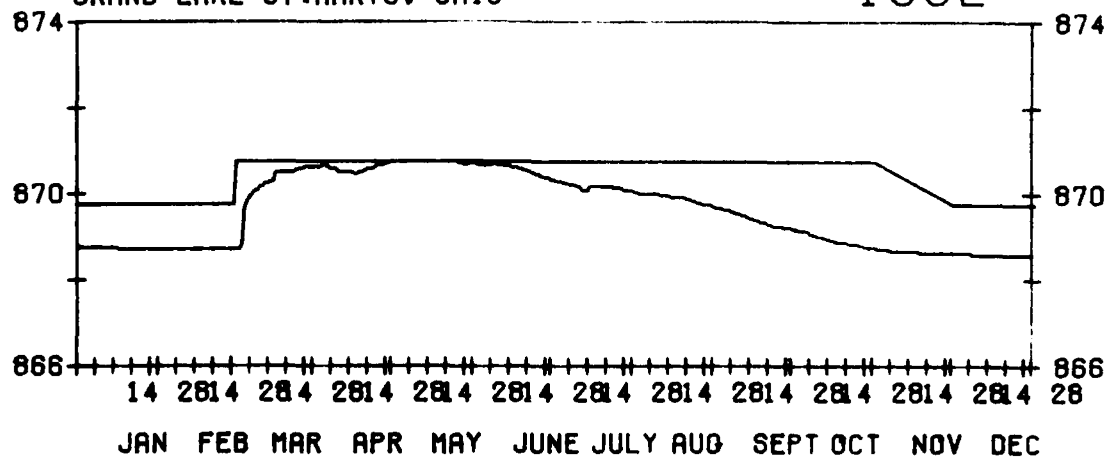


GRAND LAKE ST.MARYS, OHIO 1963

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

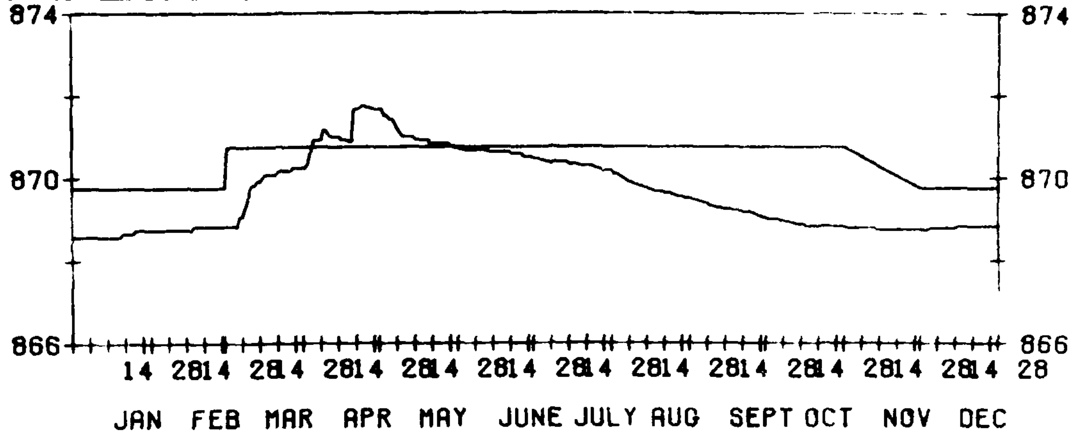
GRAND LAKE ST. MARYS

POOL HYDROGRAPHS

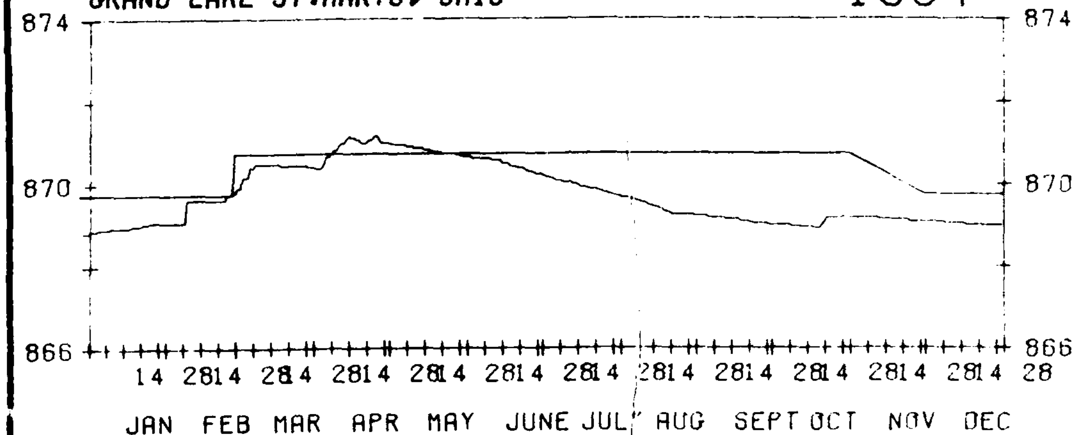
SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
ORLED-H AUGUST 1981

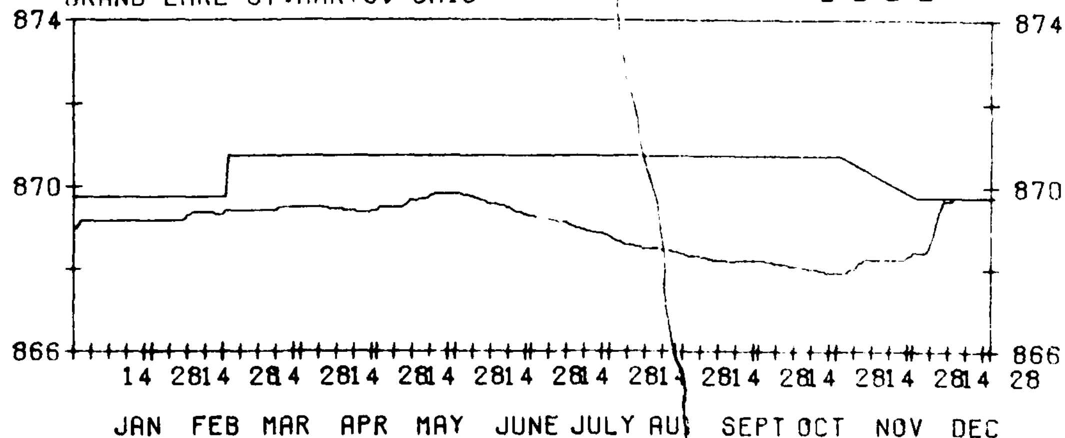
PLATE E-16



GRAND LAKE ST.MARYS, OHIO 1964



GRAND LAKE ST.MARYS, OHIO 1965



GRAND LAKE ST.MARYS, OHIO 1966

WABASH RIVER BASIN & MAUMEE RIVER BASIN, OHIO

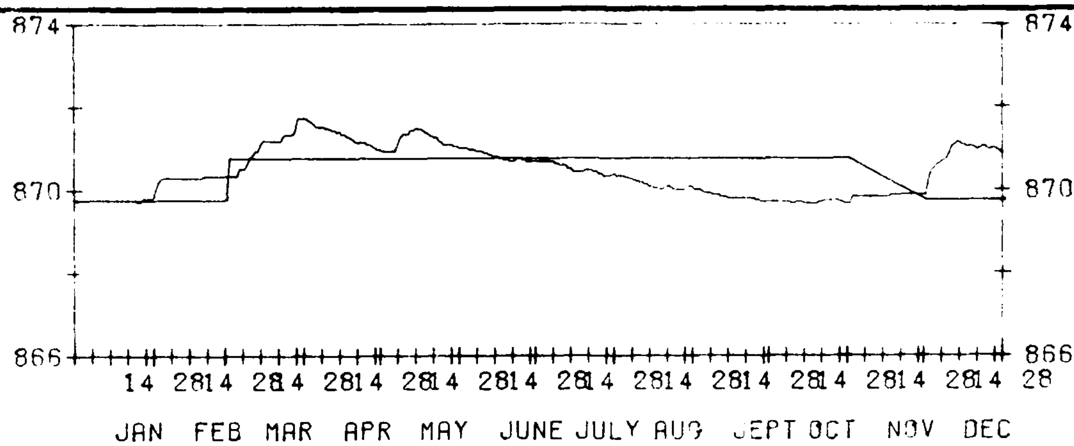
GRAND LAKE ST. MARYS

POOL HYDROGRAPHS

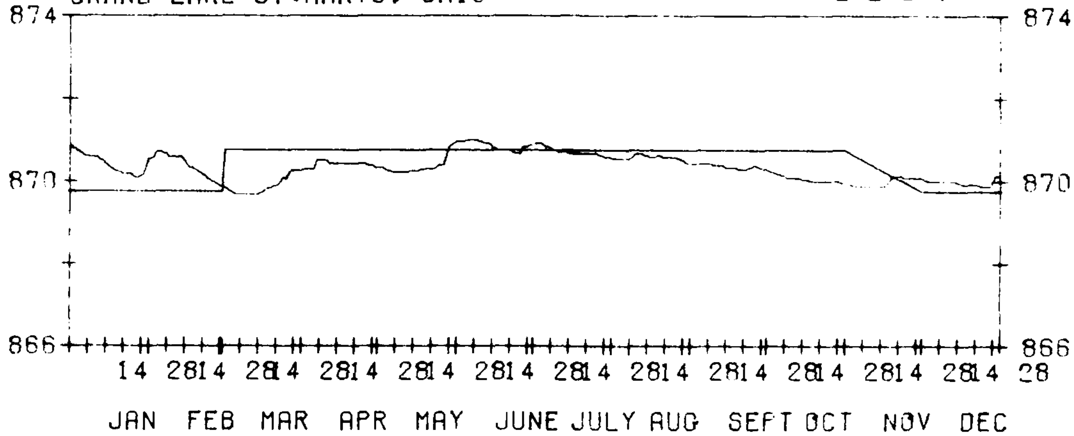
SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY.
OR ED-H AUGUST 1981

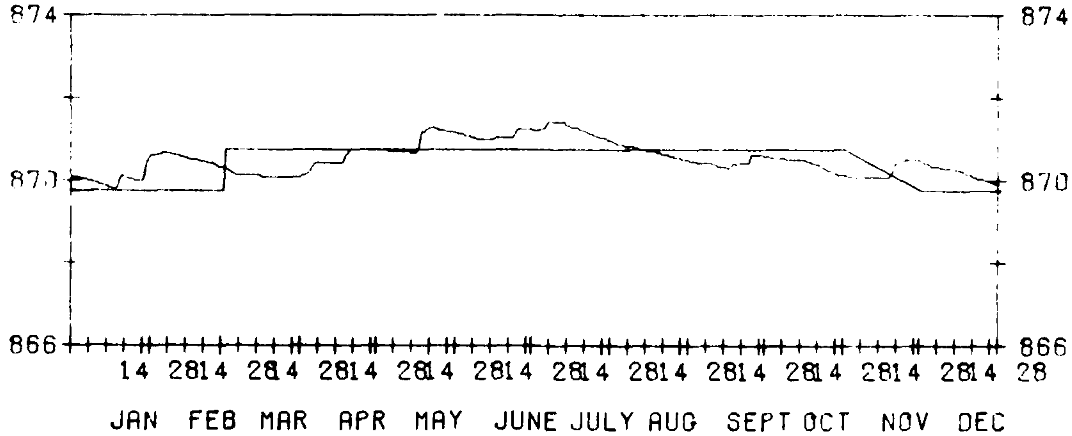
CORPS OF ENGINEERS — US ARMY



GRAND LAKE ST.MARYS, OHIO 1967



GRAND LAKE ST.MARYS, OHIO 1968



GRAND LAKE ST.MARYS, OHIO 1969

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

POOL HYDROGRAPHS

SCALES AS SHOWN

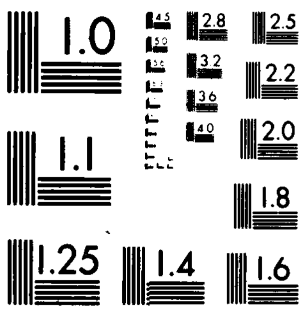
U.S. ARMY ENGINEER DISTRICT LOUISVILLE, KY
ORLED-H AUGUST 1981

PLATE E-18

AD-A112 109 ARMY ENGINEER DISTRICT LOUISVILLE KY F/G 13/2
GRAND LAKE SAINT MARYS, OHIO. SURVEY REPORT FOR FLOOD CONTROL A--ETC(U)
AUG 81

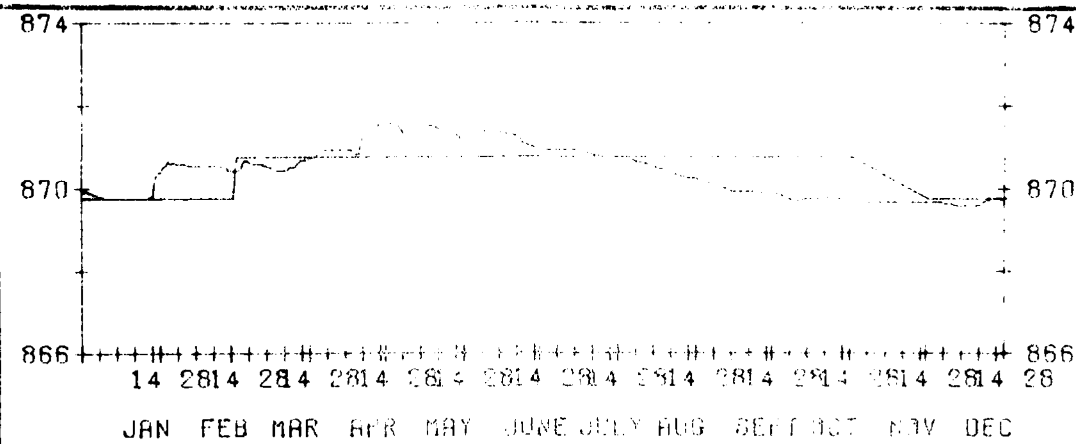
UNCLASSIFIED NL

5 of 6

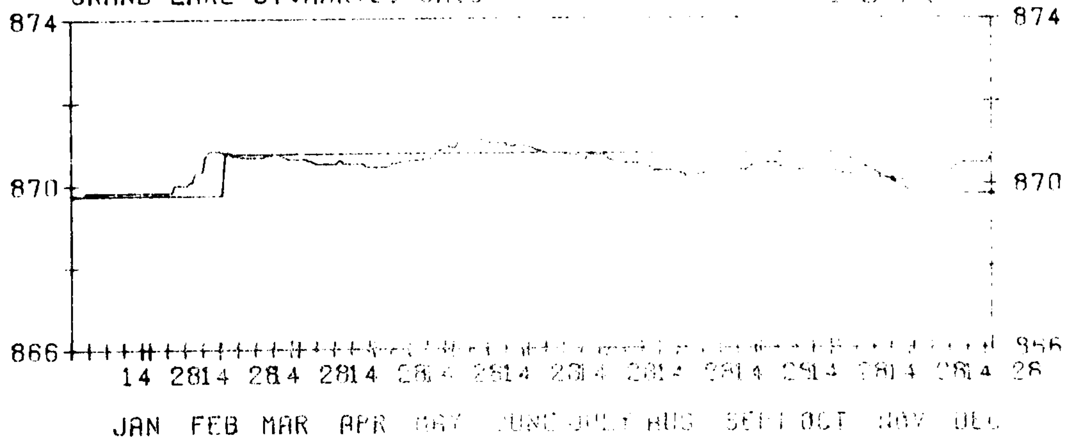


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

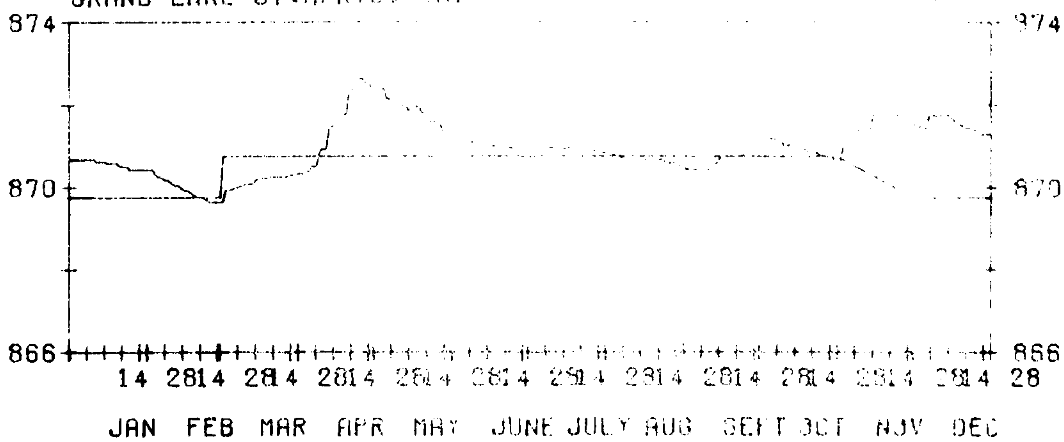
CORPS OF ENGINEERS U.S. ARMY



GRAND LAKE ST.MARYS, OHIO 1970



GRAND LAKE ST.MARYS, OHIO 1971



GRAND LAKE ST.MARYS, OHIO 1972

WABASH RIVER BASIN &
MAUMEE RIVER BASIN OHIO

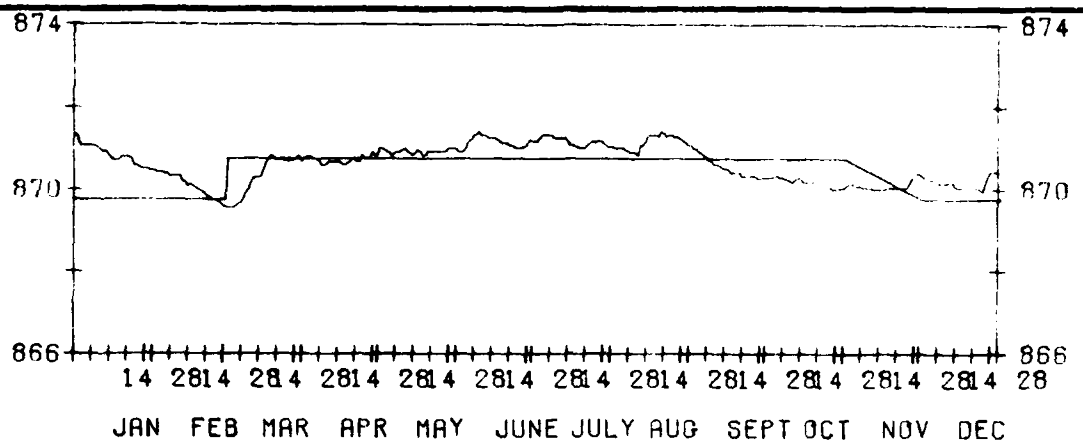
GRAND LAKE ST. MARYS

POOL HYDROGRAPHS

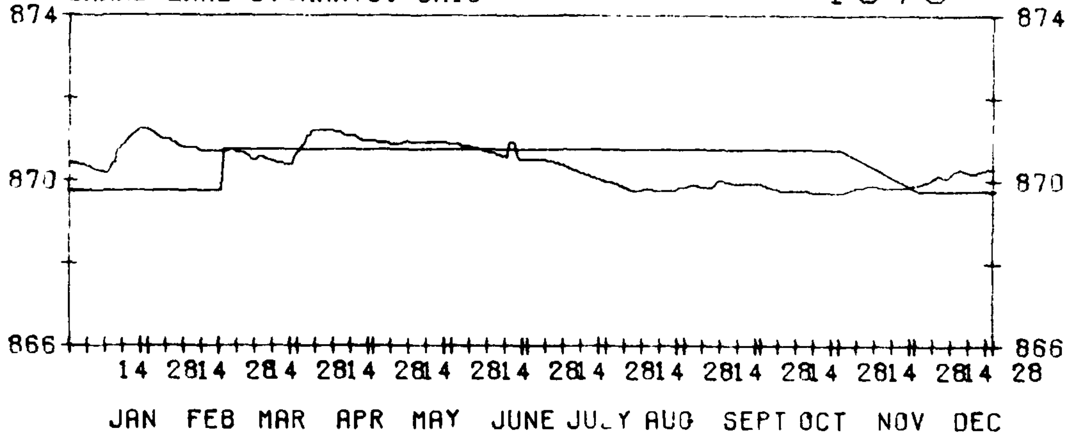
SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT LOUISVILLE, KY.
ORLED-H AUGUST 1981

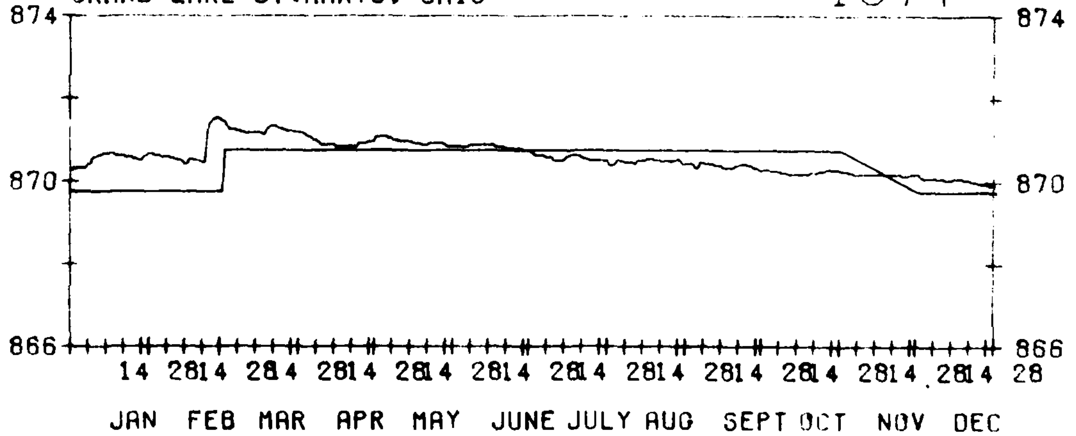
PLATE E-19



GRAND LAKE ST.MARYS. OHIO 1973



GRAND LAKE ST.MARYS. OHIO 1974



GRAND LAKE ST.MARYS. OHIO 1975

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

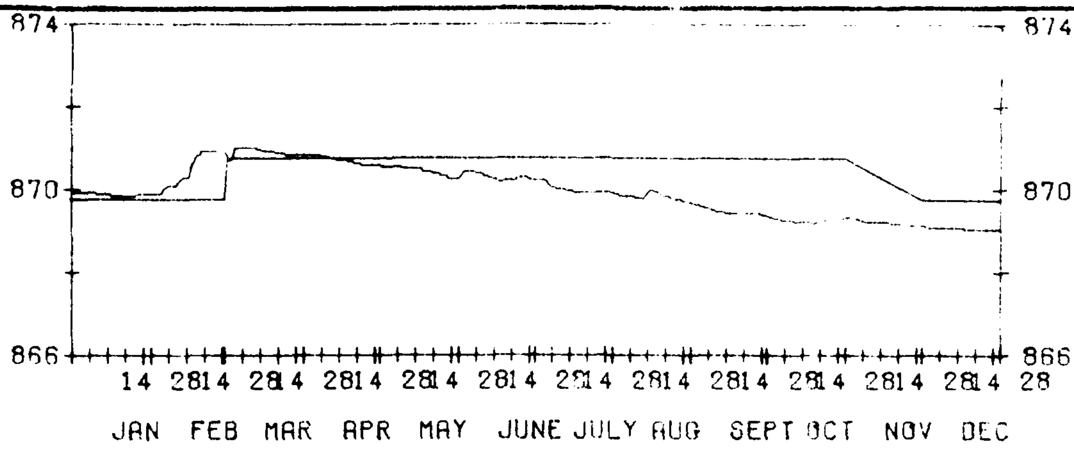
GRAND LAKE ST. MARYS

POOL HYDROGRAPHS

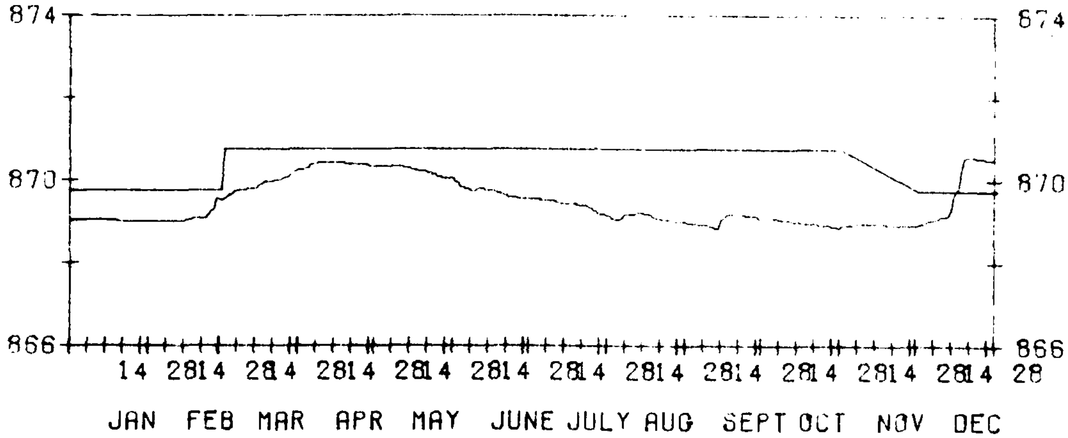
SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY
ORLED-H AUGUST 1981

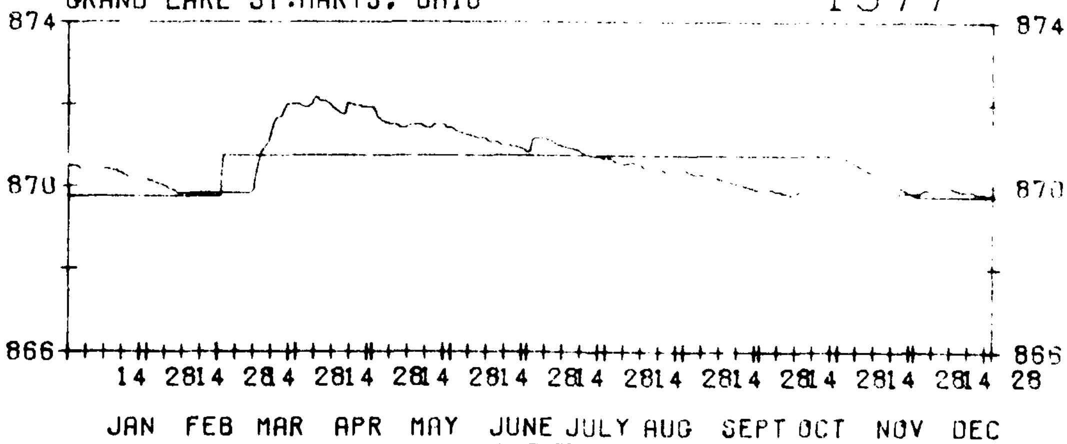
CORPS OF ENGINEERS U S ARMY



GRAND LAKE ST.MARYS, OHIO 1976



GRAND LAKE ST.MARYS, OHIO 1977



GRAND LAKE ST.MARYS, OHIO 1978

WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

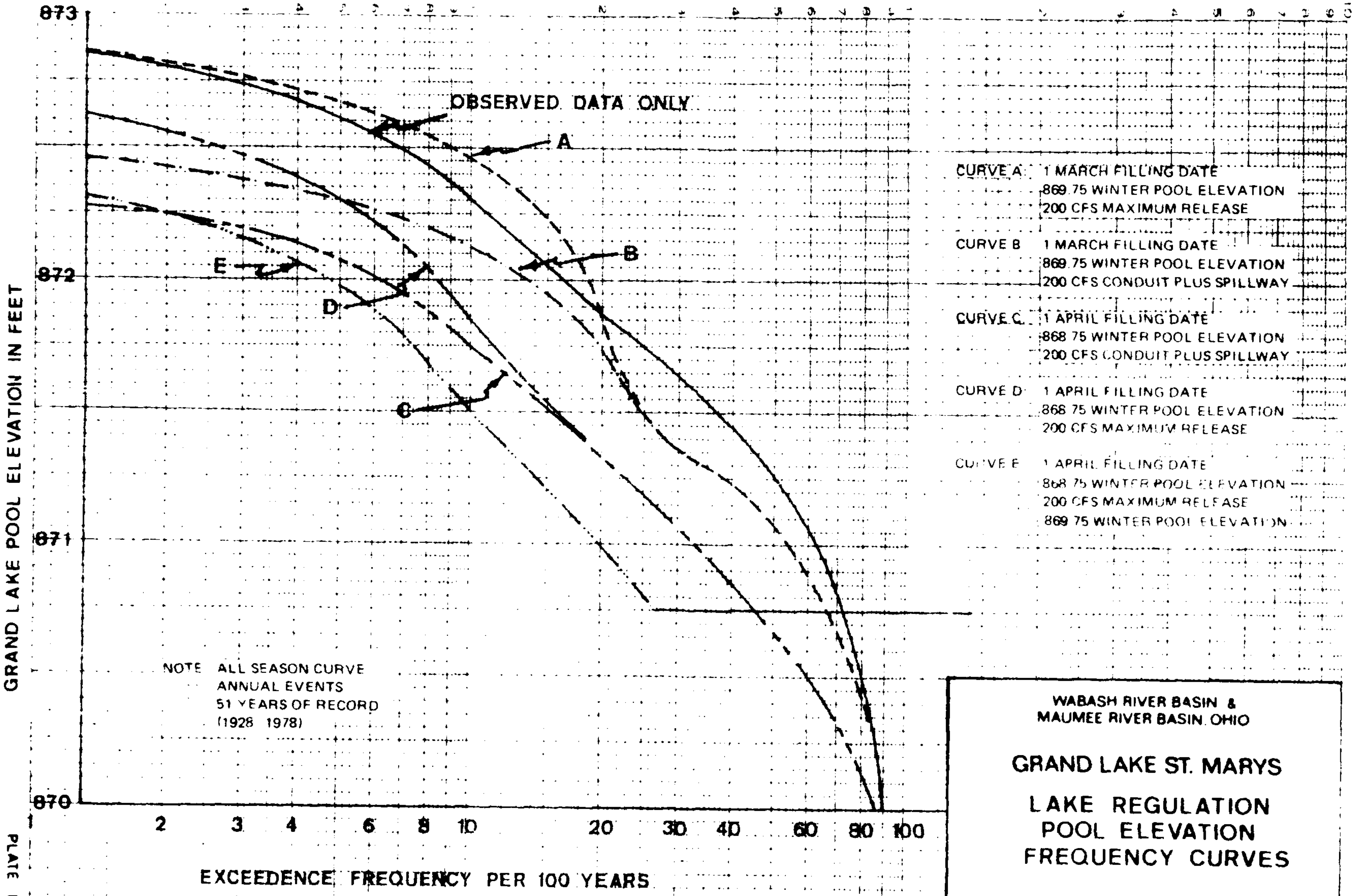
GRAND LAKE ST. MARYS

POOL HYDROGRAPHS

SCALES AS SHOWN

U S ARMY ENGINEER DISTRICT, LOUISVILLE, KY
ORLED-H AUGUST 1981

PLATE E-21



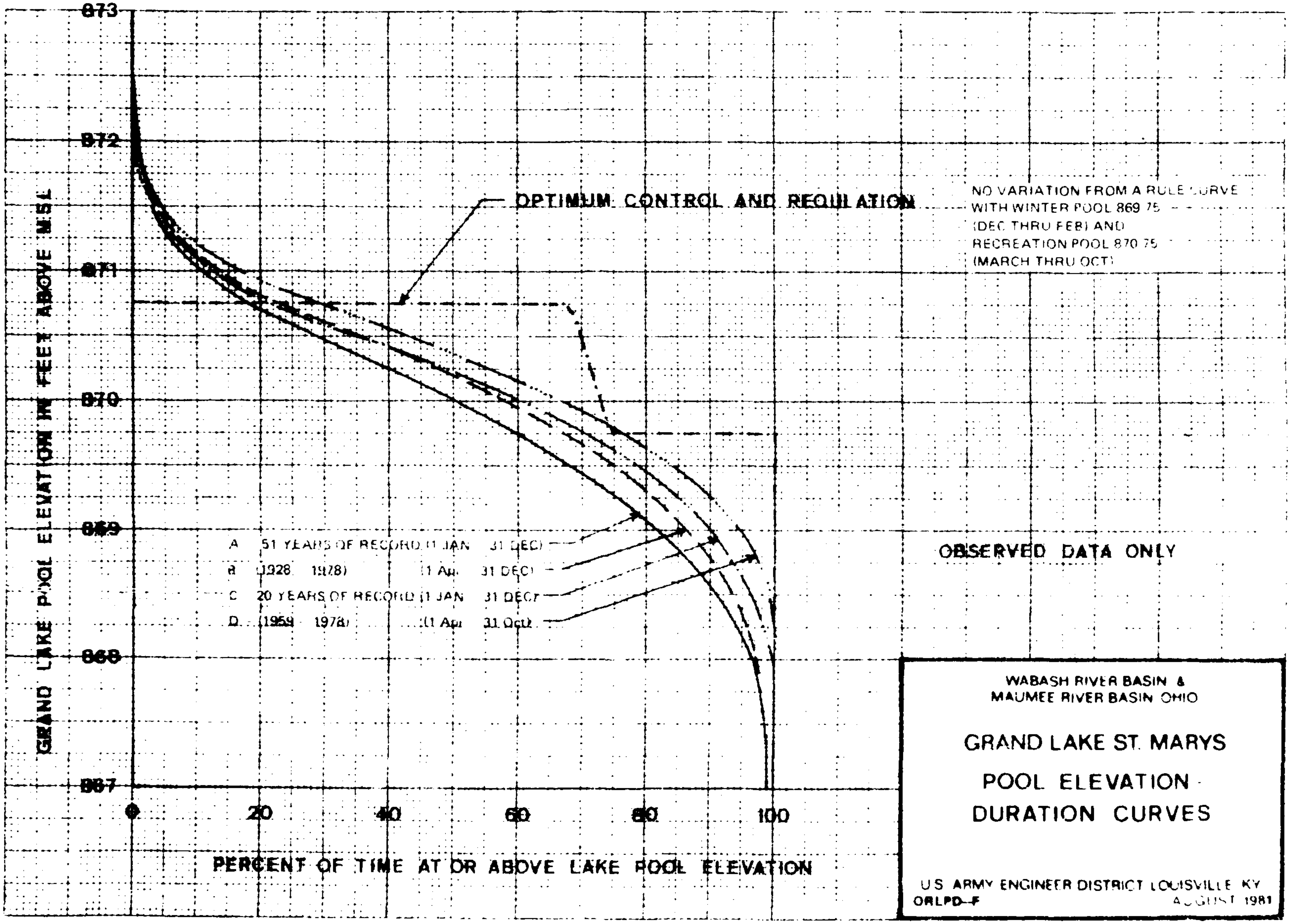
WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

LAKE REGULATION POOL ELEVATION FREQUENCY CURVES

U.S. ARMY ENGINEER DISTRICT LOUISVILLE KY

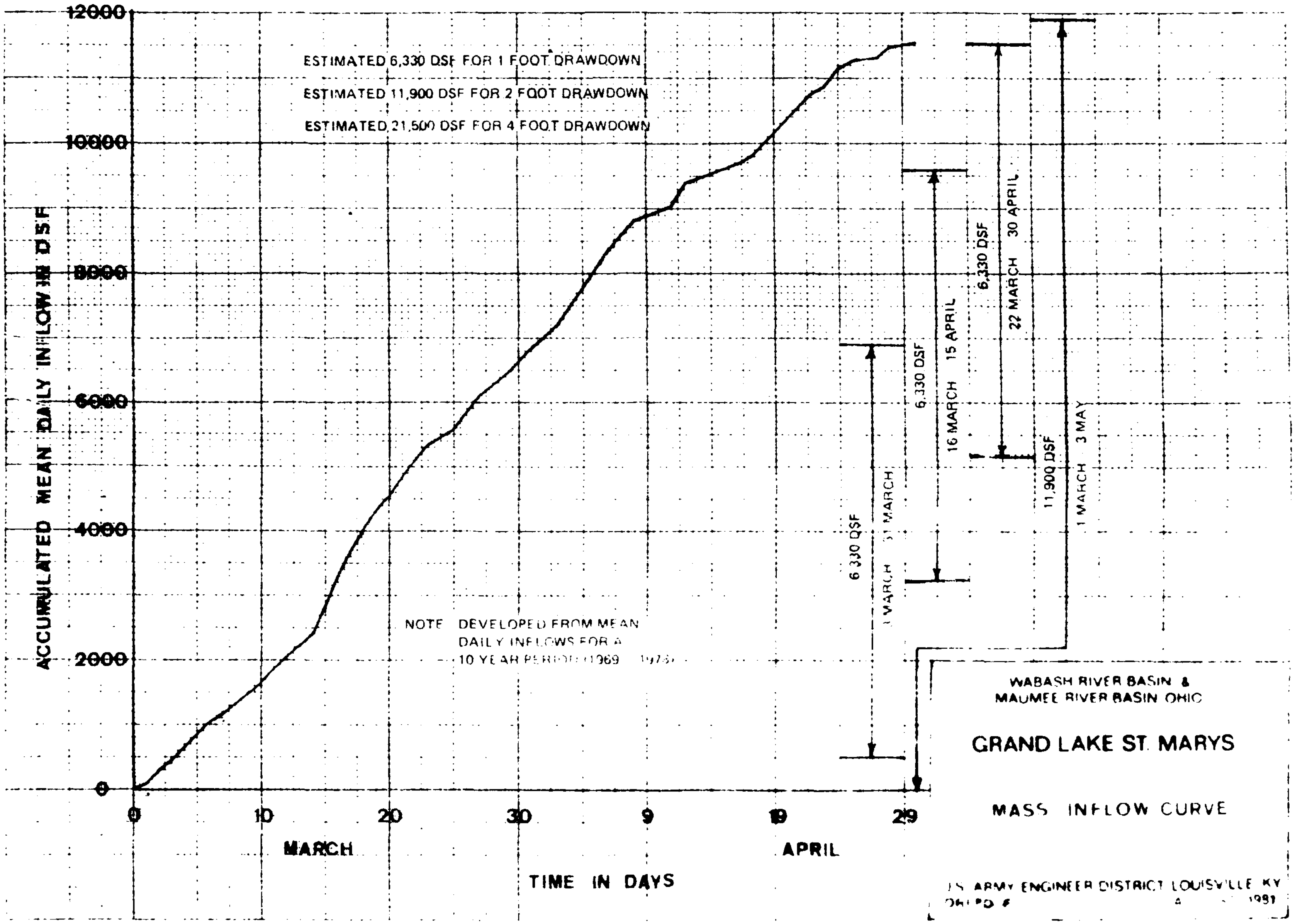
ORLPD-F AUGUST 1981



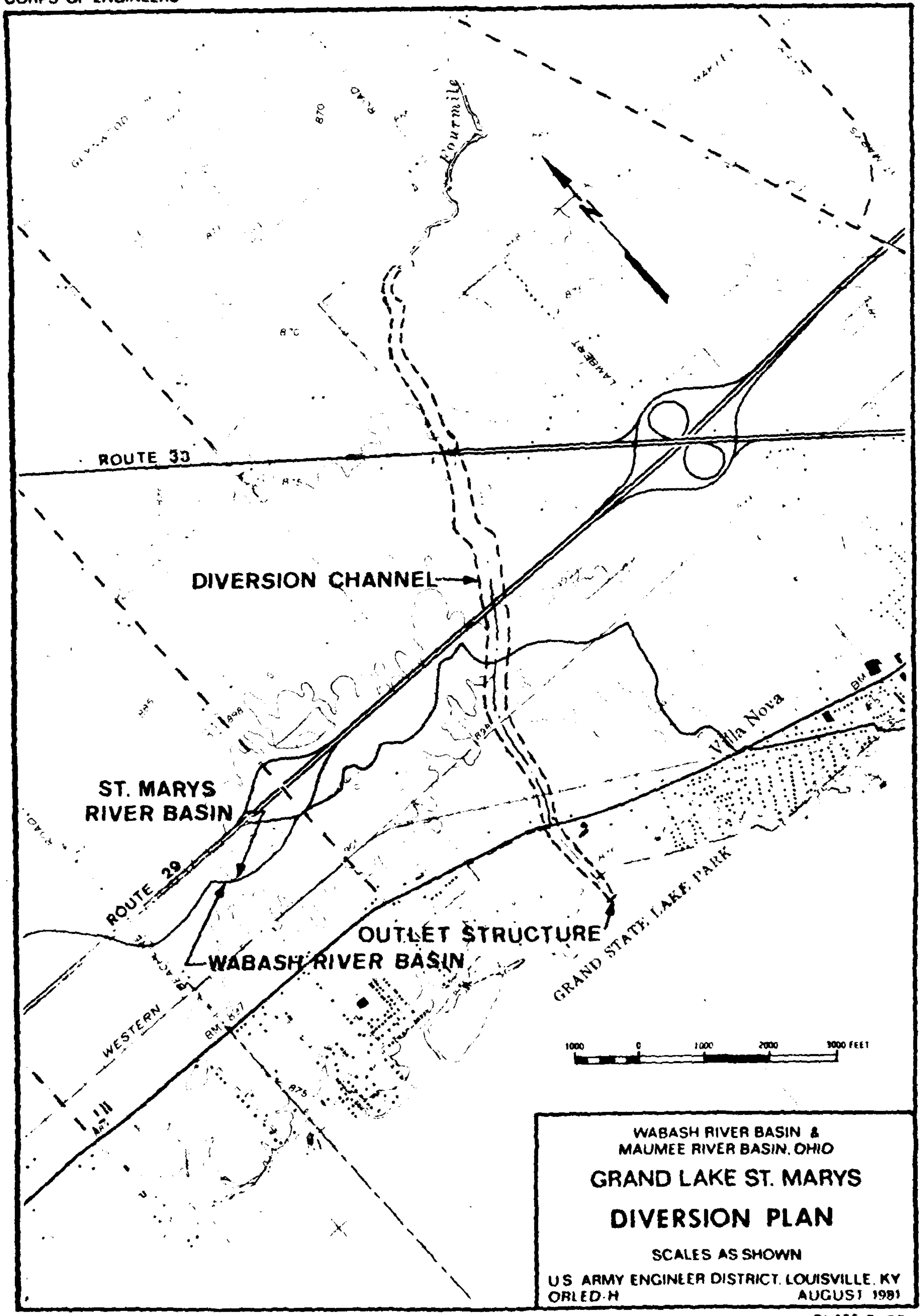
WABASH RIVER BASIN &
MAUMEE RIVER BASIN OHIO

GRAND LAKE ST. MARYS
POOL ELEVATION
DURATION CURVES

U.S. ARMY ENGINEER DISTRICT LOUISVILLE, KY
ORLPD-F AUGUST 1981


ESTIMATED 6,330 DSF FOR 1 FOOT DRAWDOWN
ESTIMATED 11,900 DSF FOR 2 FOOT DRAWDOWN
ESTIMATED 21,500 DSF FOR 4 FOOT DRAWDOWN
ACCUMULATED MEAN DAILY INFLOW IN DSF
12000
10000
8000
6000
4000
2000
0
0
10
20
30
9
19
29
MARCH
APRIL
TIME IN DAYS
NOTE DEVELOPED FROM MEAN DAILY INFLOWS FOR A 10 YEAR PERIOD (1969 - 1978)
6,330 DSF
1 MARCH 31 MARCH
6,330 DSF
16 MARCH 15 APRIL
6,330 DSF
22 MARCH 30 APRIL
11,900 DSF
1 MARCH 3 MAY
WABASH RIVER BASIN &
MAUMEE RIVER BASIN OHIO
GRAND LAKE ST. MARYS
MASS INFLOW CURVE
US ARMY ENGINEER DISTRICT LOUISVILLE KY
1981

CORPS OF ENGINEERS U.S. ARMY



WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

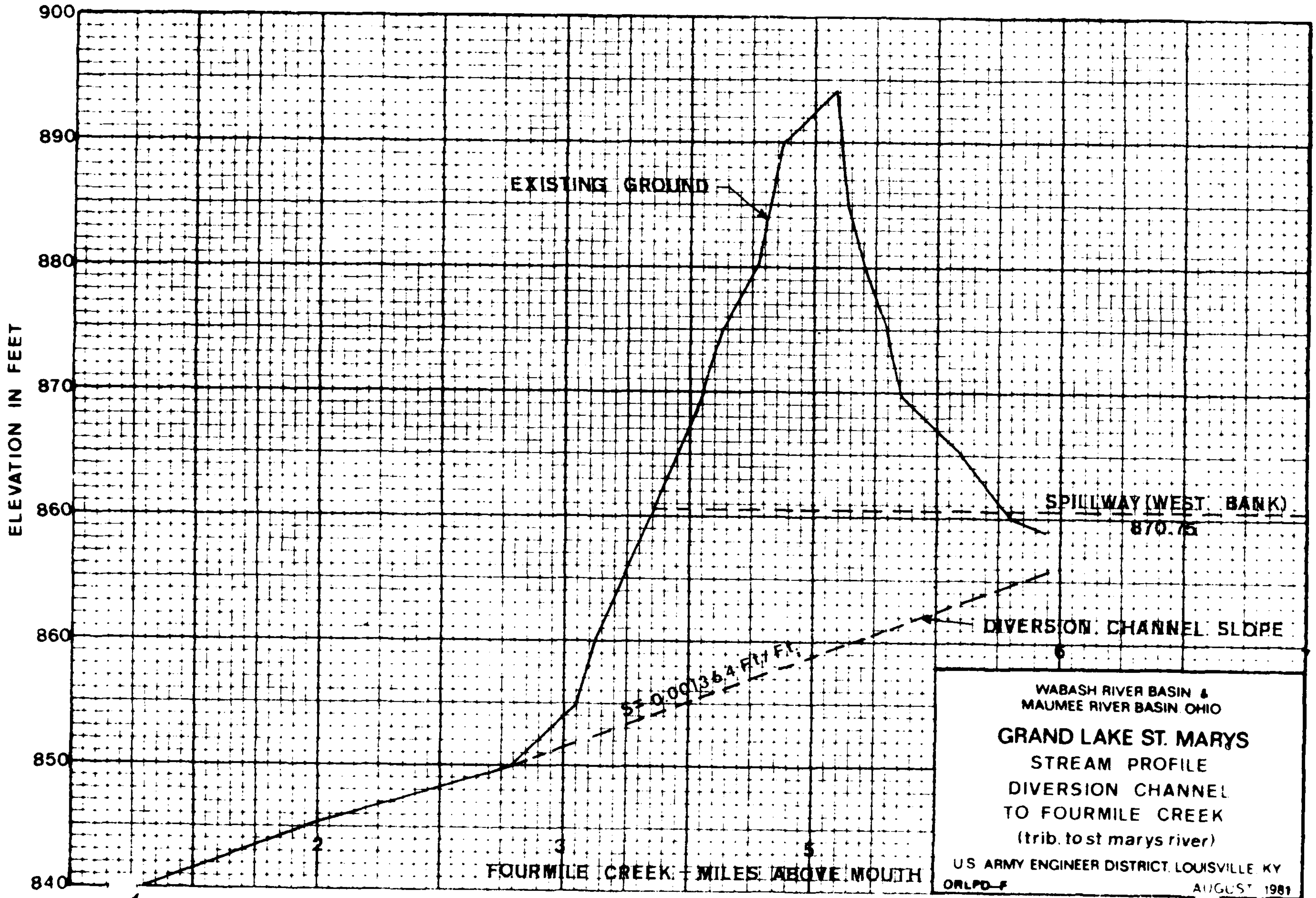
GRAND LAKE ST. MARYS

DIVERSION PLAN

SCALES AS SHOWN

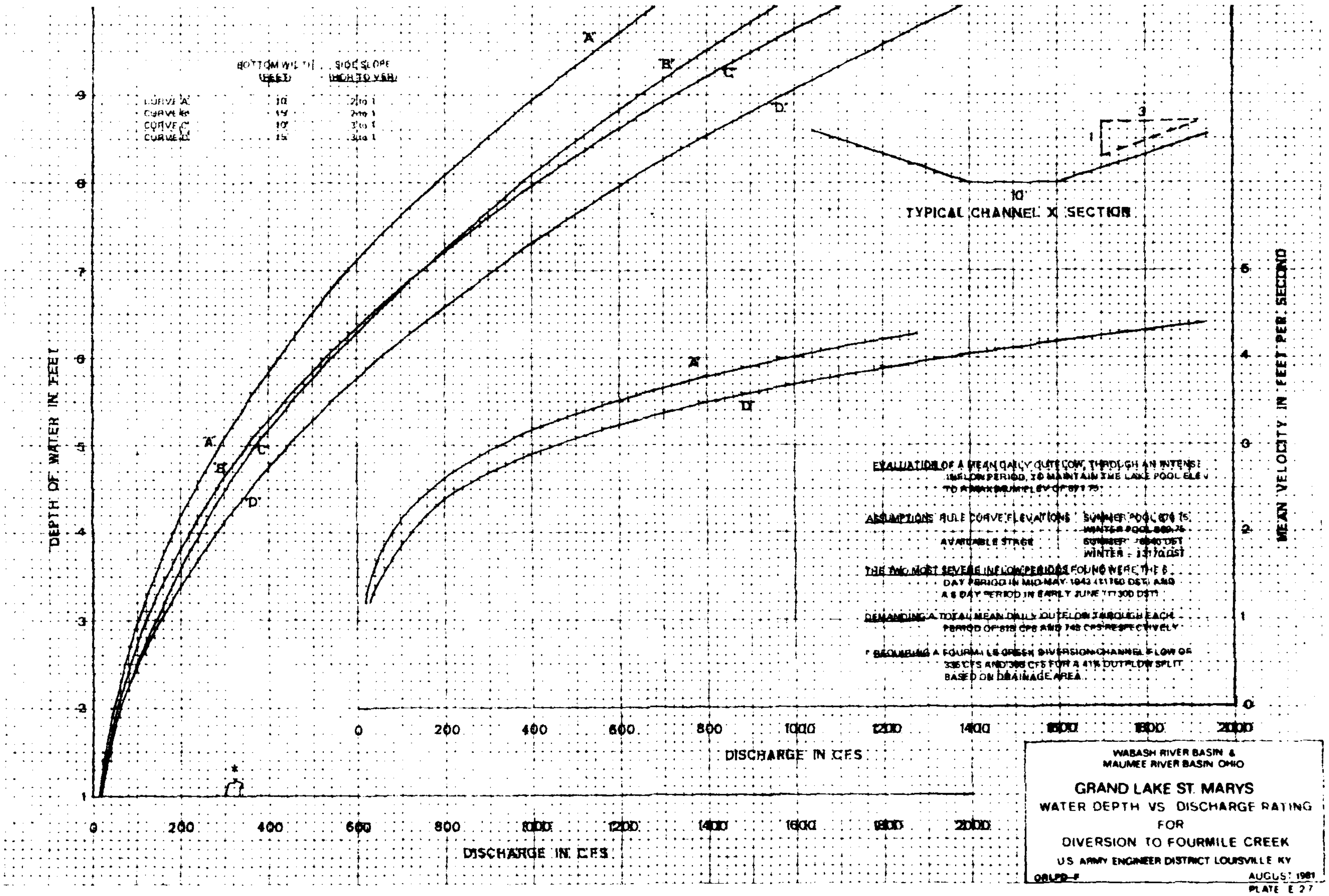
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY
ORLED-H AUGUST 1981

PLATE E-25



ELEVATION IN FEET
900
890
880
870
860
860
850
840
2
3
5
6
FOURMILE CREEK - MILES ABOVE MOUTH
EXISTING GROUND
SPILLWAY (WEST BANK)
870.75
DIVERSION CHANNEL SLOPE
S= 0.00136.4 Ft/Ft
WABASH RIVER BASIN &
MAUMEE RIVER BASIN OHIO
GRAND LAKE ST. MARYS
STREAM PROFILE
DIVERSION CHANNEL
TO FOURMILE CREEK
(trib. to st marys river)
US ARMY ENGINEER DISTRICT, LOUISVILLE KY
ORLPD-F
AUGUST 1981

ATE E-26



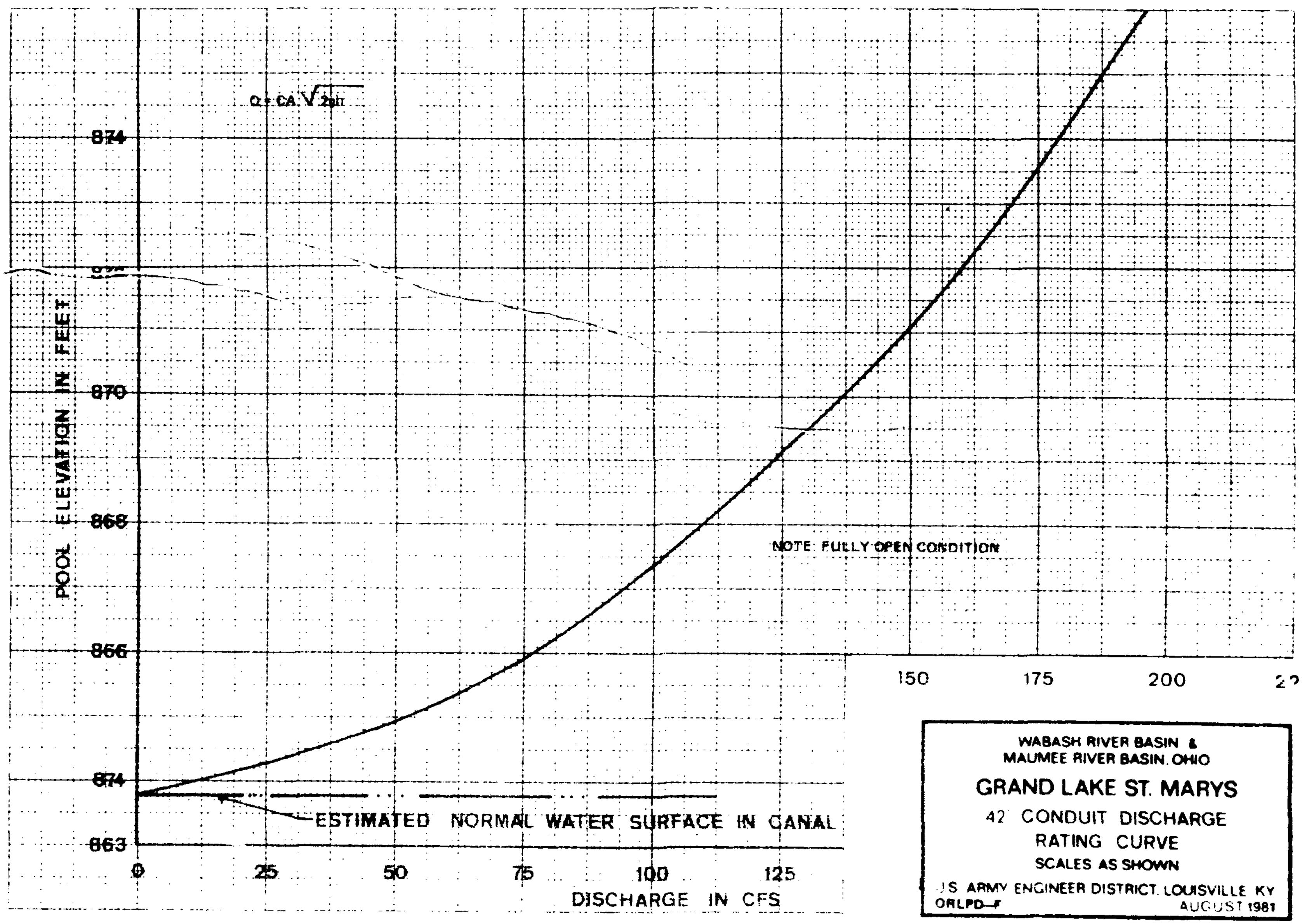
WABASH RIVER BASIN &
MAUMEE RIVER BASIN OHIO

GRAND LAKE ST. MARYS
WATER DEPTH VS DISCHARGE RATING
FOR
DIVERSION TO FOURMILE CREEK

U.S. ARMY ENGINEER DISTRICT LOUISVILLE KY

ORLPD-F AUGUST 1981

PLATE E 27



WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

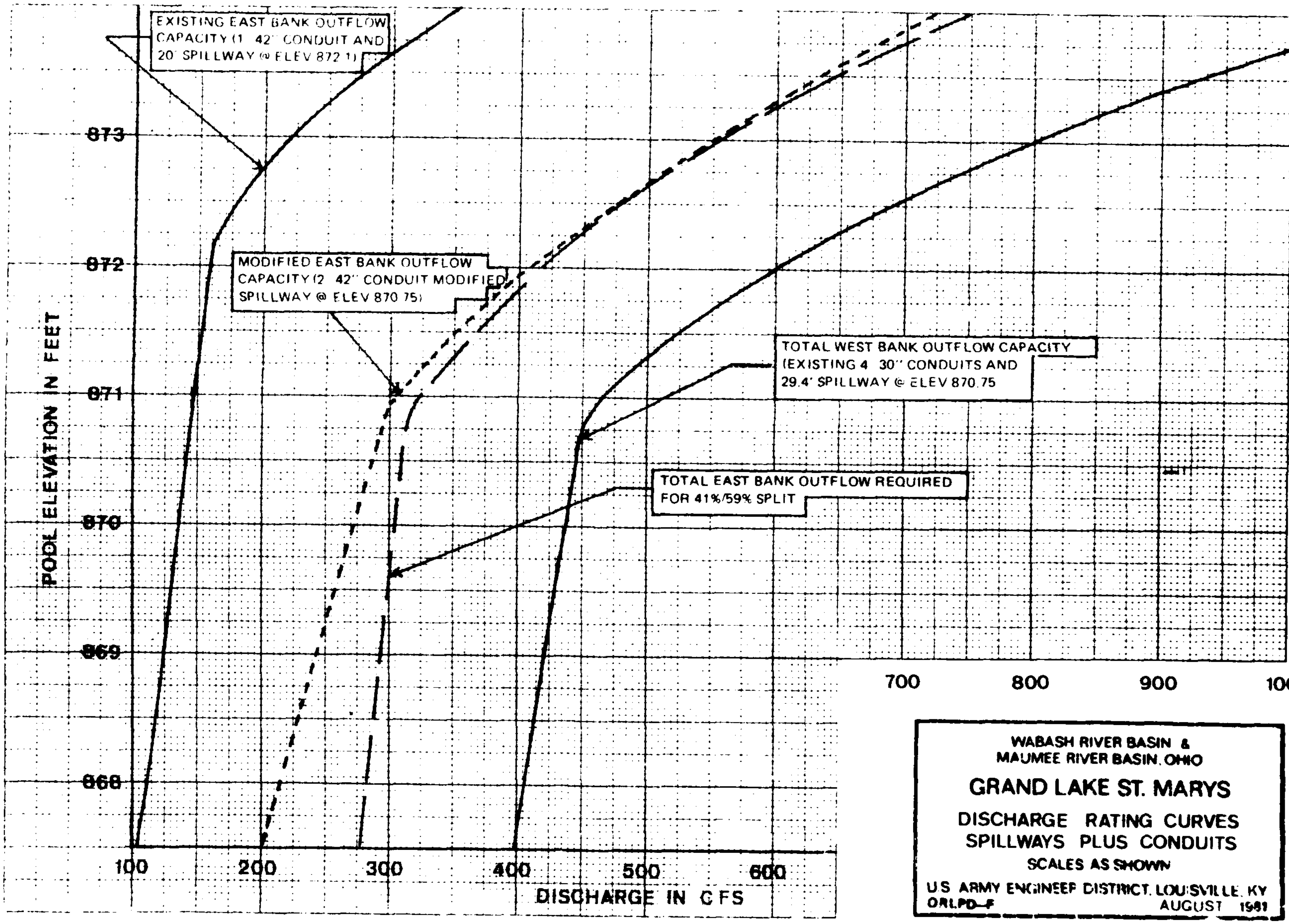
GRAND LAKE ST. MARYS

42" CONDUIT DISCHARGE
RATING CURVE

SCALES AS SHOWN

US ARMY ENGINEER DISTRICT, LOUISVILLE, KY
ORLPD—F AUGUST 1981

PLATE E-28



WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

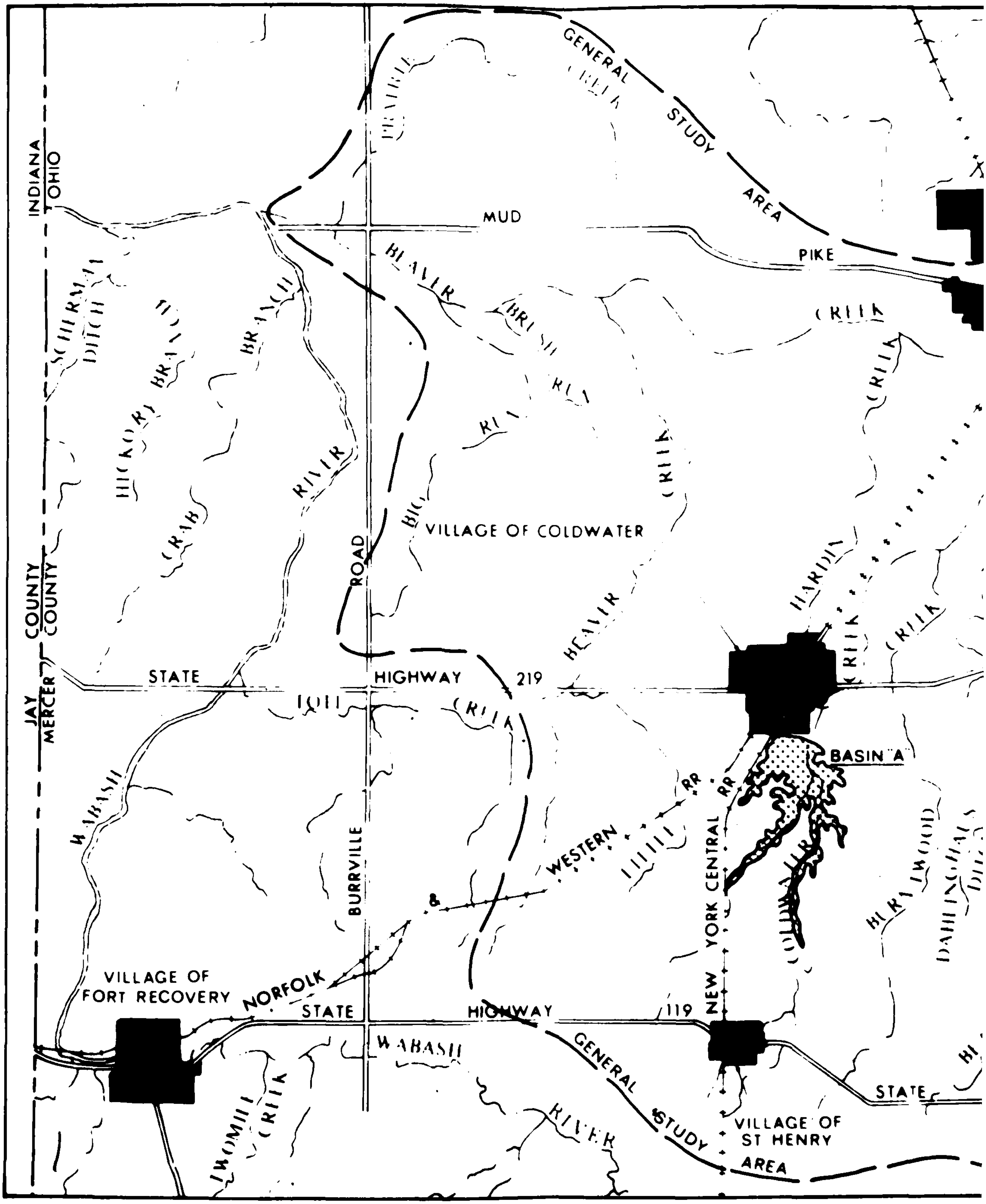
GRAND LAKE ST. MARYS

DISCHARGE RATING CURVES
SPILLWAYS PLUS CONDUITS

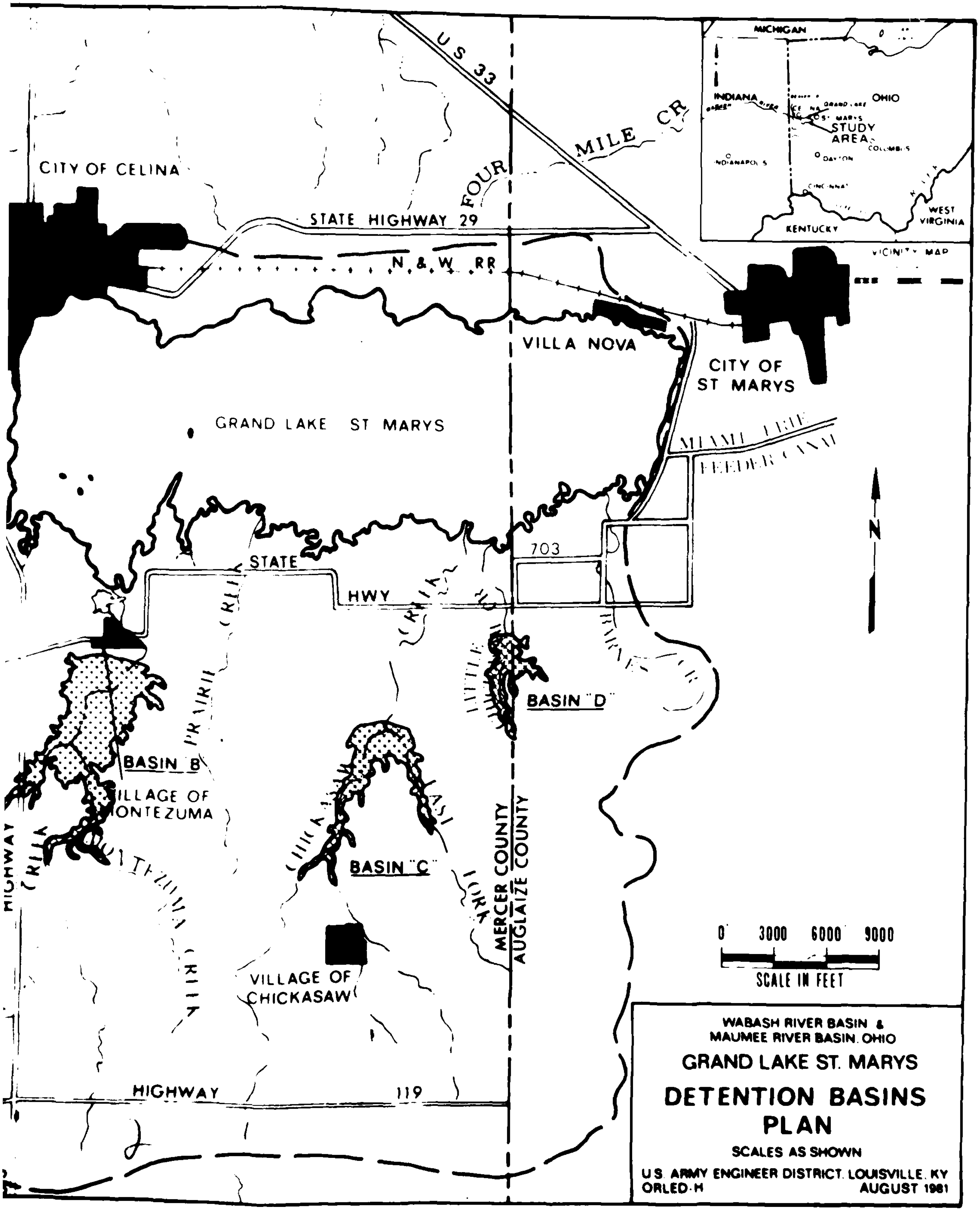
SCALES AS SHOWN

U.S. ARMY ENGINEEF DISTRICT, LOUISVILLE, KY
ORLPD–F AUGUST 1981

Pl. E-29



INDIANA
OHIO
JAY COUNTY
MERCER COUNTY
GENERAL STUDY AREA
MUD
PIKE
VILLAGE OF COLDWATER
ROAD
BURRVILLE
STATE
HIGHWAY
219
BASIN A
RR
WESTERN
&
NORFOLK
NEW YORK CENTRAL
VILLAGE OF FORT RECOVERY
STATE
HIGHWAY
119
GENERAL STUDY AREA
VILLAGE OF ST HENRY
STATE
WABASH
RIVER



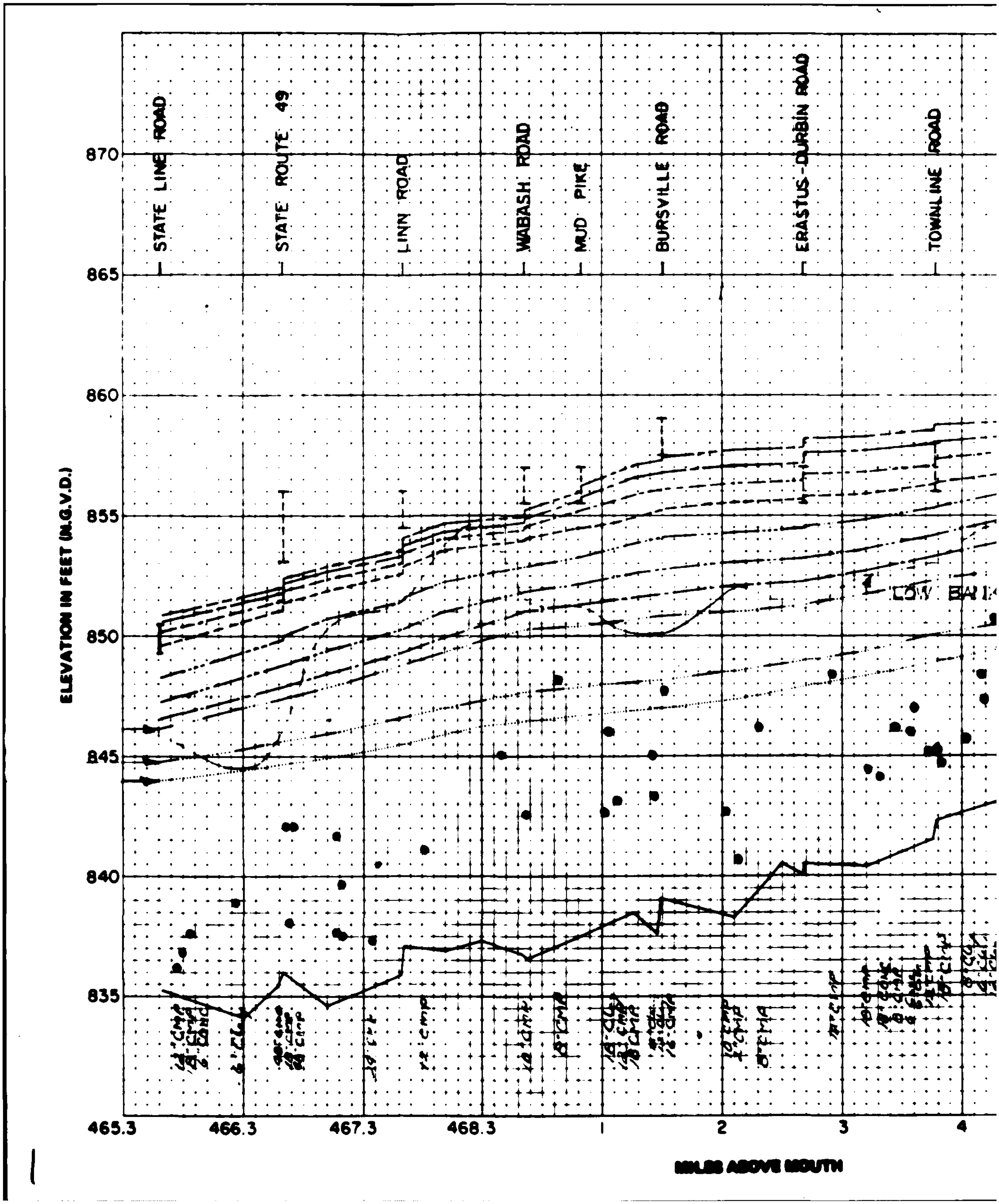
WABASH RIVER BASIN &
MAUMEE RIVER BASIN, OHIO

GRAND LAKE ST. MARYS

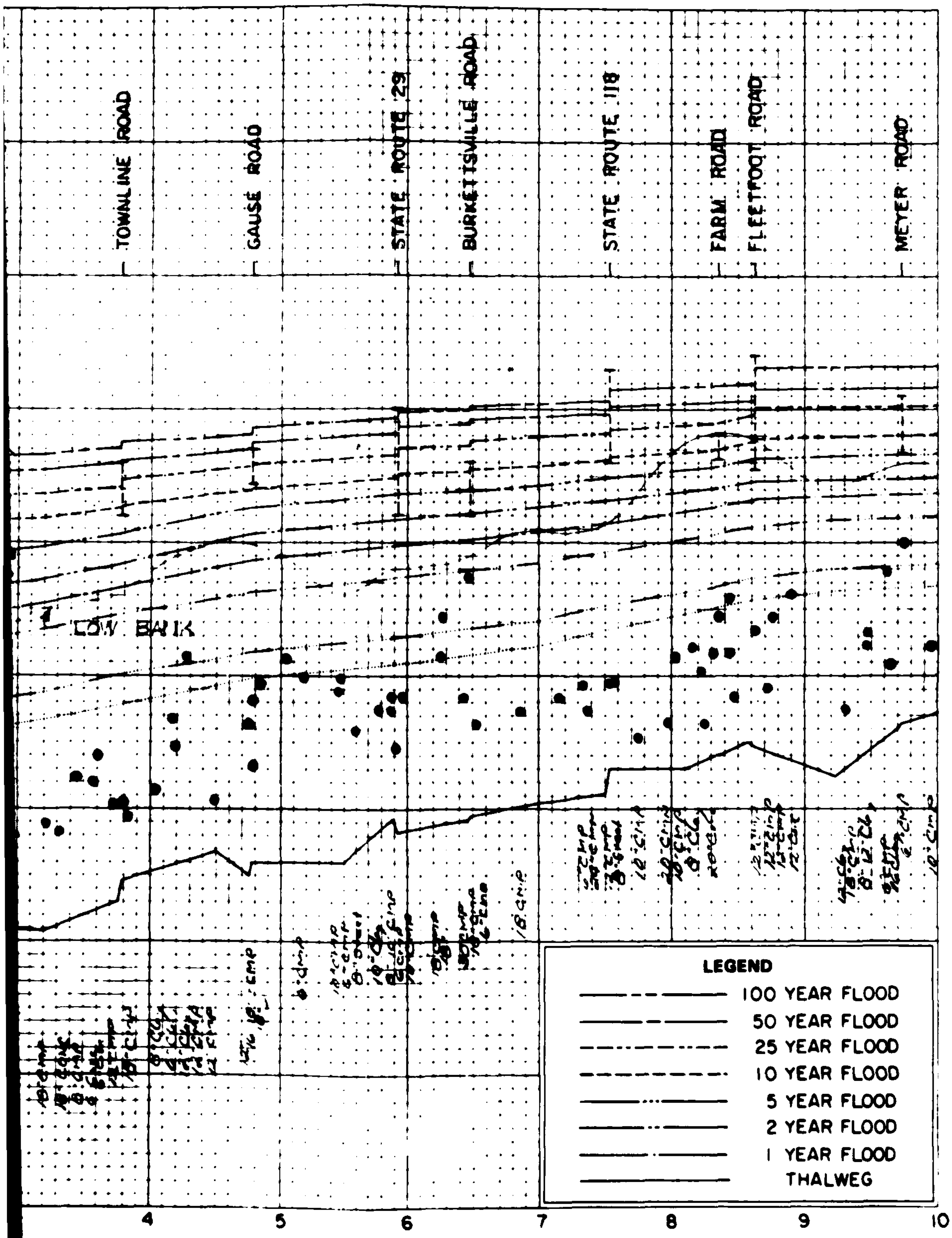
DETENTION BASINS PLAN

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, KY
ORLED-H AUGUST 1981



STATE LINE ROAD
STATE ROUTE 49
LINN ROAD
WABASH ROAD
MUD PIKE
BURSVILLE ROAD
ERASTUS-DURBIN ROAD
TOWNLINE ROAD
LOW BA
870
865
860
855
850
845
840
835
ELEVATION IN FEET (N.G.V.D.)
465.3
466.3
467.3
468.3
1
2
3
4
MILES ABOVE MOUTH



NOTE: Natural All-Season

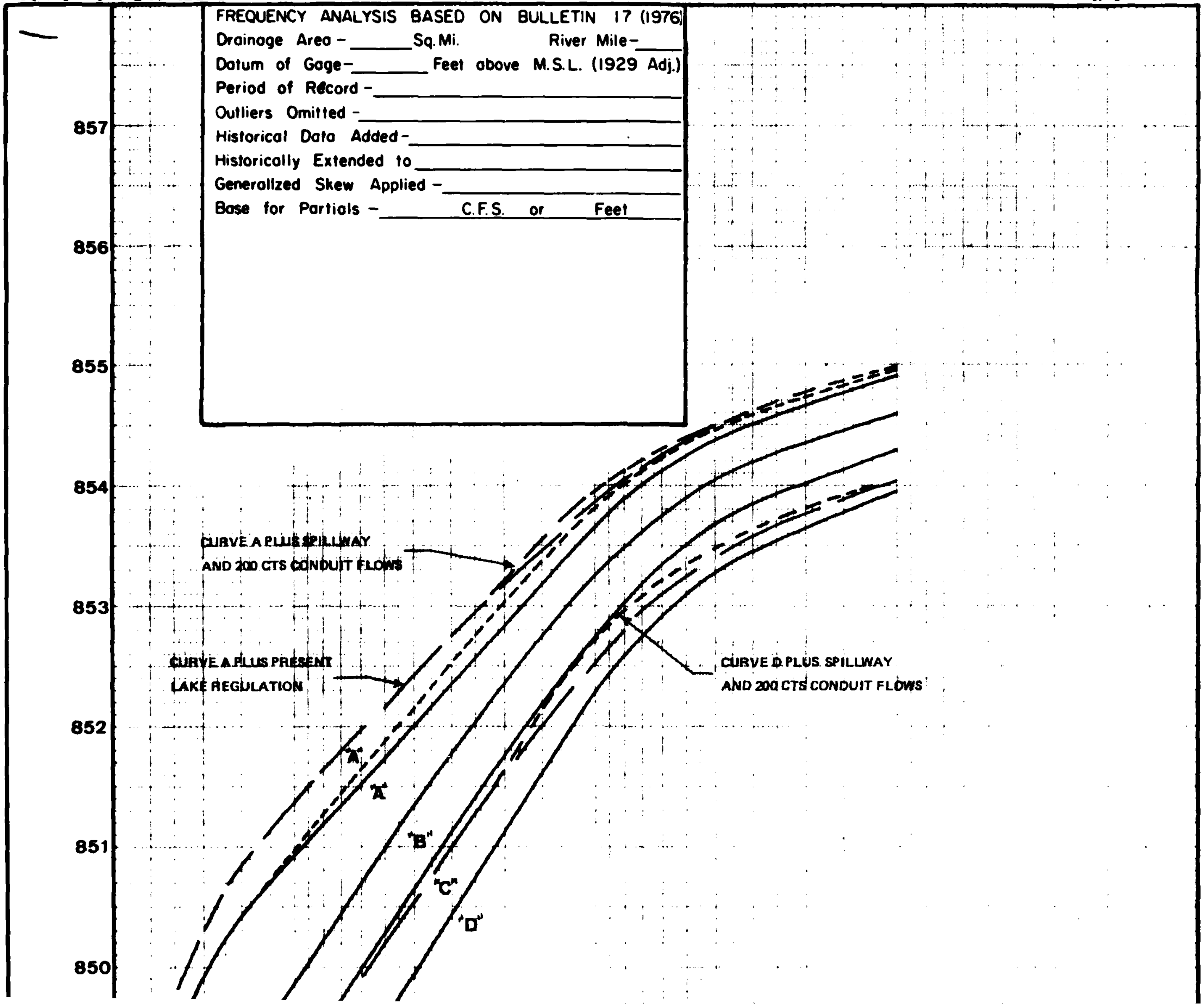
FLOOD PROFILES

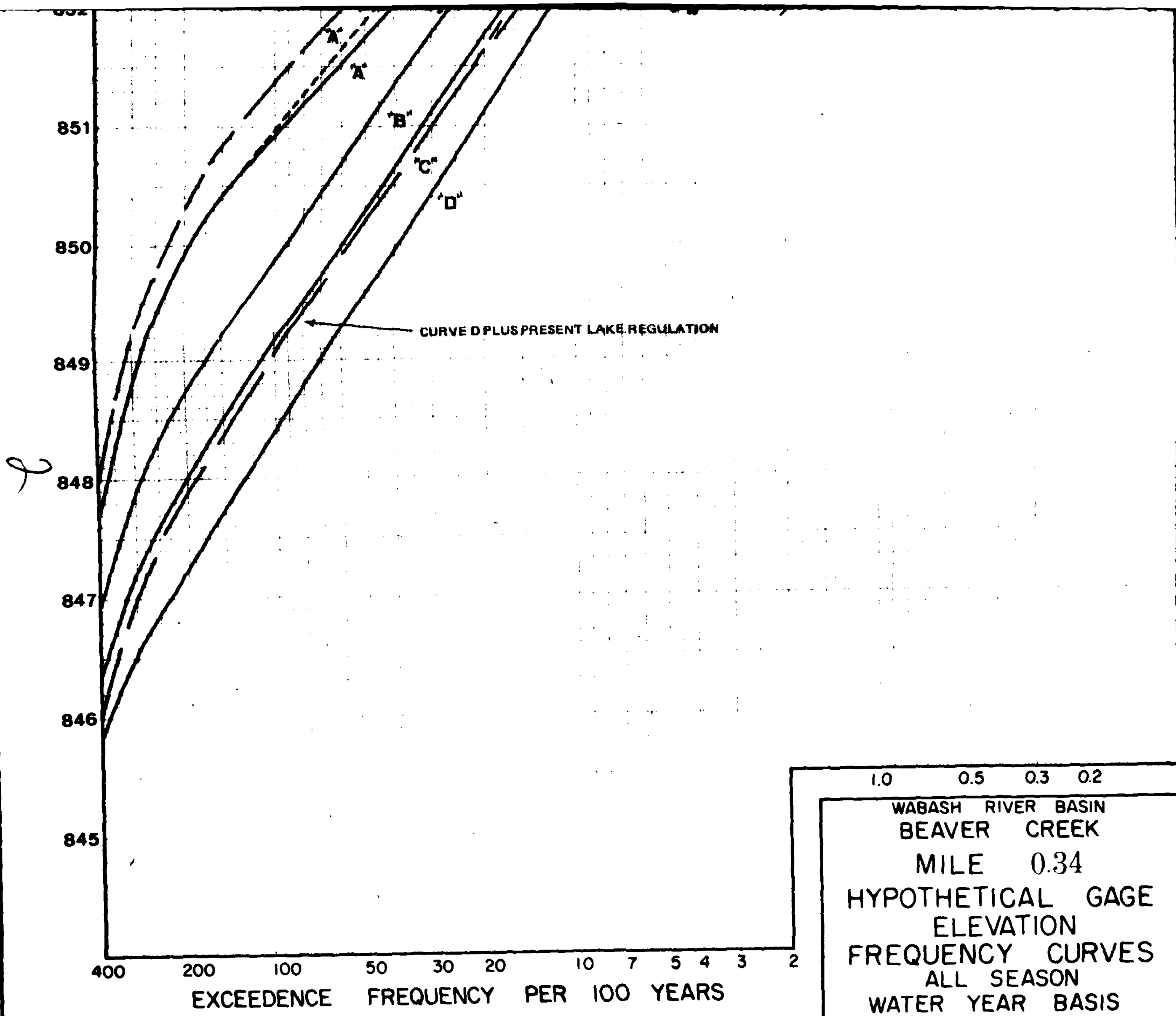
WABASH RIVER & BEAVER CREEK

GRAND LAKE - ST. MARYS, OHIO
SURVEY INVESTIGATION

PLATE E-31

CORPS OF ENGINEERS U. S. ARMY



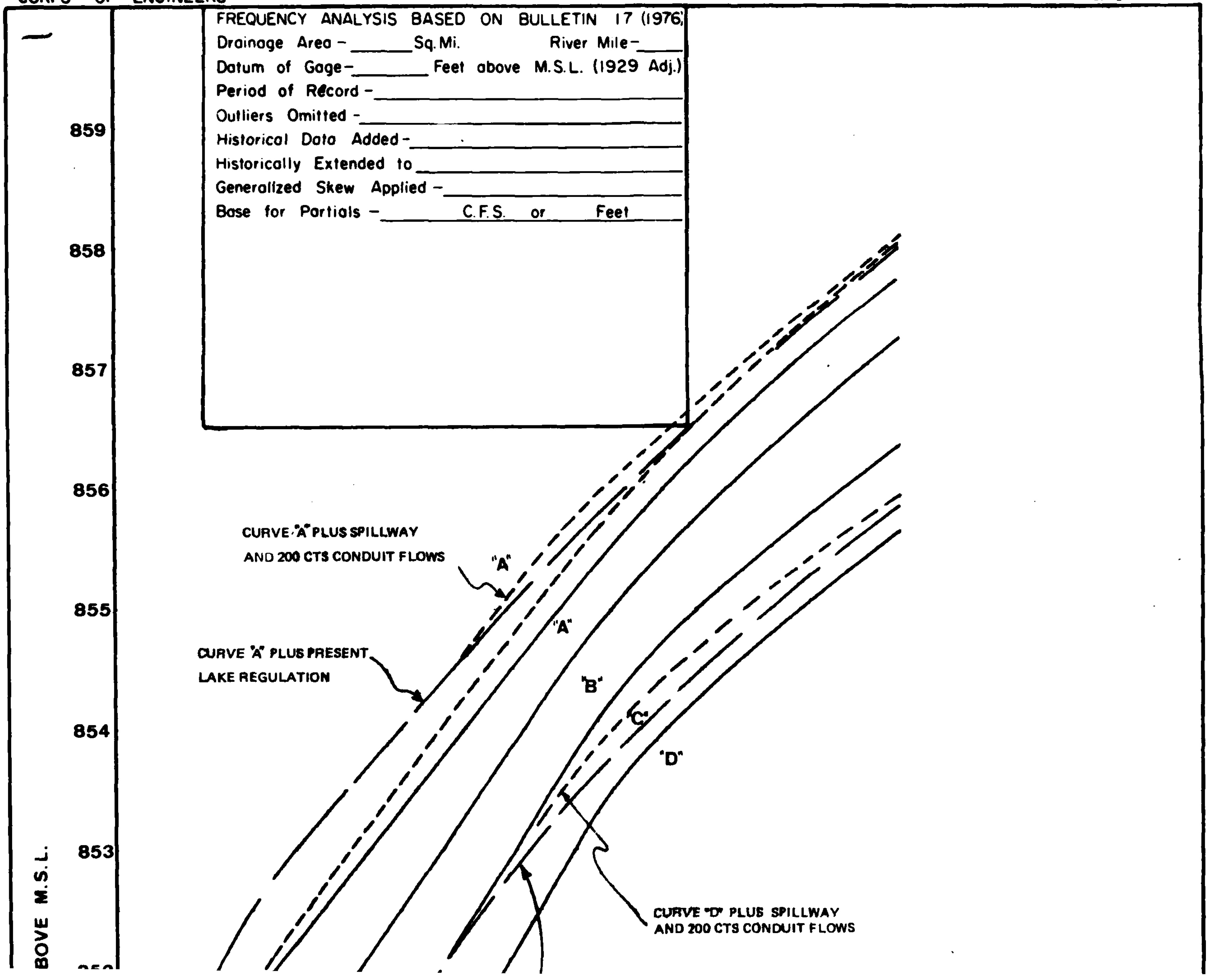


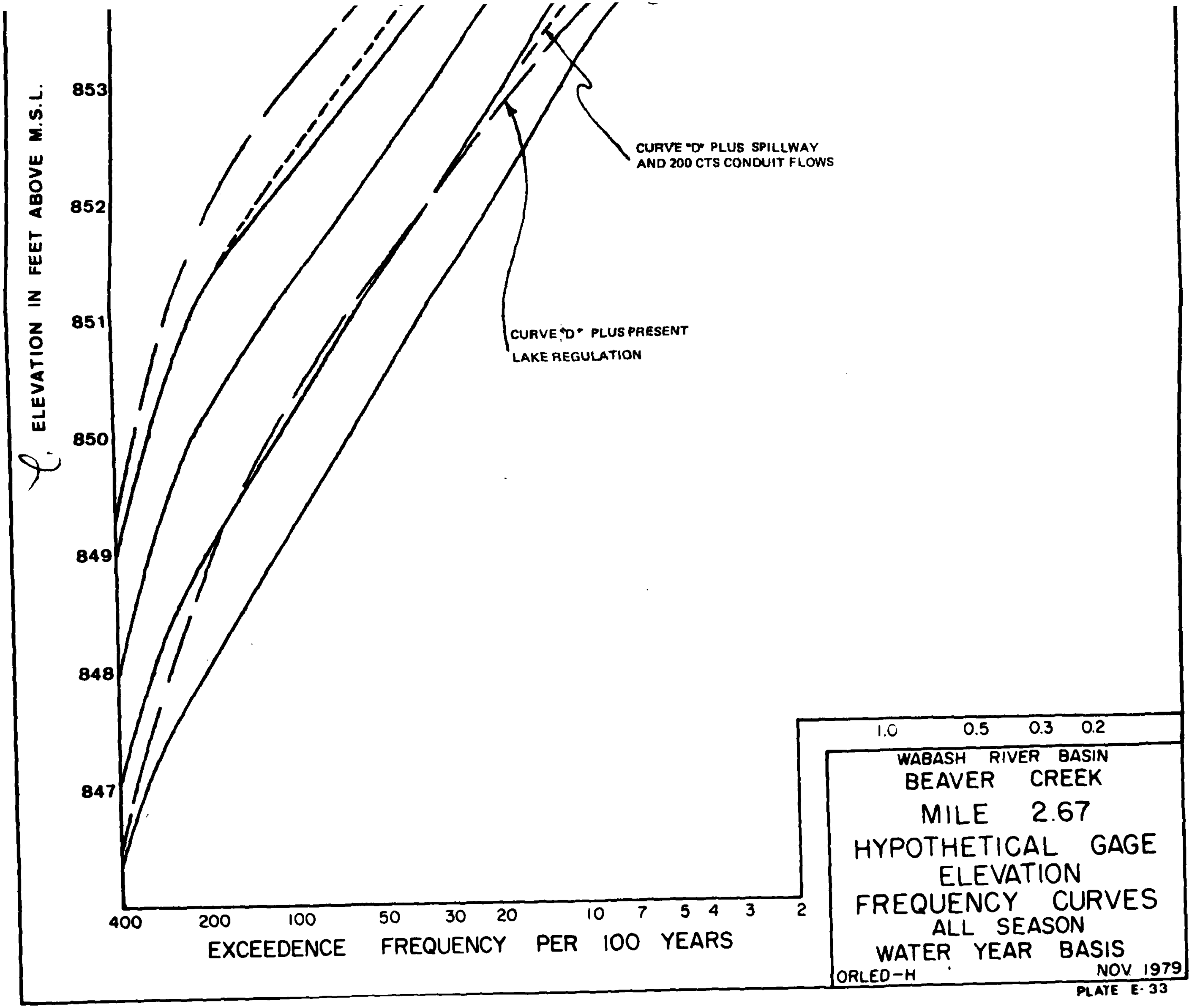
WABASH RIVER BASIN
BEAVER CREEK
MILE 0.34
HYPOTHETICAL GAGE ELEVATION FREQUENCY CURVES
ALL SEASON
WATER YEAR BASIS

ORLED-H NOV 1979

PLATE E-32

CORPS OF ENGINEERS U. S. ARMY

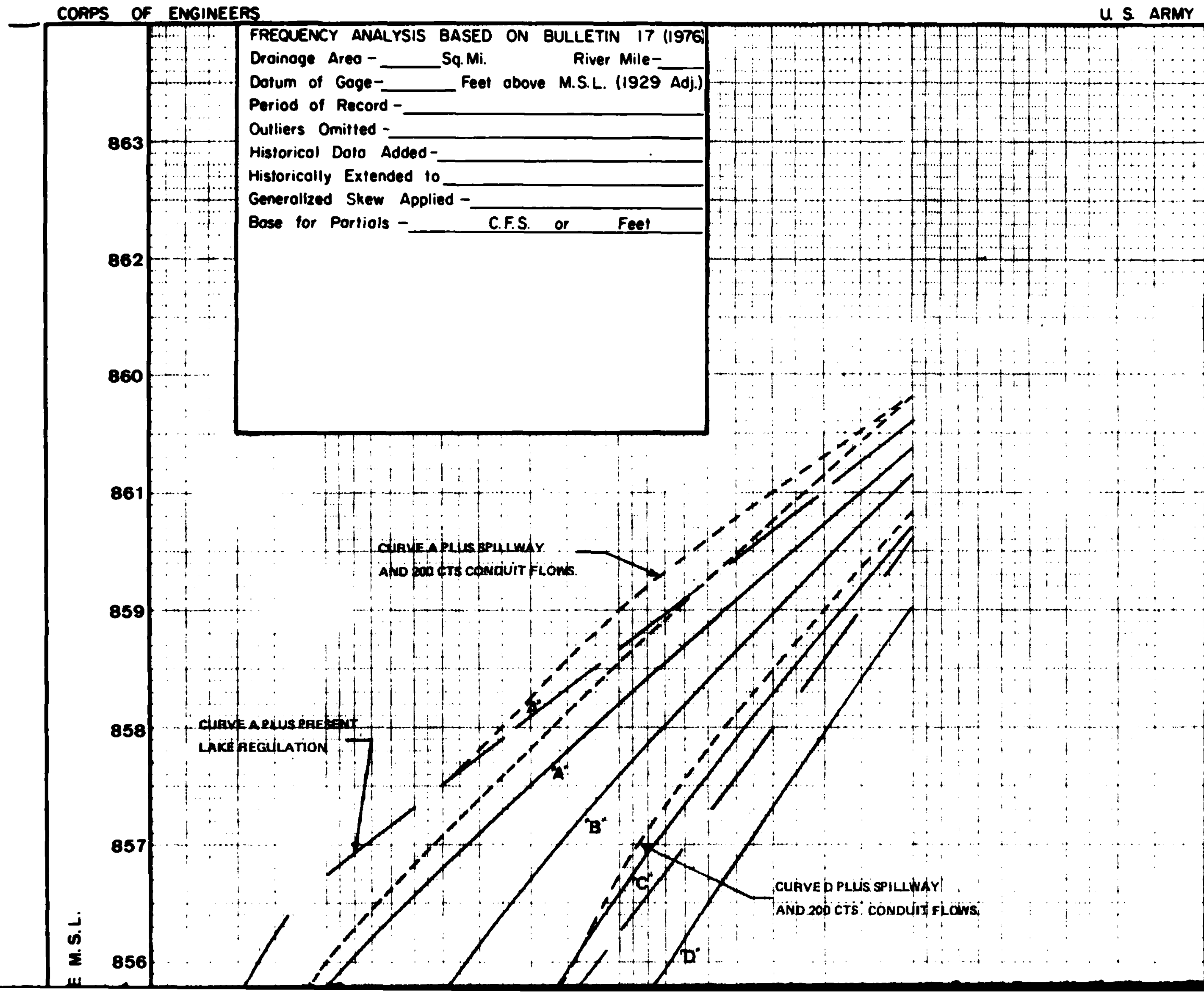


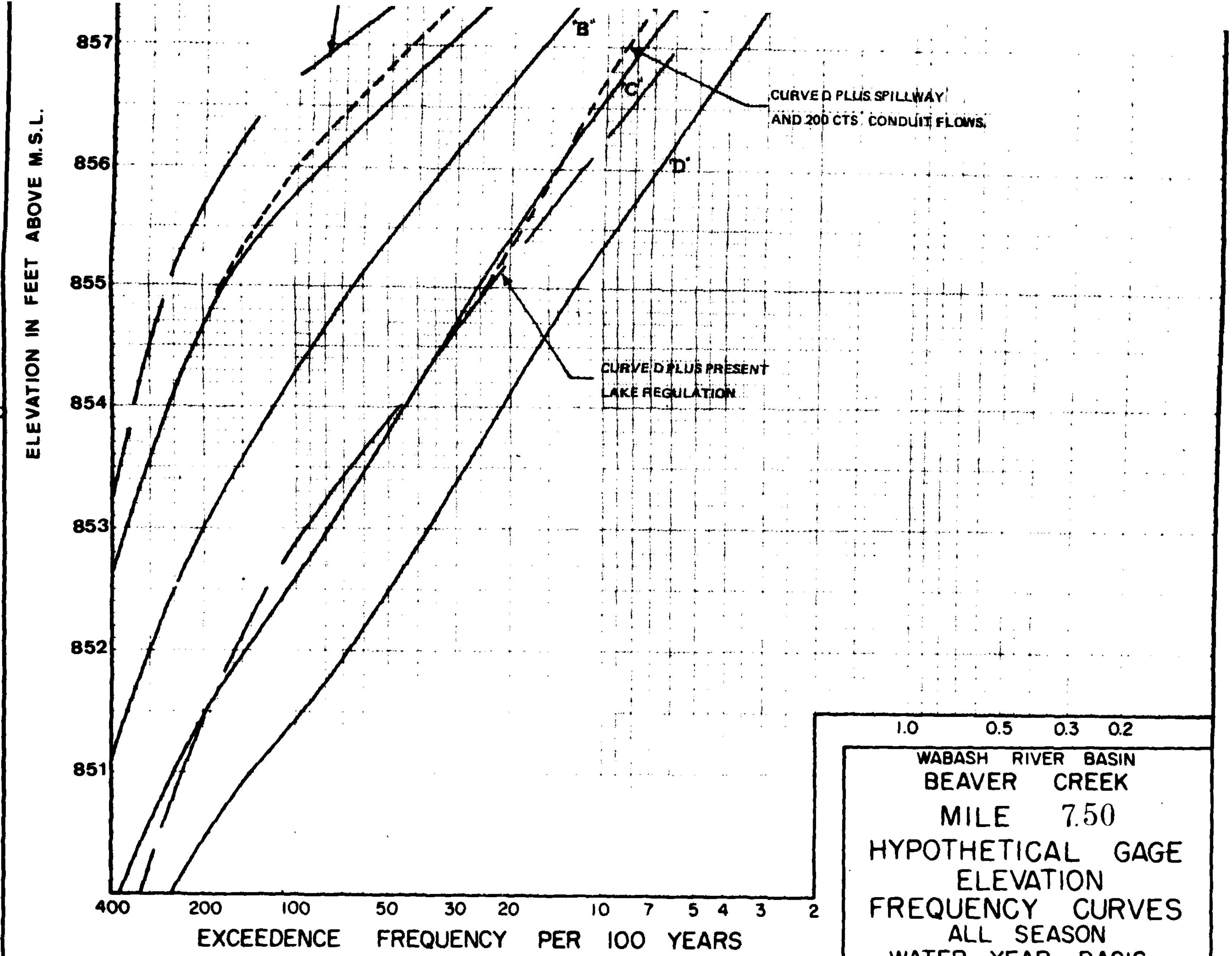


WABASH RIVER BASIN
BEAVER CREEK
MILE 2.67
HYPOTHETICAL GAGE
ELEVATION
FREQUENCY CURVES
ALL SEASON
WATER YEAR BASIS

ORLED-H NOV 1979

PLATE E-33


CORPS OF ENGINEERS
U. S. ARMY
FREQUENCY ANALYSIS BASED ON BULLETIN 17 (1976)
Drainage Area - ______ Sq. Mi. River Mile- ____
Datum of Gage- ______ Feet above M.S.L. (1929 Adj.)
Period of Record - ______
Outliers Omitted - ______
Historical Data Added - ______
Historically Extended to ______
Generalized Skew Applied - ______
Base for Partials - ______ C.F.S. or Feet
863
862
860
861
859
858
857
856
E M.S.L.
CURVE A PLUS SPILLWAY
AND 200 CTS CONDUIT FLOWS.
CURVE A PLUS PRESENT
LAKE REGULATION
'A'
'B'
'C'
'D'
CURVE D PLUS SPILLWAY
AND 200 CTS. CONDUIT FLOWS.



WABASH RIVER BASIN
BEAVER CREEK
MILE 7.50
HYPOTHETICAL GAGE ELEVATION FREQUENCY CURVES
ALL SEASON
WATER YEAR BASIS

ORLED-H NOV. 1979

PLATE E-34

SECTION F

DETAILED COST ESTIMATES

SECTION F

DETAILED COST ESTIMATES

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TABLE OF CONTENTS (Continued)

LIST OF TABLES

TABLE OF CONTENTS (Continued)

LIST OF TABLES

SECTION F

DETAILED COST ESTIMATES

FIRST COSTS

The cost estimates are based on 1979 prices. Appropriate contingencies are included to compensate for uncertain factors that could change the estimate. Engineering and design, and supervision and administration amounts are based on curves representing those costs for existing similar projects. Table F-1 summarizes the estimated costs for the various plans considered. Detailed cost estimates for the structural alternatives are shown in Tables F-2 through F-14.

TABLE F-1

SUMMARY OF ESTIMATED FIRST COSTS
FOR CONSIDERED STRUCTURAL PLANS ($1,000)

Plans	Federal	Non-Federal	Total
Detention Basins			
"A" (Coldwater Creek)	4,301	796	5,097
"B" (Beaver Creek)	3,690	1,052	4,792
"C" (Chickasaw Creek)	2,734	323	3,057
"D" (Little Chickasaw Creek)	1,748	165	1,913
Diversion Channel	3,153	358	3,511
Channel Improvements			
Clearing, Cleaning, Snagging	925	80	1,005
Enlargement			
40'-65' Width	1,316	293	1,609
60'-70' Width	3,932	1,410	5,342
Agricultural Levees			
Section 1	516	79	595
Section 2	371	69	440
Section 3	295	56	351
Section 4	572	150	722
Section 5	255	198	423
Section 6	307	52	359
Section 7	966	164	1,130
Shoreline Levees			
2' Height w/Access	808	163	971
5' Height w/Access	1,516	237	1,753
2' Height w/o Access	288	58	347
5' Height w/o Access	241	85	626
Sedimentation Ponds (4-hour Retention)			
Coldwater Creek	253	70	323
Beaver Creek (Upper)	278	74	352
Prairie Creek	75	20	95
Chickasaw Creek	248	66	314
Little Chickasaw Creek	98	26	124
Barnes Creek	53	14	67

TABLE F-2

COST ESTIMATE FOR DETENTION BASINS
GRAND LAKE ST. MARYS, OHIO

Item	Unit	Quantity Basin "A"	Basin "B"	Basin "C"	Basin "D"	Unit Cost	Cost ($1,000) "A"	"B"	"C"	"D"
DETENTION STRUCTURE (EARTH)										
Clearing & Grubbing	Job	1	1	1	1	$ L.S.	$ 26	$ [illegible]	$ [illegible]	$ [illegible]
Stream Diversion	Job	1	1	1	1	L.S.	[illegible]	[illegible]	5	[illegible]
Stripping	Job	1	1	1	1	L.S.	[illegible]	18	[illegible]	[illegible]
Inlet & Retreat Channel Excavation	Job	1	1	1	1	L.S.	[illegible]	3	[illegible]	[illegible]
Embankment	C.Y.	85,[illegible]	[illegible]	71,65[illegible]	3[illegible],132	1.6[illegible]	[illegible]	20[illegible]	[illegible]	[illegible]
Cutoff Trench	C.Y.	11,1[illegible]	[illegible]	16,66[illegible]	11,11[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Horizontal Drain (Gravel)	C.Y.	[illegible]	[illegible]	185	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
Riprap, Dumped Stone	C.Y.	12,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Filter Fabric	S.Y.	12,[illegible]	[illegible]	[illegible]	5,[illegible]	3.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Guardrails	L.F.	8,[illegible]	[illegible]	2,[illegible]	3,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Road over Dam	Job	1	1	1	1	L.S.	[illegible]	[illegible]	12[illegible]	[illegible]
Seeding	Acre	1[illegible]	[illegible]	[illegible]	[illegible]	20[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Contingencies @ 20%							[illegible]	[illegible]	[illegible]	[illegible]
Dam Construction Cost							[illegible]	[illegible]	[illegible]	[illegible]
Engineering & Design							[illegible]	[illegible]	[illegible]	[illegible]
Supervision & Inspection							[illegible]	[illegible]	[illegible]	[illegible]
Overhead							[illegible]	[illegible]	[illegible]	[illegible]
Total Dam First Cost							[illegible]	[illegible]	[illegible]	[illegible]
SPILLWAY AND OUTLET STRUCTURAL										
Clearing and Grubbing	Job	1	1	1		[illegible]	[illegible]		[illegible]	
Spillway Excavation (Emergency)	C.Y.	26,[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	
Spillway Conc. Sill	C.Y.	2,5[illegible]	290	582		135.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Structural Excavation	Job		[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
Conduit Conc.	C.Y.	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Stilling Basin Conc.	C.Y.	[illegible]	33	[illegible]		[illegible]		[illegible]		
Seeding	Acre	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Contingencies @ 20%							10[illegible]	[illegible]	[illegible]	[illegible]
Spillway and Outlet Construction Cost							[illegible]	219	[illegible]	[illegible]
Engineering and Design, Supervision and Inspection, and Overhead							195	[illegible]	[illegible]	[illegible]
Spillway and Outlet First Cost							[illegible]	[illegible]	[illegible]	[illegible]

TABLE F-2 (Continued)

Item	Unit	Quantity Basin "A"	Quantity Basin "B"	Quantity Basin "C"	Quantity Basin "D"	Unit Cost	Cost ($1,000) "A"	Cost ($1,000) "B"	Cost ($1,000) "C"	Cost ($1,000) "D"
POOL PREPARATION										
Clearing and Grubbing	Job	1	1	1	1	L.S.	$ 80	$ 100	$ 60	$ 50
Raise Roads	Job	1	1	1	1	L.S.	1,060	700	370	460
Utilities	Job	1	1	1	1	L.S.	40	60	30	[illegible]
Contingencies @ 20%							236	172	[illegible]	[illegible]
Subtotal Cost							$1,416	$1,032	$552	[illegible]
Engineering and Design							$ 269	$ 206	[illegible]	[illegible]
Supervision and Inspection							85	62	[illegible]	[illegible]
Overhead							43	41	19	[illegible]
Total Pool Preparation Cost							$1,813	$1,341	$734	[illegible]
FEDERAL COST, TOTAL							$4,301	$3,690	$2,734	$1,748
NON-FEDERAL										
Rights-of-Way										
Fee Land	Acre	427	749	239	145	850	$363	$ 637	[illegible]	[illegible]
Residential Property	Each	12	8	2		20,000	240	160	[illegible]	
Land Acquisition @ 10%							60	80	[illegible]	13
Contingencies @ 20%							133	175	[illegible]	[illegible]
NON-FEDERAL COST							$796	$1,052	[illegible]	$165
TOTAL ESTIMATED FIRST COST							$5,097	$4,792	[illegible]	$1,913

TABLE F-3

COST ESTIMATE FOR
DIVERSION TO FOURMILE CREEK

Item	Unit	Quantity	Unit Cost	Amount (Rounded)
Federal				
Clearing and Grubbing	Acre	21	$2,000.00	$ 42,000
Excavation (Earth)	CY	200,800	1.30	262,000
Excavation (Rock)	CY	133,900	8.60	1,152,000
Haul to Waste Area	CY	402,000	1.00	402,000
Norfolk & Western R.R. Br.	Job	1	L.S.	240,000
Outlet Structure	Job	1	L.S.	110,000
Contingencies @ 20%				441,600
Subtotal				$2,649,600
Engineering and Design @ 11%				291,460
Supv. & Insp. @ 5%				132,500
Overhead @ 3%				79,500
Subtotal				$3,153,000
Non-Federal				
Rights-of-Way Land	Acre	16	$1,200.00	$ 20,000
Waste Area Land	Acre	11	40 .00	5,000
2 - 72" RCP Drainage Pipes	Job	1	L.S.	10,000
2 Bridges	Job	1	L.S.	200,000
Guardrails	Job	1	L.S.	1,000
Land Acquisition	Job	1	L.S.	15,000
Contingencies @ 20%				50,000
Total Non-Federal First Cost				$301,000
Engineering and Design @ 12%				$ 33,000
Supervision & Inspection @ 6%				16,000
Overhead @ 3%				8,000
Subtotal - Non-Federal				$ 358,000
TOTAL ESTIMATED FIRST COST				$3,511,000

TABLE F-4

COST ESTIMATE FOR
CLEARING AND CLEANING BEAVER CREEK

Item	Unit	Quantity	Unit Cost	(Rounded)
Federal				
Clearing and Snagging	Acre	20	$2,900.00	$58,000
Channel Excavation	CY	212,000	2.40	508,000
Riprap	CY	2,660	25.00	66,500
Tile Pipe Extensions	LF	1,350	10.00	13,500
Filter Cloth	SY	4,800	2.50	12,000
Seeding and Fertilizer	Acre	50	1,400.00	70,000
Subtotal				$728,000
Contingencies @ 10%				73,000
Engineering @ 11%				80,000
Supvervision and Inspection @ 6%				44,000
Subtotal, Federal				$925,000
Non-Federal				
Rights-of-way	Acre	99	600	$ 59,000
Acquisition				5,000
Contingencies				15,000
Subtotal, Non-Federal				$ 80,000
TOTAL ESTIMATED FIRST COST				$1,005,000

TABLE F-5

COST ESTIMATE FOR BEAVER CREEK CHANNEL WIDENING FROM MILE 0.0 TO MILE 6.0

Item	Unit	Quantity 5-Year	Quantity 10-Year	Cost	Amount (Rounded) 5-Year	Amount (Rounded) 10-Year
Federal						
Clearing and Grubbing	Job	1	1	$ L.S.	$ 120,000	$ 148,000
Channel Excavation	C.Y.	193,400	620,600	2.60	503,000	1,614,000
Concrete Paving	C.Y.	80	590	45.00	4,000	27,000
Filling and Plugging Abandoned Pipes	Job	1	1	L.S.	3,000	3,000
Restoring Headers for Existing Pipes	Job	1	1	L.S.	30,000	30,000
Excavating Waste	C.Y.	232,080	744,720	1.00	233,000	745,000
Extend 2 RR Bridges	Job	1	1	L.S.	-	180,000
Riprap	Job	1	1	L.S.	10,000	12,000
Filter Cloth	Job	1	1	L.S.	1,000	1,000
Seeding and Fertilizer	Acre	30	30	550	17,000	17,000
Contingencies 20%					184,000	555,000
Subtotal					$1,105,000	$3,332,000
Engineering and Design		11%	10.5%		122,000	350,000
Supervision and Inspection		5.5%	5.2%		61,000	173,000
Overhead		2.5%	2.3%		28,000	77,000
Subtotal, Federal					$1,316,000	$3,932,000
Non-Federal						
Land Rights-of-Way	Acre	100	123	$1,300.00	$ 130,000	$ 160,000
Relocate Petroleum Pipeline	L.F.	80	100	40.00	4,000	4,000
Relocate Understream Telephone Cable	L.F.	80	80	15.00	2,000	2,000
Relocate Understream 16" CMP Pipe	L.F.	80	80	40.00	4,000	4,000
Extend Bridges	Job	1	1	L.S.	-	150,000
Replace Bridges	Job	1	1	L.S.	-	600,000
Land Acquisition	Tract	51	51	2,000.00	102,000	102,000
Contingencies 20%					48,000	205,000
Subtotal					$ 48,000	$1,227,000
Engineering and Design, Supervision and Inspection, and Overhead		25%	20%		3,000	183,000
Subtotal, Nonfederal					$ 293,000	$1,410,000
TOTAL ESTIMATED FIRST COST					$1,609,000	$5,342,000

TABLE F-6

DETAILED ESTIMATED COST
BEAVER CREEK LEVEE UNIT 1
10-YEAR PROTECTION
GRAND LAKE ST. MARYS, OHIO

Item	Unit	Quantity	Unit Cost	Amount (Rounded)
Federal				
Light Clearing	Acre	10	$700.00	$ 7,000
Stripping, Excavation	C.Y.	14,800	1.00	15,000
Inspection Trench	C.Y.	17,267	3.00	52,000
Embankment	C.Y.	41,948	1.00	42,000
Borrow Excavation	C.Y.	50,338	1.10	56,000
96" RCP Drainage Pipes	L.F.	110	1,200.00	132,000
Concrete Closure and Vault	Job	1	L.S.	20,000
Seeding and Fertilizing	Acre	23	900.00	21,000
Contingencies @ 20%				69,000
Construction Cost				$ 414,000
Engineering and Design @ 15%				62,000
Supervision and Inspection @ 6%				25,000
Overhead @ 3.5%				15,000
Federal Cost				$516,000
Non-Federal				
Levee Right-of-Way	Acre	15	1,500.00	23,000
Borrow Right-of-Way	Acre	6	500.00	3,000
Utilities and Relocation	Job	1	L.S.	20,000
Land Acquisition	Job	1	L.S.	20,000
Contingencies @ 20%				13,000
Total Non-Federal Cost				$ 79,000
Total Project Cost				$595,000

TABLE F-7

DETAILED ESTIMATED COST
BEAVER CREEK LEVEE UNIT 2
10-YEAR PROTECTION
GRAND LAKE ST. MARYS, OHIO

Item	Unit	Quantity	Unit Cost	Amount (Rounded)
Federal				
Light Clearing	Acre	11	$700.00	$ 8,000
Stripping, Excavation	C.Y.	10,500	1.00	11,000
Inspection Trench	C.Y.	13,400	3.00	40,000
Embankment	C.Y.	26,200	1.00	27,000
Borrow Excavation	C.Y.	31,425	1.10	35,000
96" RCP Drainage Pipes	L.F.	80	1,200.00	96,000
Concrete Closure and Vault	Job	1	L.S.	15,000
Seeding and Fertilizing	Acre	14	900.00	13,000
Contingencies @ 20%				49,000
Construction Cost				$ 294,000
Engineering and Design @ 15%				47,000
Supervision and Inspection @ 6%				18,000
Overhead @ 3.5%				12,000
Federal Cost				$371,000
Non-Federal				
Levee Right-of-Way	Acre	10	1,500.00	15,000
Borrow Right-of-Way	Acre	3	500.00	2,000
Utilities and Relocation	Job	1	L.S.	20,000
Land Acquisition	Job	1	L.S.	20,000
Contingencies @ 20%				12,000
Total Non-Federal Cost				$ 69,000
Total Project Cost				$440,000

TABLE F-8

DETAILED ESTIMATED COST
BEAVER CREEK LEVEE UNIT 3
10-YEAR PROTECTION
GRAND LAKE ST. MARYS, OHIO

Item	Unit	Quantity	Unit Cost	Amount (Rounded)
Federal				
Light Clearing	Acre	6	$700.00	$ 4,000
Stripping, Excavation	C.Y.	15,160	1.00	15,000
Inspection Trench	C.Y.	9,650	3.00	29,000
Embankment	C.Y.	16,750	1.00	17,000
Borrow Excavation	C.Y.	20,100	1.10	22,000
96" RCP Drainage Pipes	L.F.	55	1,200.00	66,000
Concrete Closure and Vault	Job	1	L.S.	30,000
Seeding and Fertilizing	Acre	9	900.00	9,000
Contingencies @ 20%				38,000
Construction Cost				$ 230,000
Engineering and Design @ 15%				40,000
Supervision and Inspection @ 6%				15,000
Overhead @ 3.5%				10,000
Federal Cost				$295,000
Non-Federal				
Levee Right-of-Way	Acre	7	1,500.00	11,000
Borrow Right-of-Way	Acre	2	500.00	1,000
Utilities and Relocation	Job	1	L.S.	20,000
Land Acquisition	Job	1	L.S.	15,000
Contingencies @ 20%				9,000
Total Non-Federal Cost				$ 56,000
Total Project Cost				$351,000

TABLE F-9

DETAILED ESTIMATED COST
BEAVER CREEK LEVEE UNIT 4
10-YEAR PROTECTION
GRAND LAKE ST. MARYS, OHIO

Item	Unit	Quantity	Unit Cost	Amount (Rounded)
Federal				
Light Clearing	Acre	13	$700.00	$ 9,000
Stripping, Excavation	C.Y.	18,670	1.00	19,000
Inspection Trench	C.Y.	18,670	3.00	56,000
Embankment	C.Y.	63,000	1.00	63,000
Borrow Excavation	C.Y.	75,600	1.10	83,000
96" RCP Drainage Pipes	L.F.	80	1,200.00	96,000
Concrete Closure and Vault	Job	1	L.S.	30,000
Seeding and Fertilizing	Acre	26	900.00	24,000
Contingencies @ 20%				76,000
Construction Cost				$ 456,000
Engineering and Design @ 15%				73,000
Supervision and Inspection @ 6%				27,000
Overhead @ 3.5%				16,000
Federal Cost				$572,000
Non-Federal				
Levee Right-of-Way	Acre	17	1,500.00	26,000
Borrow Right-of-Way	Acre	8	500.00	4,000
Utilities and Relocation	Job	1	L.S.	20,000
Land Acquisition	Job	1	L.S.	75,000
Contingencies @ 20%				25,000
Total Non-Federal Cost				$150,000
Total Project Cost				$722,000

TABLE F-10

DETAILED ESTIMATED COST
BEAVER CREEK LEVEE UNIT 5
10-YEAR PROTECTION
GRAND LAKE ST. MARYS, OHIO

Item	Unit	Quantity	Unit Cost	Amount (Rounded)
Federal				
Light Clearing	Acre	9	$700.00	$ 6,000
Stripping, Excavation	C.Y.	8,500	1.00	9,000
Inspection Trench	C.Y.	13,225	3.00	40,000
Embankment	C.Y.	17,150	1.00	17,000
Borrow Excavation	C.Y.	20,570	1.10	23,000
96" RCP Drainage Pipes	L.F.	40	1,200.00	48,000
Concrete Closure and Vault	Job	-	-	-
Seeding and Fertilizing	Acre	4	900.00	4,000
Contingencies @ 20%				29,000
Construction Cost				$ 176,000
Engineering and Design @ 15%				30,000
Supervision and Inspection @ 6%				12,000
Overhead @ 3.5%				7,000
Federal Cost				$225,000
Non-Federal				
Levee Right-of-Way	Acre	9	1,500.00	14,000
Borrow Right-of-Way	Acre	2	500.00	1,000
Utilities and Relocation	Job	1	L.S.	100,000
Land Acquisition	Job	1	L.S.	50,000
Contingencies @ 20%				33,000
Total Non-Federal Cost				$198,000
Total Project Cost				$423,000

TABLE F-11

DETAILED ESTIMATED COST
BEAVER CREEK LEVEE UNIT 6
10-YEAR PROTECTION
GRAND LAKE ST. MARYS, OHIO

Item	Unit	Quantity	Unit Cost	Amount (Rounded)
Federal				
Light Clearing	Acre	10	$700.00	$ 7,000
Stripping, Excavation	C.Y.	10,800	1.00	11,000
Inspection Trench	C.Y.	10,100	3.00	31,000
Embankment	C.Y.	39,600	1.00	40,000
Borrow Excavation	C.Y.	47,500	1.10	52,000
96" RCP Drainage Pipes	L.F.	40	1,200.00	48,000
Concrete Closure and Vault	Job	-	-	-
Seeding and Fertilizing	Acre	14	900.00	13,000
Contingencies @ 20%				40,000
Construction Cost				$ 242,000
Engineering and Design @ 15%				39,000
Supervision and Inspection @ 6%				16,000
Overhead @ 3.5%				10,000
Federal Cost				$307,000
Non-Federal				
Levee Right-of-Way	Acre	10	1,500.00	15,000
Borrow Right-of-Way	Acre	5	500.00	3,000
Utilities and Relocation	Job	1	L.S.	10,000
Land Acquisition	Job	1	L.S.	15,000
Contingencies @ 20%				9,000
Total Non-Federal Cost				$ 52,000
Total Project Cost				$359,000

TABLE F-12

DETAILED ESTIMATED COST
BEAVER CREEK LEVEE UNIT 7
10-YEAR PROTECTION
GRAND LAKE ST. MARYS, OHIO

Item	Unit	Quantity	Unit Cost	Amount (Rounded)
Federal				
Light Clearing	Acre	25	$700.00	$ 18,000
Stripping, Excavation	C.Y.	29,500	1.00	30,000
Inspection Trench	C.Y.	21,780	3.00	65,000
Embankment	C.Y.	141,120	1.00	141,000
Borrow Excavation	C.Y.	169,350	1.10	186,000
96" RCP Drainage Pipes	L.F.	140	1,200.00	168,000
Concrete Closure and Vault	Job	-	L.S.	-
Seeding and Fertilizing	Acre	43	900.00	39,000
Contingencies @ 20%				129,000
Construction Cost				$ 776,000
Engineering and Design @ 15%				116,000
Supervision and Inspection @ 6%				47,000
Overhead @ 3.5%				27,000
Federal Cost				$966,000
Non-Federal				
Levee Right-of-Way	Acre	25	1,500.00	38,000
Borrow Right-of-Way	Acre	17	500.00	9,000
Utilities and Relocation	Job	1	L.S.	30,000
Land Acquisition	Job	1	L.S.	60,000
Contingencies @ 20%				27,000
Total Non-Federal Cost				$ 164,000
Total Project Cost				$1,130,000

TABLE F-13

COST ESTIMATE FOR SHORELINE LEVEES
(MOORMAN ROAD EXAMPLE)

Item	Cost per Lin. Ft.		Amount (Rounded)			
			Access Channel Maintained		Access Channels Not Maintained	
	2' Levee	5' Levee	2' Levee	5' Levee	2' Levee	5' Levee
			14,000 LF	14,000 LF	5,000 LF	5,000 LF
Federal						
Light Clearing	$ .46	$ .67	$ 6,400	$ 9,400	$ 2,300	$ 3,400
Stripping, Excavation	5.92	8.60	82,900	120,400	29,600	43,000
Embankment	13.04	32.16	182,600	450,300	65,200	160,800
Placed Riprap (lakeside)	14.00	24.60	210,000	344,400	75,000	123,000
Seeding and Fertilizing	4.52	6.42	63,300	89,900	22,600	32,100
Subtotal	$37.94	$72.45	$545,200	$1,014,400	$194,700	$362,300
Contingencies @ 20%	7.59	14.49	106,300	202,900	38,000	72,500
Construction Cost	$45.53	$86.94	$651,500	$1,217,300	$232,700	$434,800
Engineering and Design @ 15%	6.83	13.04	95,600	182,600	24,100	65,200
Supervision and Inspection @ 6%	2.73	5.22	38,200	73,100	13,600	26,100
Overhead @ 3.5%	1.59	3.04	22,300	42,600	8,000	15,200
Subtotal, Federal Cost	$56.68	$108.24	$807,600	$1,515,600	$288,400	$541,300
Non-Federal						
Levee Right-of-Way	$ 9.18	$13.31	$128,500	$186,300	$45,900	$66,500
Land Acquisition Cost	.55	.80	7,700	11,200	2,700	4,000
Subtotal	$ 9.73	$14.11	$136,200	$197,500	$48,600	$70,500
Contingencies @ 20%	$ 1.95	$ 2.82	27,200	39,500	9,700	14,100
Subtotal, Non-Federal Cost	$11.68	$16.93	$163,400	$237,000	$58,300	$84,600
TOTAL ESTIMATED FIRST COST	$68.36/LF	$125.17/LF	$957,000	$1,752,600	$342,000	$626,000

TABLE F-14

COST ESTIMATE FOR SEDIMENT PONDS ON MAJOR TRIBUTARIES
GRAND LAKE ST. MARYS, OHIO

	Coldwater Creek		Beaver Creek		Prairie Creek		Chickasaw Creek		L. Chickasaw Creek		Barnes Creek	
	4 hr.	20 hr.	4 hr.	20 hr.	4 hr.	20 hr.	4 hr.	20 hr.	4 hr.	20 hr.	4 hr.	20 hr.
Federal												
Clearing and Grubbing	$ 12,100	$ 63,500	$ 13,300	$ 67,700	$ 3,200	$ 16,700	$ 11,900	$ 60,600	$ 4,300	$ 22,400	$ 2,100	$ 11,500
Excavation	45,800	240,600	50,500	256,300	12,100	63,300	44,900	229,400	16,500	84,600	8,000	43,400
Embankment	36,200	189,900	40,000	202,300	9,600	49,900	35,400	181,100	13,000	66,800	6,300	34,200
Outlet Works	50,000	262,500	55,100	279,700	13,200	69,000	48,900	250,300	18,000	92,300	8,700	47,300
Sampling Facilities	6,500	6,500	6,500	6,500	6,500	6,500	6,500	6,500	6,500	6,500	6,500	6,500
Contingencies, 25%	37,700	190,800	41,400	203,100	11,200	51,300	36,900	182,000	14,600	68,100	7,900	35,700
Subtotal	$188,300	$ 953,800	$206,800	$1,015,600	$55,800	$256,700	$184,500	$ 909,900	$ 72,900	$340,700	$39,500	$178,600
Engineering and Design, 25%	47,000	238,500	51,700	253,900	13,900	64,200	46,100	227,500	18,200	85,300	9,800	44,700
Supv. & Insp., 6%	11,300	57,200	12,400	61,000	3,300	15,400	11,100	54,600	4,400	20,400	2,400	10,700
Overhead, 3.5%	6,600	33,400	7,300	35,500	2,000	9,000	6,400	31,800	2,500	11,900	1,400	6,200
Subtotal, Federal	$253,200	$1,282,900	$278,200	$1,366,000	$ 75,000	$345,300	$248,100	$1,223,800	$ 98,000	$458,300	$ 53,100	$240,200
Non-Federal												
Rights-of-way, Land	52,500	256,500	55,500	273,000	15,000	69,000	49,500	244,500	19,500	91,500	10,500	48,000
Acquisition, 8%	4,200	20,500	4,400	21,800	1,200	5,500	4,000	19,600	1,600	73,000	800	3,800
Contingencies, 25%	13,100	64,100	13,900	68,200	3,800	17,200	12,400	61,100	4,900	22,900	2,600	12,000
Subtotal, Non-Federal	$ 69,800	$341,100	$ 73,800	$363,000	$20,000	$ 91,700	$ 65,900	$325,200	$ 26,000	$121,700	$13,900	$ 63,800
TOTAL ESTIMATED FIRST COST	$323,000	$1,624,000	$352,000	$1,729,000	$95,000	$437,000	$314,000	$1,549,000	$124,000	$580,000	$67,000	$304,000

ANNUAL COSTS

Construction time was estimated to require less than two years for any of the structural plans; therefore, investment costs are based on first costs for construction. Annual costs are computed using 7-1/8 percent interest rate and 50-year economic life. Operation and maintenance costs are estimated after reviewing these costs accruing to similar projects. Annual costs for the structural alternatives are developed in Table F-15.

TABLE F-15

ANNUAL COSTS 1/ FOR CONSIDERED STRUCTURAL PLANS

Item	Beaver Creek/Lakeshore		Lakeshore			
			Levees (Moorman Road Example)			
	Detention Basins "A","B","C","D"	Diversion to Fourmile Creek	w/Boater Access		w/o Boater Access	
			2-foot	5-foot	2-foot	5-foot
Federal						
Interest (.07125)	1,019.5	224.6	57.5	108.0	20.6	38.6
Amortization (.00236)	33.8	7.5	1.9	3.6	.7	1.3
Inspection	1.2	.5	.2	.2	.2	.2
Subtotal, Federal	1,054.5	232.0	59.6	111.8	21.5	40.1
Non-Federal						
Interest (.07125)	166.5	25.5	11.6	16.9	4.2	6.0
Amortization (.236)	5.6	.9	.4	.6	.2	.2
Operation and Maintenance	162.5	30.0	3.9	3.9	1.4	1.4
Subtotal, Non-Federal	334.6	56.4	15.9	21.4	5.8	7.6
TOTAL ANNUAL COST	1,389.1	299.0	75.5	133.2	27.3	47.7

1/ At 7-1/8 percent interest rate and 50-year economic life.

TABLE F-15 (Continued)

ANNUAL COSTS 1/ FOR CONSIDERED STRUCTURAL PLANS ($1,000)

Item	Clearing, Cleaning, Snagging	Beaver Creek Channel Widening		Agricultural Levees						
				Levee Section						
		45-65'	60-70'	1	2	3	4	5	6	7
Federal										
Interest (.07125)	65.9 2/	93.8	280.2	36.7	26.4	21.0	40.8	16.0	21.9	68.8
Amortization (.00236)	14.5 2/	3.1	9.3	1.3	.9	.7	1.4	.6	.8	1.0
Inspection	4.0	.3	.3	.2	.2	.2	.2	.2	.2	.2
Subtotal, Federal	84.4	97.2	289.8	38.2	27.5	21.9	42.4	16.8	22.9	70.0
Non-Federal										
Interest (.07125)	1.4 2/	20.9	100.5	5.6	4.9	4.0	10.7	14.1	3.7	11.7
Amortization (.00236)	1.3 2/	.7	3.3	.2	.2	.2	.4	.5	.2	.4
Operation and Maintenance	10.5	111.0	130.0	3.0	2.4	1.5	3.4	2.4	1.8	4.0
Subtotal, Non-Federal	13.2	131.6	233.8	8.8	7.5	5.7	14.7	17.0	5.7	16.1
TOTAL ANNUAL COST	97.6	228.8	523.6	47.0	35.0	27.6	56.9	33.8	28.6	86.1

1/ At 7-1/8 percent interest rate and 50-year economic life except where noted.
2/ At 7-1/8 percent interest rate and 25-year economic life.

SECTION G

FLOOD DAMAGES AND BENEFITS

SECTION G

FLOOD DAMAGES AND BENEFITS

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SECTION G

FLOOD DAMAGES AND BENEFITS

FLOOD DAMAGES

The areas considered for evaluation of flood damages and benefits include the 10.6-mile reach of Beaver Creek from its confluence with the Wabash River at mile point 0.0, upstream to mile point 10.6 at the western outlet of Grand Lake St. Marys, and the south shore rim of Grand Lake St. Marys from the southwest corner to the extreme southeast corner. The extent of flooding and character of flood losses were determined from a survey and appraisal of property in these two distinct areas. Office studies included the compilation and analysis of the collected data, determination of affected areas, preparation of work data, stage-damage curves, frequency damage curves, and computations of average annual damages. The conditions of development and price level are based on the field investigations made especially for this report in May 1979, November 1979, and February 1980.

Extent and Character of the Study Area

The study area is situated in Mercer and Auglaize Counties in west central Ohio on the watershed divide between the Wabash and St. Marys Rivers. The lake has a surface area of approximately 21 square miles, is eight miles in length, and averages over two miles in width, north and south. Beaver Creek flows approximately 10.6 miles from the western end of Grand Lake St. Marys to its confluence with the Wabash River, while the eastern discharge flows into the St. Marys River, via the Miami and Erie Canal. For study purposes, Beaver Creek is divided into two reaches, reach BC-1 extends from the confluence of Beaver Creek and the Wabash River at stream mile 0.0, to stream mile 4.75, and Reach BC-2 from stream mile 4.75 to Grand Lake St. Marys at stream mile 10.6. Selected representative gauging locations within the lower and upper reaches were selected at stream miles 2.67 and 7.50, respectively.

Within those areas immediately adjacent to the lake, the land is primarily agricultural and open land, approximately sixty percent of which is equipped with some form of tile drainage system. Per field survey efforts in conjunction with pertinent office data, it was determined that the majority of land in the Beaver Creek flood plain is used for corn, soybeans, and hay production, with average per acre yields of 101 bushels, 28 bushels, and 1.5 tons, respectively, under flood-free conditions.

Two local real estate agents were contacted during the December 1979 field survey effort concerning the evaluation of property within the estimated 3,216-acre flood plain of Beaver Creek. A conservative overall estimate of the value of the farmland was $800 less per acre for farms in the Beaver Creek flood plain than for comparable farms in the county removed from flooding problems. The prevailing price for medium size farms, with improvements, was estimated to average $2,700 per acre in the general primary areas of Mercer County compared to approximately $1,900 an acre for properties located in the Beaver Creek flood plain. Area-inundated curves for reaches BC-1 and BC-2 are shown in Plates G-2 and G-3.

The land adjacent to the lake, particularly along the south shore, consists of many private and commercial establishments used primarily for recreational purposes, along with several residential subdivisions. Much of the land to the north of the lake remains undeveloped. To the surrounding towns of St. Marys, Celina, Montezuma, Coldwater and Wapokoneta, there are sizeable revenues to be earned each year from the commercial base directly dependent upon recreation on the lake. Table G-1 presents a summary of the number and value of units within the study area affected by the 100-year flood.

TABLE G-1

ESTIMATED VALLUE AND NUMBER OF UNITS
AFFECTED BY THE 100-YEAR FLOOD[1/]
GRAND LAKE, ST. MARYS, OHIO

Area	Type Property	Units	Value ($1,000)
Grand Lake, South Shore	Residential	142	6,390
Beaver Creek Reach BC-1	Agricultural	1,815 [2/]	3,450
	Transportation & Utilities	L.S.	3,600
Total Reach BC-1			7,050
Reach BC-2	Agricultural	1,400 [2/]	2,660
	Transportation & Utilities	L.S.	1,550
Total Reach BC-2			4,160
Total Study Area			17,600

1/ October 1979 prices and conditions.
2/ Acres.

Tangible Damages

Present (1979) flood damages were determined for crop, non-crop, transportation facilities, and public utilities categories along Beaver Creek. Residential damages were evaluated for the Grand Lake St. Marys south shore properties. Estimation of these damages was based on field survey data gathered during May 1979, November 1979, and February 1980, and subsequent office studies. Damage to each category of development within the 100-year and the 10-year flood frequency zones are tabulated in Table G-2.

It has been determined that two present condition assumptions currently exist. Through discussion with the Grand Lake St. Marys Park Management it was determined that the present conditions are represented by an estimated 200 cfs annual outflow and 200 cfs maximum west bank conduit release depicted as frequency-elevation Curve A. Through observation, curve A^1 was also computed and plotted to reflect present conditions for Beaver Creek with a coincident spillway outflow from Grand Lake St. Marys. The damages and benefits accruing to Beaver Creek and Grand Lake St. Marys which appear in the preceding tables were evaluated from both sets of present condition assumptions.

TABLE G-2

ESTIMATED DAMAGES FOR OCCURRENCE
OF SPECIFIC FLOODS[1/]
GRAND LAKE ST. MARYS, OHIO

Area	Property Category	100-Year Flood	10-Year Flood
Grand Lake, South Shore	Residential	635.0	465.0
Beaver Creek Reach BC-1[2/]	Crop	18.3	14.5
	Non-Crop	21.5	18.0
	Transportation Facilities	8.0	2.6
	Public Utilities	9.6	7.2
	Subtotal	57.4	42.3
Reach BC-2[2]	Crop	19.5	19.0
	Non-Crop	10.1	4.6
	Transportation Facilities	11.6	3.7
	Public Utilities	13.9	4.6
	Subtotal	55.1	31.9
	Total	747.5[3/]	539.2[3/]
Reach BC-1[4/]	Crop	18.3	14.4
	Non-Crop	21.6	17.6
	Transportation Facilities	8.1	2.5
	Public Utilities	9.7	7.1
	Subtotal	57.7	41.6
Reach BC-2[4/]	Crop	21.7	18.9
	Non-Crop	10.6	4.0
	Transportation Facilities	11.9	3.1
	Public Utilities	15.4	4.3
	Subtotal	59.6	30.3
	Total	752.3[3/]	536.9[3/]

1/ October 1979 price levels and conditions.
2/ Based on A as the present condition.
3/ Damages for Grand Lake St. Marys included in totals.
4/ Based on A^1 as the present condition.

Character of Flood Losses

The general character of losses to major property categories of development are discussed in the following paragraphs.

Crop. The analysis of crop damages involved relating flooding along Beaver Creek to crop gross valuation data. The gross crop damage per acre values for reaches BC-1 and BC-2 were determined for the major crops produced in the study area (corn, soybeans, and hay) based on estimated current average flood-free yields and normalized prices provided by the U.S. Water Resources Council, dated September 1979. Crop damage curves, developed by relating crop area inundation data and gross crop valuation data, are shown on Plates G-4 and G-5 for reaches BC-1 and BC-2.

Non-Crop Damages. This category consists of damage to agricultural properties other than crop, i.e., siltation of tile, debris removal, land erosion, and repair and maintenance of surface ditches and on farm roads and levees. Damage to personal property such as farm buildings, feedlots, and fencing is virtually nonexistent; therefore, it will not be considered in this report. Plates G-6 and G-7 show estimated non-crop damage curves for reaches BC-1 and BC-2.

Transportation Damages. This category includes estimates of physical damages to roads, road fills, bridges and culverts based on interviews with county and state highway departments and supplemented by pertinent in-office data. Disruptions of public traffic due to floods were described as very infrequent, involving isolated cases of short duration. Estimated transportation damages curves for reaches BC-1 and BC-2 appear as Plates G-8 and G-9.

Public Utilities. Representatives of telephone, gas and electric, water, and other public utility services were contacted about flood damage costs incurred along Beaver Creek. In most cases, problems resulting from flooding were described as minimal and were considered to be little more than the cost of normal maintenance. Damages to public utilities, although not of great significance in the study area, are illustrated by the public utilities damage curves presented as Plates G-10 and G-11.

Urban. Flood damage surveys were made at selected residences along the Grand Lake St. Marys shoreline area. Because commercial establishments in the area were located either at elevations out of reach of flooding, or sufficiently removed from the lake shore, damages were virtually nonexistent, and therefore not evaluated here. A sampling of dwellings were surveyed as to dollar amounts of residential damage, debris removal, content damages, and other areas in which costs were incurred as a result of flooding.

The residential damage curve is shown as Plate G-12. The total value of residences along the south shore of the lake was estimated at $6,390,000.

Average Annual Damage

Average annual damages are the weighted averages of all damages that would be expected to occur on a yearly average basis. Present (1979) average annual flood damages were computed by relating damage curve data to that provided by all-season flood frequency curves for reaches BC-1, BC-2, and the lake shore area.

Present average annual damages for the south shore are estimated to be $150,000 for some 142 private shoreline properties. Average annual damages in reaches BC-1 and BC-2 of Beaver Creek were evaluated for the two present condition assumptions. Present average annual damages in the considered area are presented in Table G-3.

Flood damages for the lake shoreline area are attributed to a high lake level combined with wave action. The probability of damage is depicted on the damage-frequency curve, which is developed by plotting damage for stage (from the stage damage curve) against flood exceedence frequency for comparable increments of stage. The damage frequency

TABLE G-3

ESTIMATED AVERAGE ANNUAL DAMAGES 1/
PRESENT AND FUTURE
GRAND LAKE ST. MARYS, OHIO

Area	Damage Category	Average Annual Damages 1979 ($1,000)	1985 ($1,000)	2035 ($1,000)	Total AAFD ($1,000)
Grand Lake, South Shore	Residential	150.0	161.0	192.7	185.0
Beaver Creek					
Reach BC-1 2/	Crop	30.8	33.8	51.2	39.7
	Non-Crop	9.7	9.7	9.7	9.7
	Transportation Facilities	1.4	1.4	1.4	1.4
	Public Utilities	3.9	3.9	3.9	3.9
	Subtotal	45.8	48.8	66.2	54.7
Reach BC-2 2/	Crop	32.4	35.7	55.3	42.5
	Non-Crop	3.2	3.2	3.2	3.2
	Transportation Facilities	1.3	1.3	1.3	1.3
	Public Utilities	2.2	2.2	2.2	2.2
	Subtotal	39.1	42.4	62.0	49.2
Reach BC-1 3/	Crop	21.2	23.3	35.3	27.3
	Non-Crop	7.7	7.7	7.7	7.7
	Transportation Facilities	1.1	1.1	1.1	1.1
	Public Utilities	3.4	3.4	3.4	3.4
	Subtotal	33.4	35.5	47.5	39.5
Reach BC-2 3/	Crop	21.6	23.8	36.9	28.3
	Non-Crop	1.8	1.8	1.8	1.8
	Transportation Facilities	1.2	1.2	1.2	1.2
	Public Utilities	1.7	1.7	1.7	1.8
	Subtotal	26.3	28.5	41.6	33.0
	TOTALS 4/	209.7	225.0	281.8	257.5

1/ Based on October 1979 price levels.
2/ Based on curve A as the present condition.
3/ Based on A1 as the present condition.
4/ Average annual damages from Grand Lake south shore included in totals.

curve for the Grand Lake St. Marys south shore is shown on Plate G-13. Based on curve A as the present condition, composite damage-frequency curves for Beaver Creek reaches BC-1 and BC-2 are shown as Plates G-14 and G-15, respectively. Based on curve A^1 as the present condition, the composite damage frequency curves for Beaver Creek reaches BC-1 and BC-2 are shown as Plates G-16 and G-17, respectively.

Intangible Damages

Occasionally the greatest damages caused by floods are those that have little economic relevancy. In the Grand Lake St. Marys study area the occurrence of flooding disrupts social well-being and contributes to the deterioration of the environment, housing, business, economic development, and recreation. Flooding discourages further development, reduces motivation and strains local resources.

Future Conditions

The magnitude of future flood damages in the urban area on the south shore of Grand Lake St. Marys can be affected by changes in both the number of structures and the real value of damageable property in the flood plain. Increases in the real value of damageable property, primarily contents of residential structures, or affluence growth, was evaluated and appears in Table G-3.

In the Beaver Creek portion of the study area, crop yield increases are expected to account for most future increases in damages. The Economic Research Service, USDA, has developed crop yield projections for the nation and for the states where the commodity amounts to one percent or more of the national output. By use of the ERS methods and procedures, crop yield projections were developed for the study area, and extended to the year 2035 to provide a 50-year projection period. The data were utilized to project future crop damages. The future damages were then discounted at the current FY 71 7-1/8 percent Federal interest rate. The present and average annual equivalent flood damages for Beaver Creek also appear in Table G-3.

FLOOD REDUCTION BENEFITS

Flood damage reductions were evaluated for each of the alternative plans discussed herein. Tangible average annual benefits occur from the reduction in present average annual damages resulting from the full operation of the alternative channel improvement plans for Beaver Creek reaches BC-1 and BC-2 (Plate G-1), and the lake regulation and levee plans for Grand Lake St. Marys.

The concept of shoreline levees has been considered as a measure to reduce flood damage due to high, uncontrolled lake levels resulting from isolated storm events. Two levee heights, two feet and five feet, were selected for analysis based on stage-frequency data for lake levels. To evaluate the economic feasibility of a levee system along the south shore of the lake, the area located west of Moorman Road and State Route 703, which was considered representative of conditions along the south shore, was selected. Two cases of levee layout were examined; the first retains total channel access to the lake, and the second minimizes levee length by cutting off the access channels. It was concluded, based on total project construction cost and benefits (Section D, Table D-7) that the two 2-foot high levee across the access channels was the only cost effective levee plan.

In order to derive average annual equivalent benefits for Beaver Creek reaches BC-1 and BC-2, future (1985) damages were discounted at the 7-1/8 percent Federal interest rate, then added to base year damages for each of the alternative channel modification plans to derive average annual equivalent (AAE) damages; the AAE damages were then subtracted from AAE damges computed for the present condition, resulting in total average annual equivalent benefits.

Affluence benefits to base year and future residential property contents were evaluated for Grand Lake St. Marys based on per capita income projected by OBERS for BEA Economic Area 069, within which the study area is located. The affluence projects were carried out to the year in which the value of the residential contents equates to 75 percent of the value of the residential structures with no increase thereafter. The reduction in present average annual damages afforded by each of the alternative plans considered, and the resultant average annual equivalent benefits, are presented in Table G-4 for Beaver Creek and G-5 for Grand Lake St. Marys. A comparison of flood reductions along Beaver Creek, by foot, between the alternatives, is shown in Table G-6. The reduction in the Grand Lake St. Marys pool elevation by the considered lake regulation plan considered is presented in Table G-7.

TABLE G-4

FLOOD DAMAGE REDUCTION
CONSIDERED PLANS OF IMPROVEMENT
GRAND LAKE ST. MARYS, OHIO

BEAVER CREEK

Area	Considered Plan	Flood Damage Reduction	Avg. Annual Equivalent Benefits
Beaver Creek			
Reach BC-1 2/	Channel Improvement		
	28-ft bottom width 3/	27.0	32.4
	48-ft bottom width 4/	35.7	42.7
	60-ft bottom width 4/	39.8	47.7
	68-ft bottom width 5/	36.3	43.4
Reach BC-2 2/	28-ft bottom width 3/	29.5	37.3
	48-ft bottom width 4/	35.1	44.7
	60-ft bottom width 4/	37.3	46.9
	68-ft bottom width 5/	35.8	45.2
Total	28-ft bottom width 3/	56.5	69.7
	48-ft bottom width 4/	70.8	87.0
	60-ft bottom width 4/	77.1	94.6
	68-ft bottom width 5/	72.1	88.6
Reach BC-1 6/	28-ft bottom width 3/	14.4	17.0
	48-ft bottom width 4/	23.1	27.4
	60-ft bottom width 4/	27.3	32.3
	68-ft bottom width 5/	23.8	28.0
Reach BC-2 6/	28-ft bottom width 3/	16.6	21.0
	48-ft bottom width 4/	22.2	28.0
	60-ft bottom width 4/	24.4	30.7
	68-ft bottom width 5/	22.9	28.9
Total	28-ft bottom width 3/	31.0	38.0
	48-ft bottom width 4/	45.3	55.4
	60-ft bottom width 4/	51.7	63.0
	68-ft bottom width 5/	46.7	56.9

1/ October 1979 price levels and conditions.
2/ Curve A represents the natural condition.
3/ C&S Mercer County channel improvement.
4/ With no spillway outflow
5/ With present lake regulation.
6/ Curve A^1 represents the natural condition.

TABLE G-5

FLOOD DAMAGE REDUCTION
CONSIDERED PLANS OF IMPROVEMENT
GRAND LAKE ST. MARYS, OHIO

GRAND LAKE ST. MARYS

Area	Considered Plan	Flood Damage Reduction	Avg. Annual Equivalent Benefits 2/
Grand Lake St, Marys	Lake regulation: 200 cfs conduit plus spillway discharge 1/	21.5	26.6
	Shoreline levee: 2 feet in height	23.0	28.4
	Shoreline levee: 5 feet in height	23.0	28.4

1/ Represents plan which allows for maximum attainment of the recreation pool and minimization of the flood damages along the south shore: a winter pool drawdown of 1 foot, a 1 March filling date, and a 200 cfs conduit plus spillway discharge.

2/ Average annual equivalent benefits include affluence growth to residential contents

TABLE G-6

COMPARATIVE FLOOD REDUCTION DATA
ALTERNATIVE PLANS OF IMPROVEMENT
GRAND LAKE ST. MARYS, OHIO

BEAVER CREEK

Area	Considered Plan	Flood Reduction in Feet 1/ 1-Year Flood	10-Year Flood	100-Year Flood
Beaver Creek	Channel Improvement			
Reach BC-1 2/	28-ft bottom width	1.7	0.9	0.8
	48-ft bottom width	2.9	1.7	1.8
	60-ft bottom width	3.8	2.5	2.4
	68-ft bottom width	2.8	2.1	1.7
Reach BC-2 2/	28-ft bottom width	2.5	1.1	0.5
	48-ft bottom width	4.1	2.1	0.9
	60-ft bottom width	5.3	3.4	1.1
	68-ft bottom width	3.8	2.5	1.0
Reach BC-1 3/	28-ft bottom width	1.2	0.8	1.2
	48-ft bottom width	2.3	1.6	2.2
	60-ft bottom width	3.2	2.4	2.9
	68-ft bottom width	2.2	2.0	2.7
Reach BC-2 3/	28-ft bottom width	1.8	1.0	0.7
	48-ft bottom width	3.4	2.0	1.1
	60-ft bottom width	4.6	3.2	1.8
	68-ft bottom width	3.1	2.4	1.1

1/ At hypothetical gage miles 2.67 and 7.50 Beaver Creek, reaches BC-1 and BC-2, respectively.
2/ Based on curve A as the natural condition.
3/ Based on curve A^1 as the natural condition.

TABLE G-7

COMPARATIVE FLOOD REDUCTION DATA
ALTERNATIVE PLANS OF IMPROVEMENT
GRAND LAKE ST. MARYS, OHIO

GRAND LAKE ST. MARYS

Area	Considered Plan	Flood Reduction in Feet 1/ 1-Year Flood	10-Year Flood	100-Year Flood
Grand Lake St. Marys	Lake Regulation: 200 cfs conduit plus plus spillway discharge	0.4	0.3	Nil

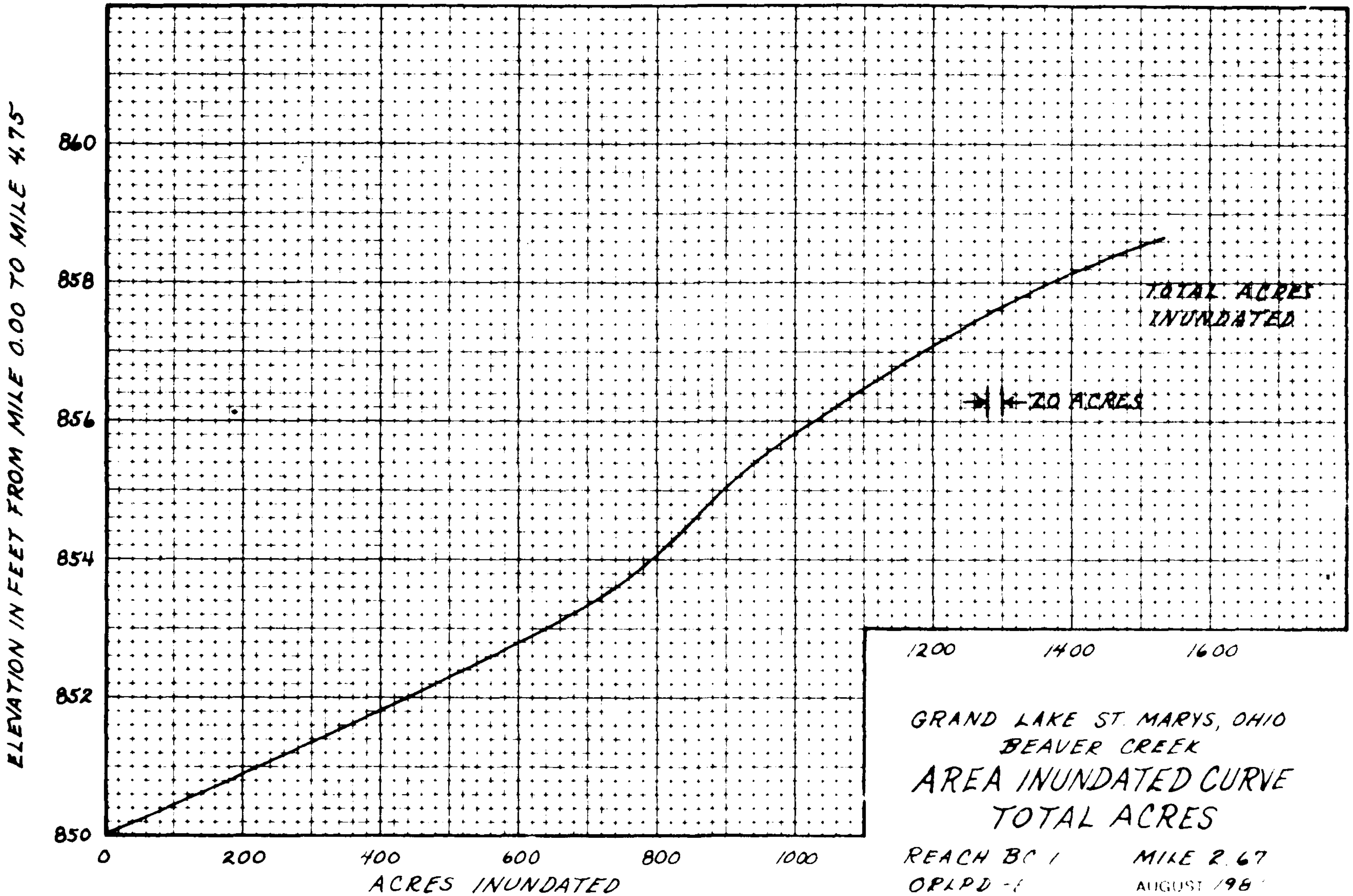
1/ Represents winter pool drawdown of 1 foot, a 1 March filling date, and a 200 cfs conduit plus spillway discharge

SECTION G

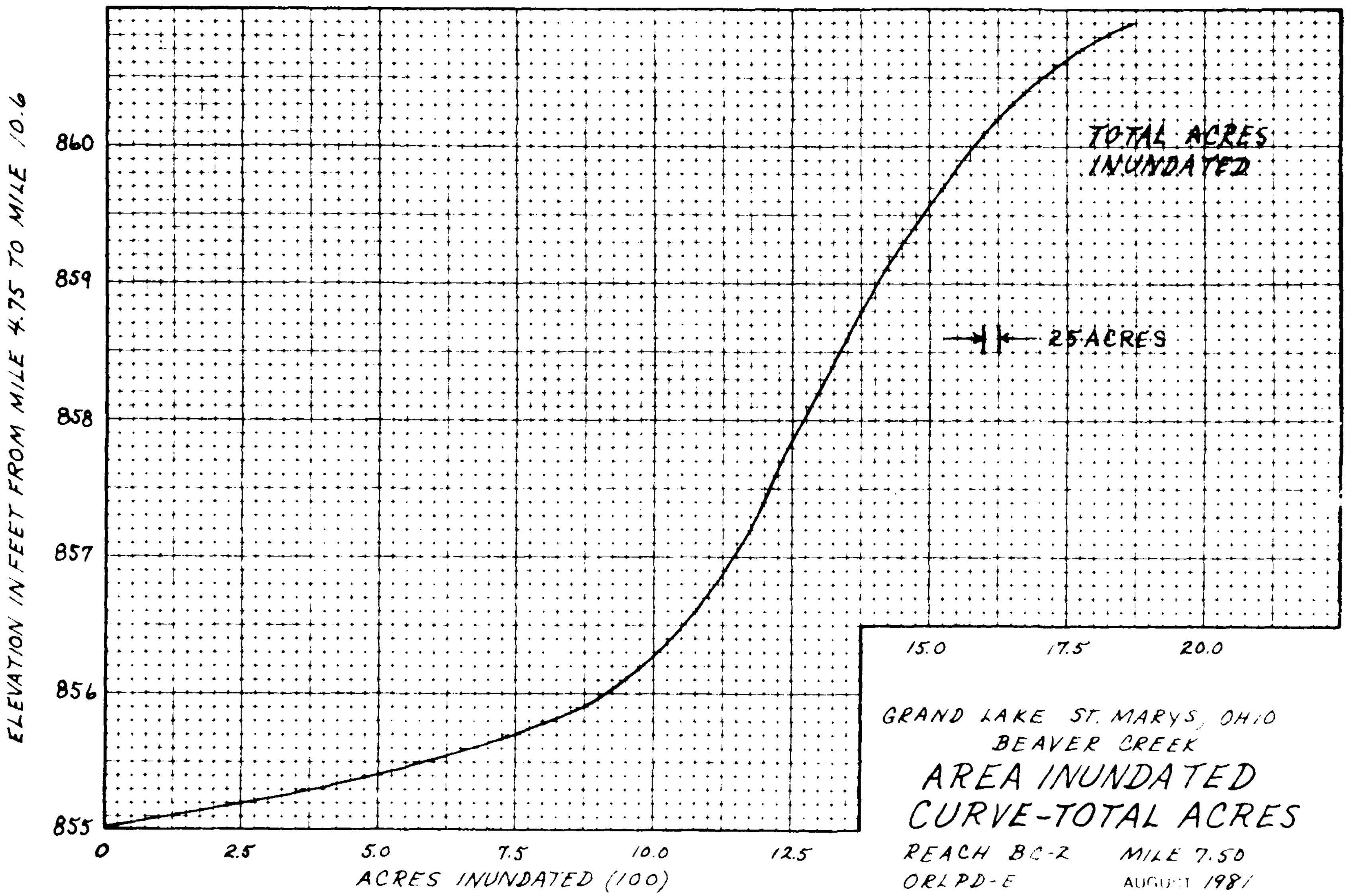
PLATES

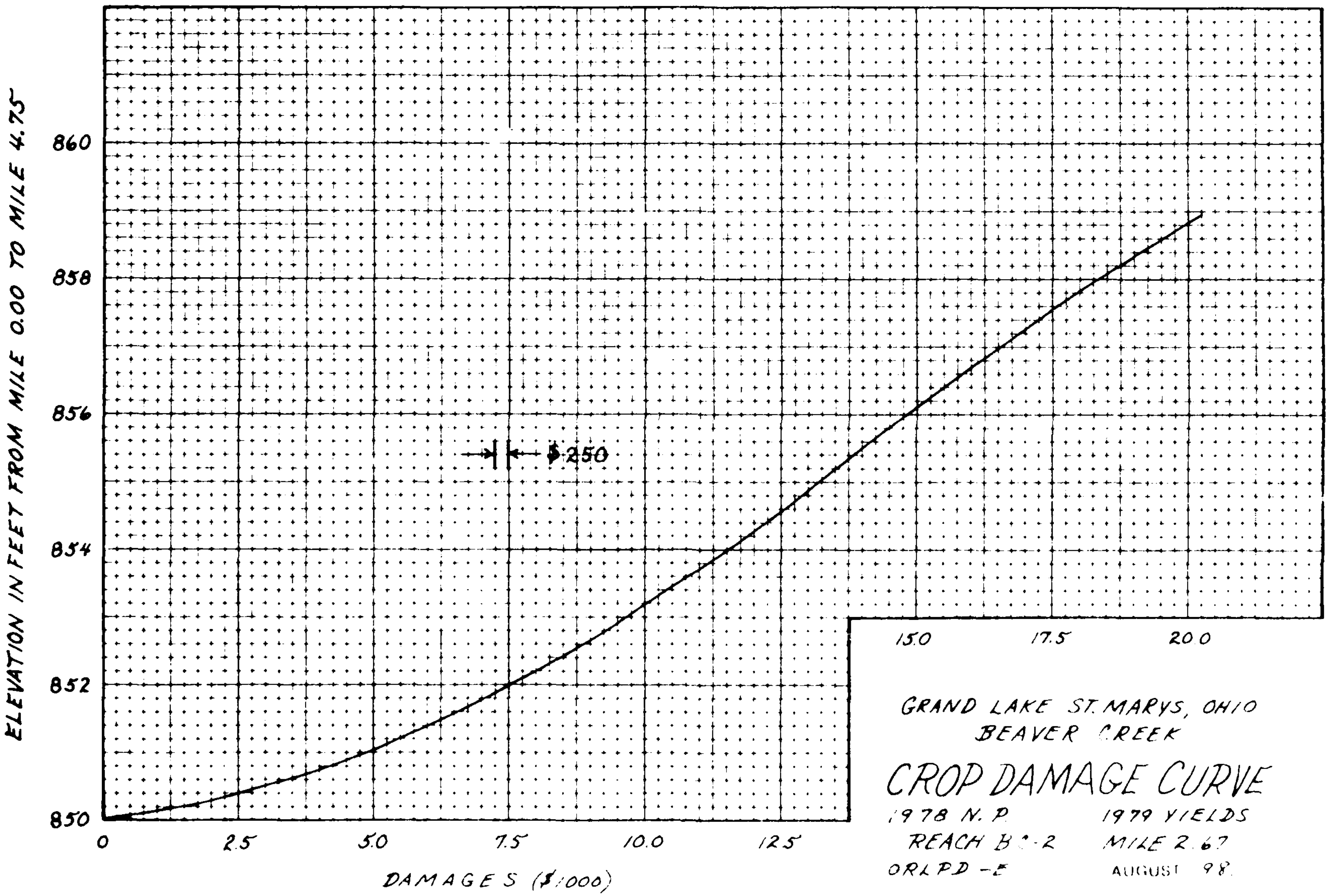
SUMMARY OF ALTERNATIVE CHANNEL IMPROVEMENT PLANS
AND PRESENT CONDITIONS

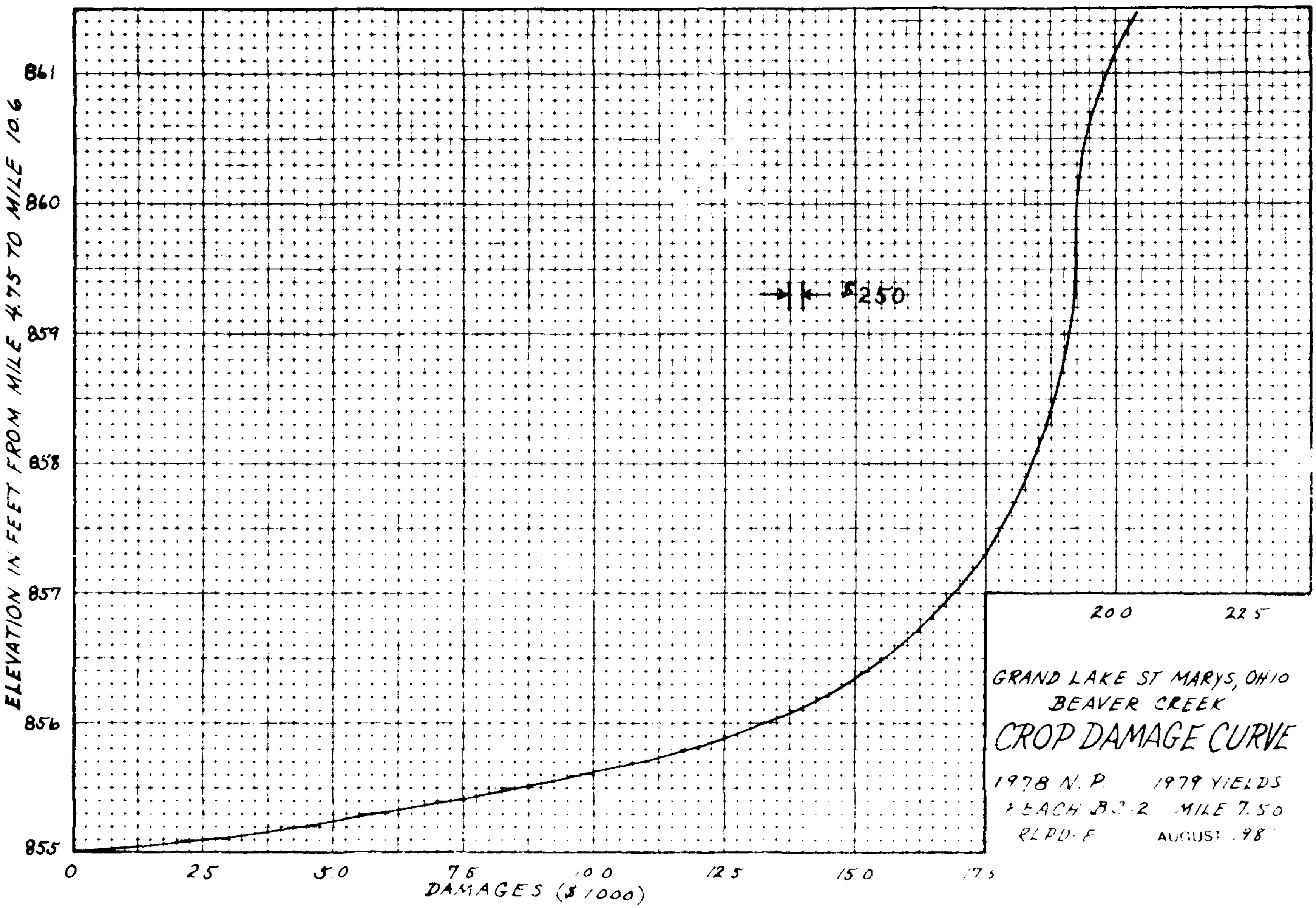
A'	Present conditions; coincident flows (Beaver Creek plus Grand Lake spillway outflow)
A	Assume 200 cfs annual outflow and 200 cfs maximum controlled release
B	28-foot channel improvement (C & S Mercer County channel improvement)
C	48-foot channel improvement, no spillway outflow
D	60-foot channel improvement, no spillway outflow
D'	68-foot modified channel present lake regulation



GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK
AREA INUNDATED CURVE
TOTAL ACRES
REACH BC 1
MILE 2.67
AUGUST 198
TOTAL ACRES INUNDATED
20 ACRES
ELEVATION IN FEET FROM MILE 0.00 TO MILE 4.75
ACRES INUNDATED
850
852
854
856
858
860
0
200
400
600
800
1000
1200
1400
1600

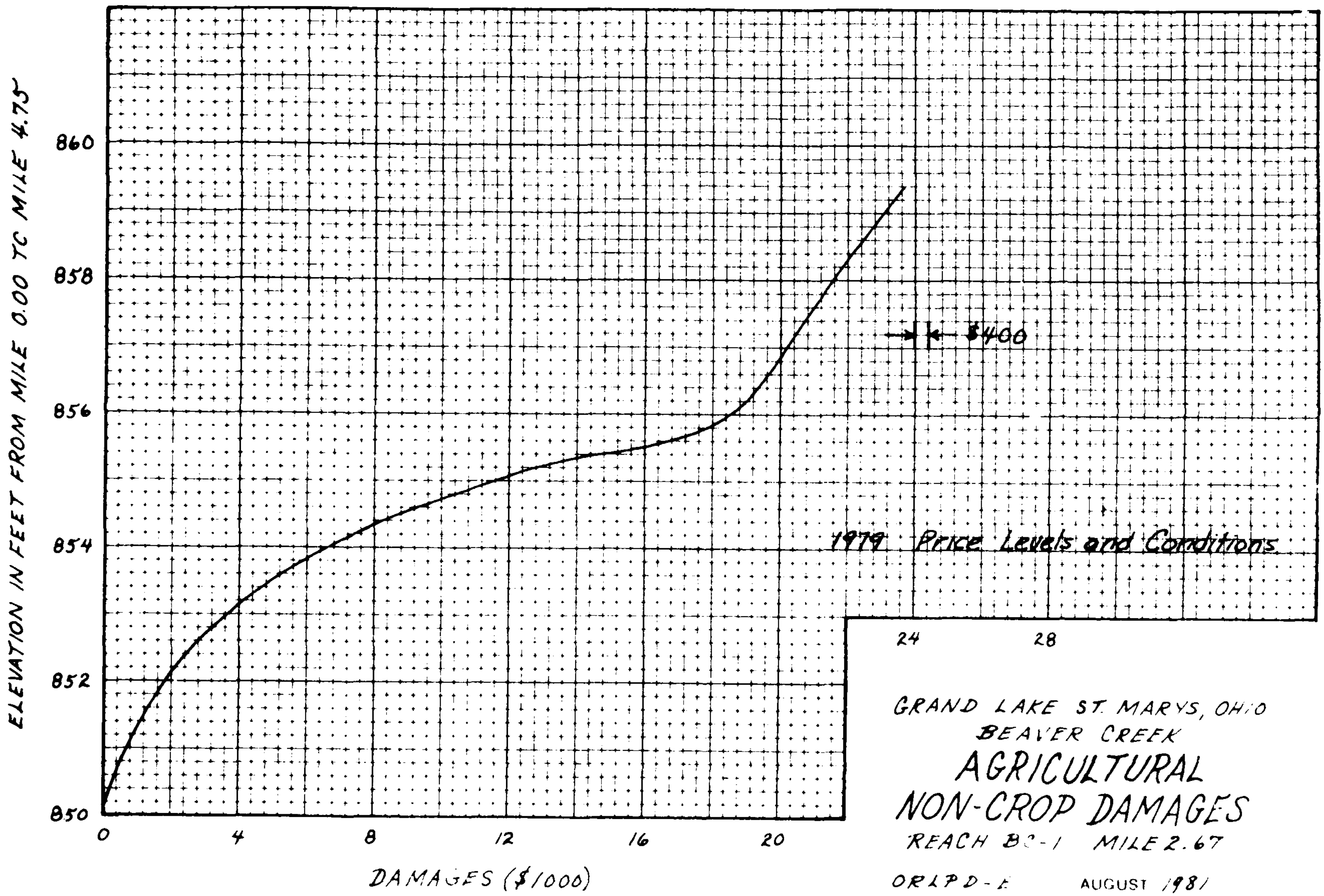

ELEVATION IN FEET FROM MILE 4.75 TO MILE 10.6
855
856
857
858
859
860
0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
ACRES INUNDATED (100)
TOTAL ACRES INUNDATED
25 ACRES
GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK
AREA INUNDATED
CURVE-TOTAL ACRES
REACH BC-2 MILE 7.50
ORLPD-E
AUGUST 1981


ELEVATION IN FEET FROM MILE 0.00 TO MILE 4.75
860
858
856
854
852
850
$250
0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
DAMAGES ($1000)
GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK
CROP DAMAGE CURVE
1978 N.P.
1979 YIELDS
REACH B
MILE 2.6
ORLPD -E
AUGUST



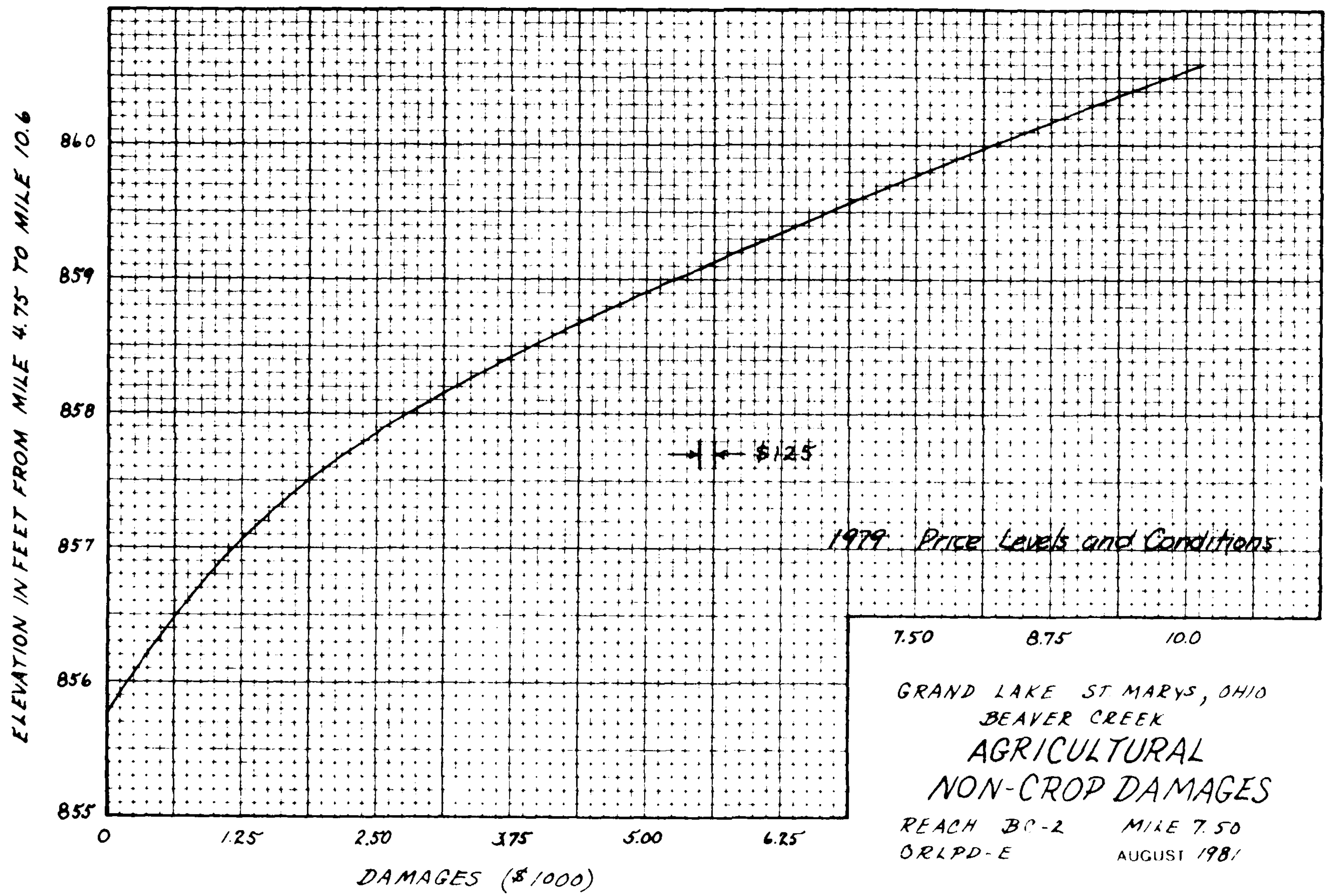
GRAND LAKE ST MARYS, OHIO
BEAVER CREEK
CROP DAMAGE CURVE
1978 N.P.
1979 YIELDS
MILE 7.50
ELEVATION IN FEET FROM MILE 4.75 TO MILE 10.6
DAMAGES ($1000)
$250
861
860
859
858
857
856
855
0
25
50
75
100
125
150
200
225

PLATE G-5



GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK
AGRICULTURAL
NON-CROP DAMAGES
REACH BC-1 MILE 2.67

ORLPD-E AUGUST 1981



ELEVATION IN FEET FROM MILE 4.75 TO MILE 10.6
860
859
858
857
856
855
0
1.25
2.50
3.75
5.00
6.25
7.50
8.75
10.0
DAMAGES ($1000)
$125
1979 Price Levels and Conditions
GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK
AGRICULTURAL
NON-CROP DAMAGES
REACH BC-2 MILE 7.50
ORLPD-E AUGUST 1981

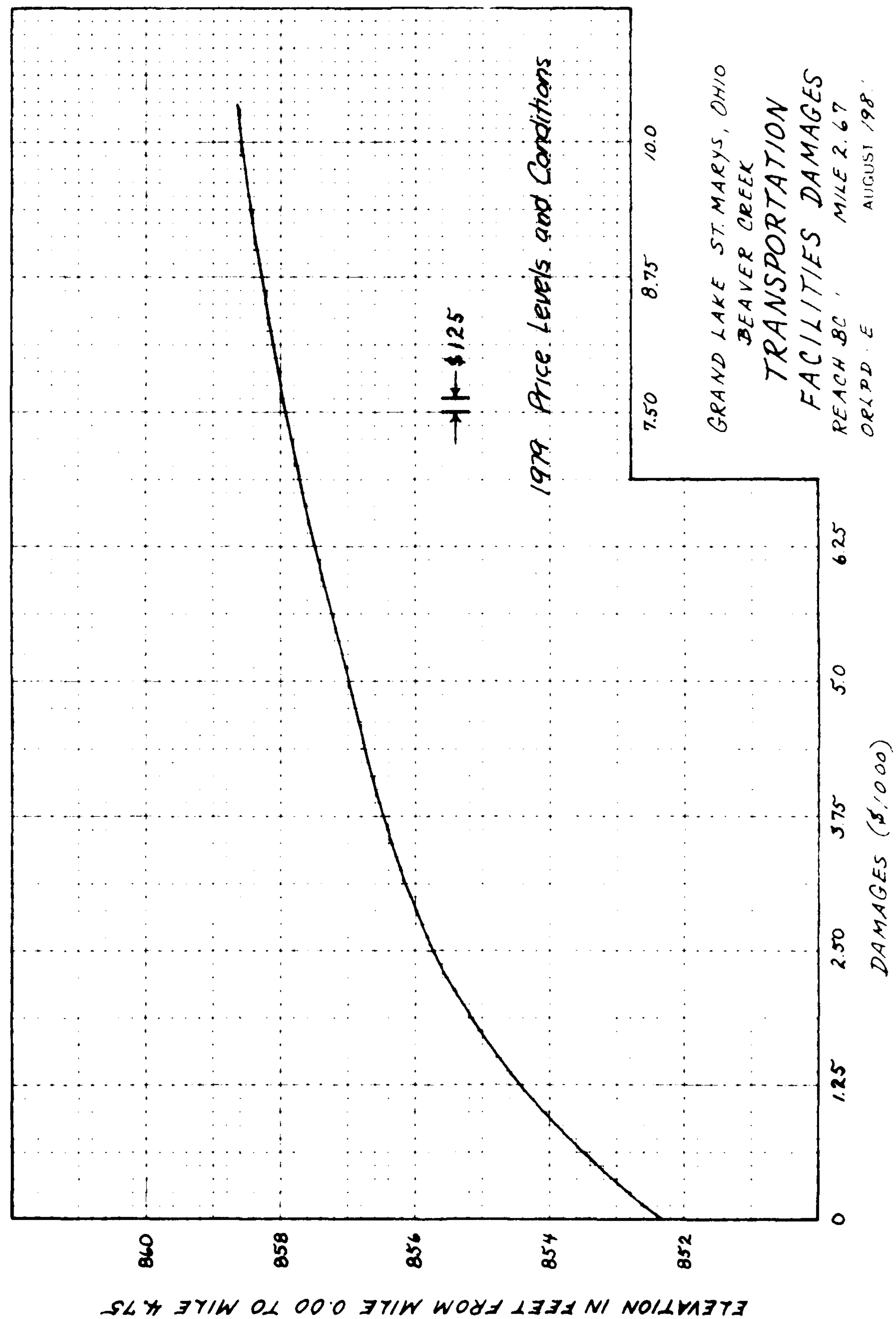
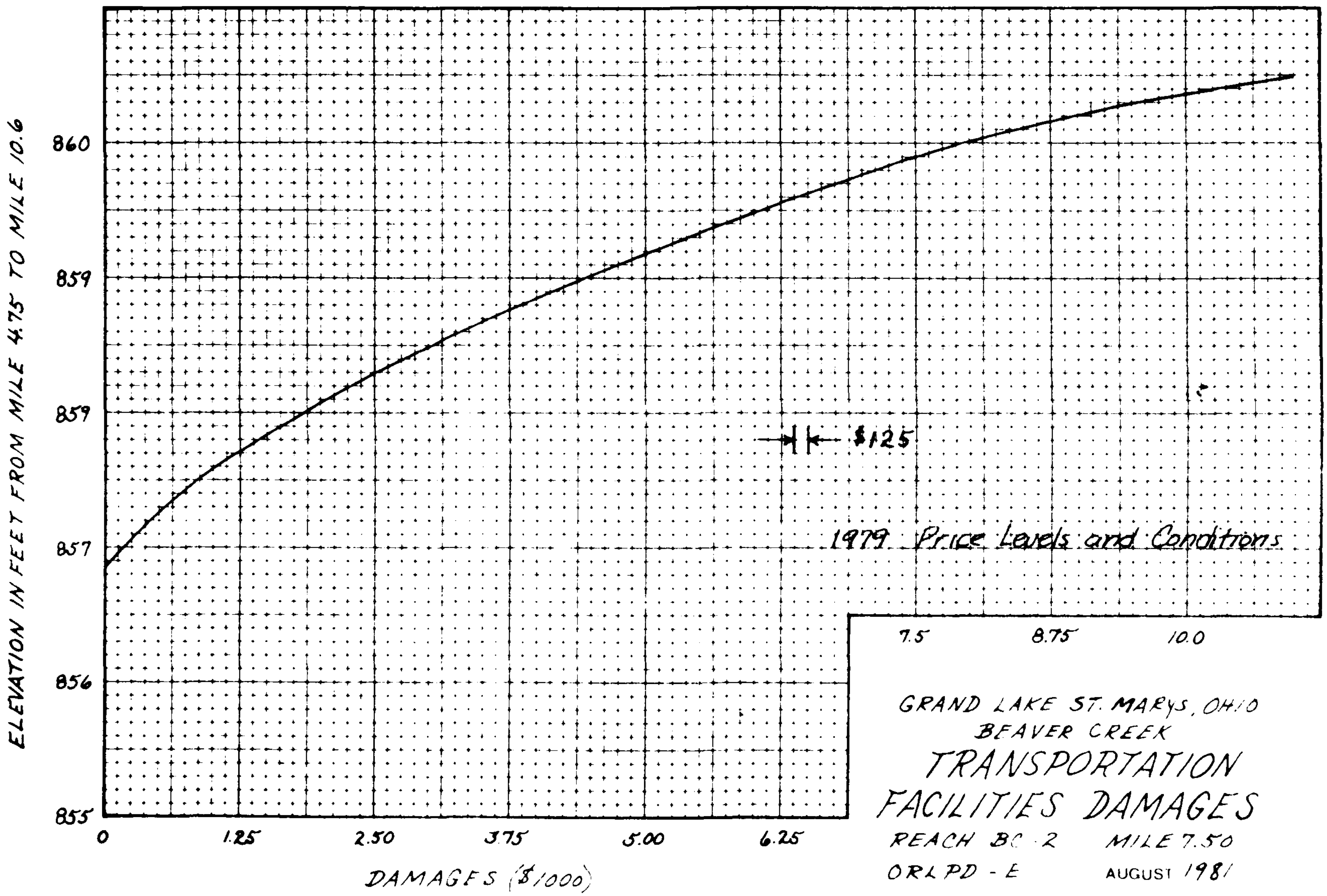

GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK
TRANSPORTATION
FACILITIES DAMAGES
REACH BC MILE 2.67
ORLPD E AUGUST 1981
1979 Price Levels and Conditions
$125
DAMAGES ($1,000)
0
1.25
2.50
3.75
5.0
6.25
7.50
8.75
10.0
ELEVATION IN FEET FROM MILE 0.00 TO MILE 4.75
852
854
856
858
860

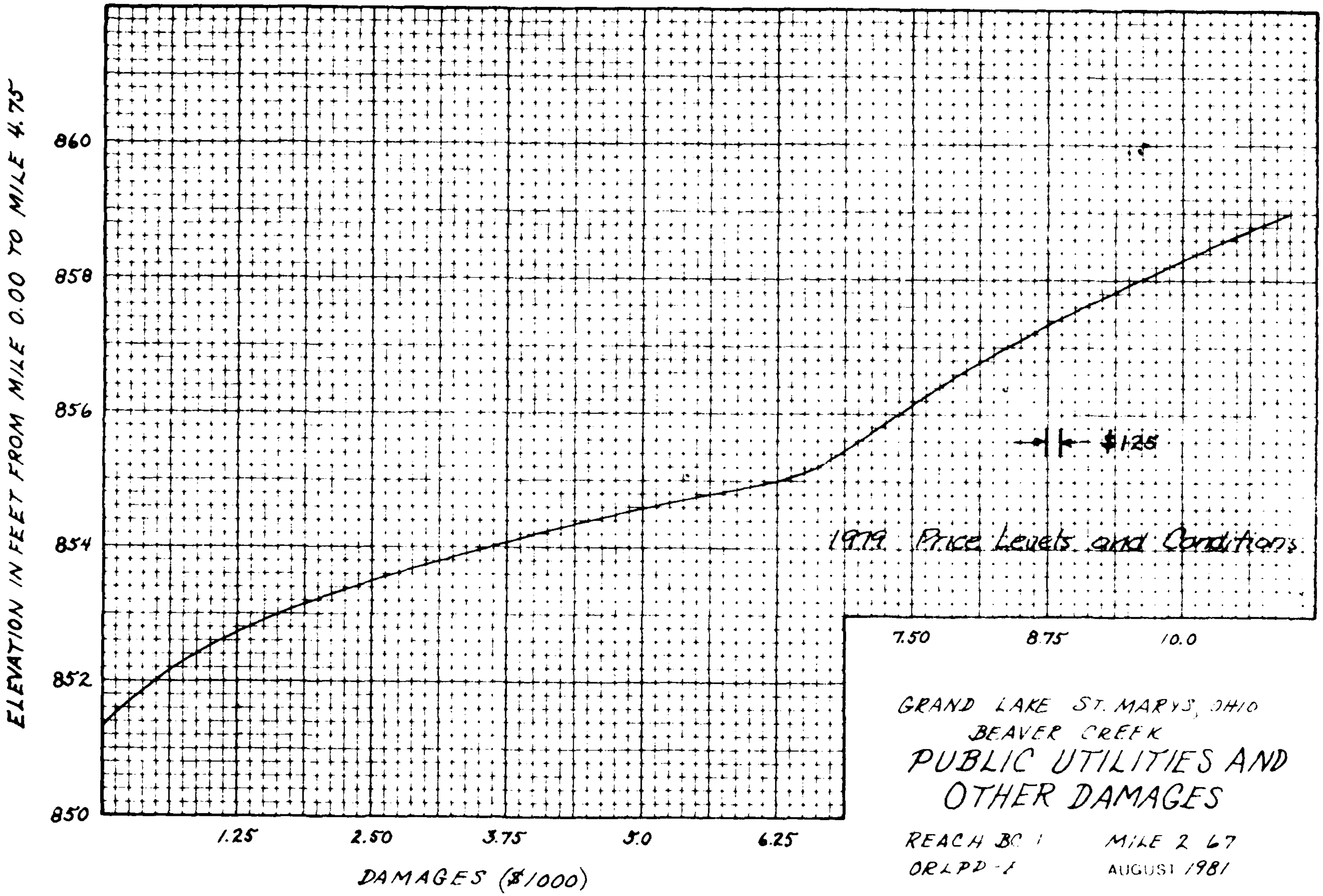
PLATE G 8



GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK

TRANSPORTATION
FACILITIES DAMAGES

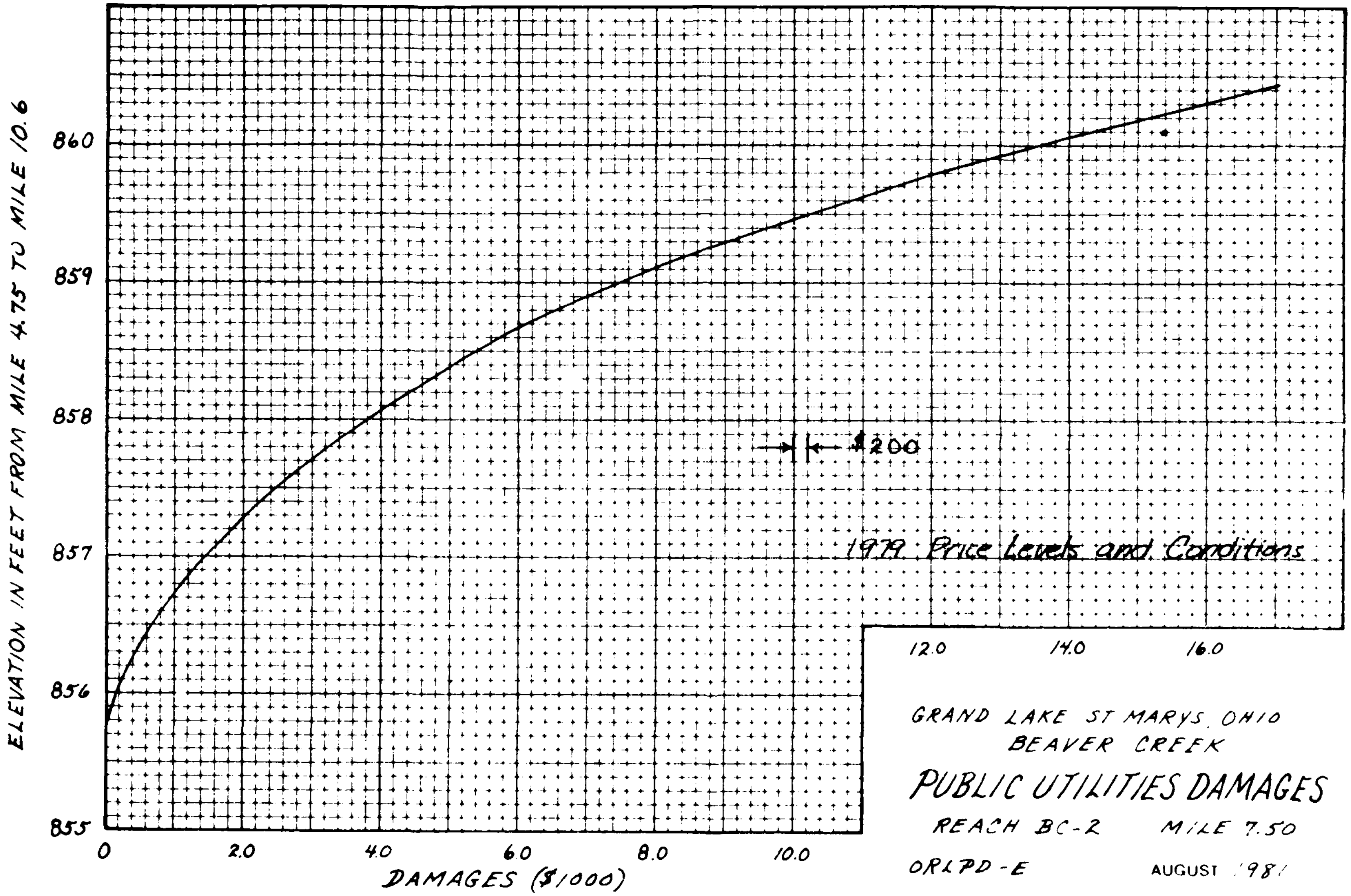
REACH BC-2 MILE 7.50
ORLPD - E AUGUST 1981



GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK

PUBLIC UTILITIES AND OTHER DAMAGES

REACH BC-1 MILE 2.67
ORLPD-1 AUGUST 1981



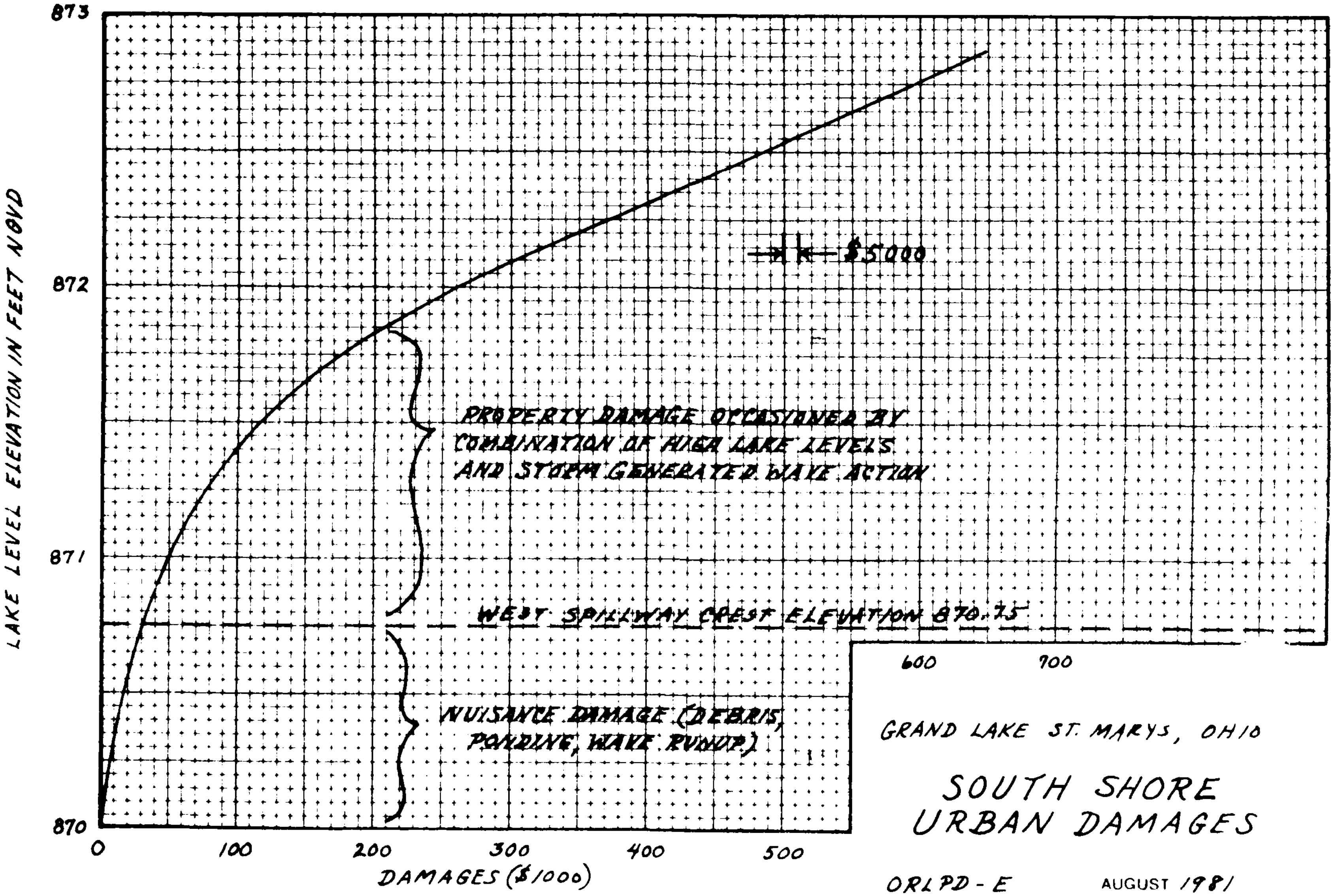
GRAND LAKE ST MARYS, OHIO
BEAVER CREEK

PUBLIC UTILITIES DAMAGES

REACH BC-2 MILE 7.50

ORLPD-E AUGUST 1981

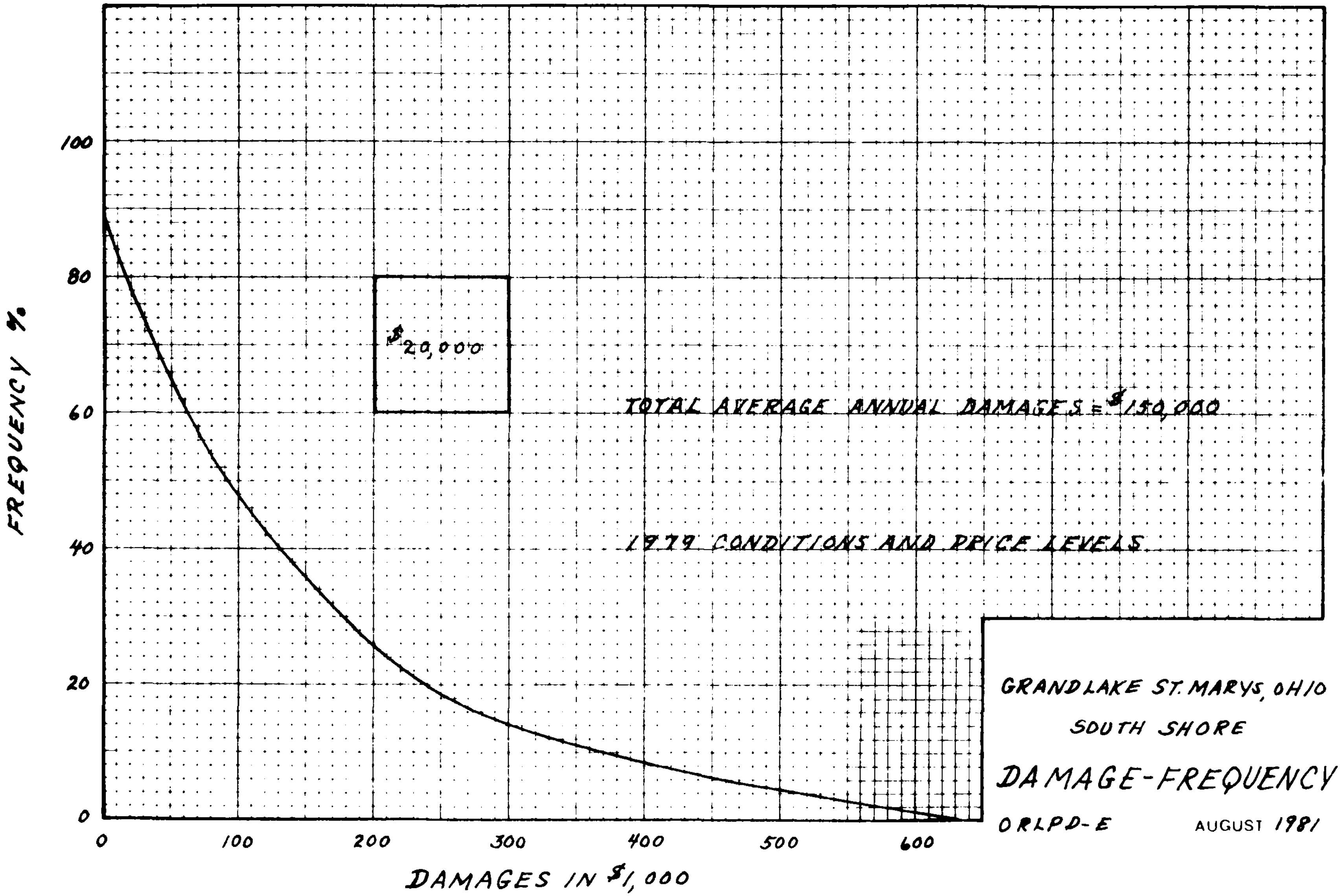
PLATE G-11



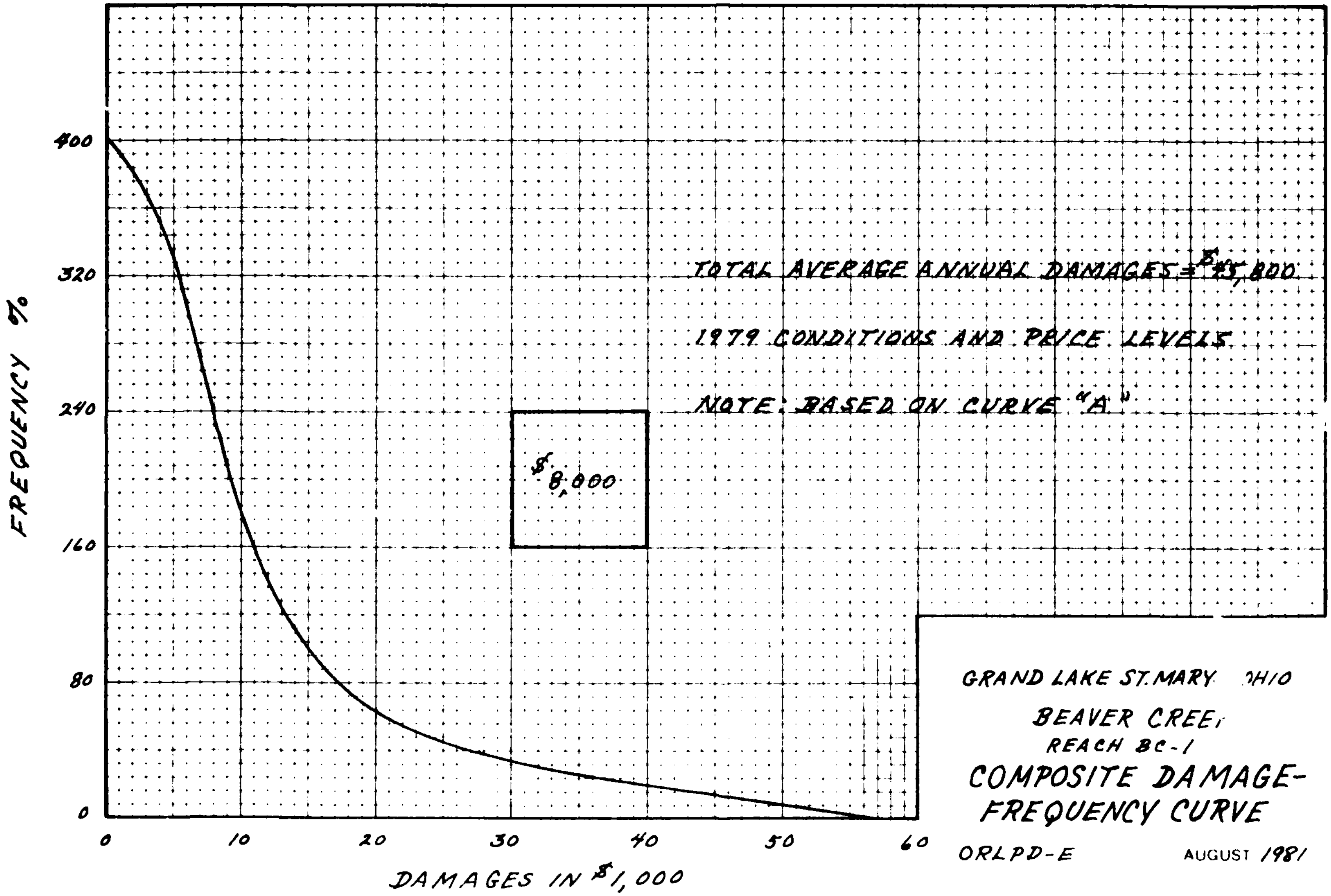
GRAND LAKE ST. MARYS, OHIO

SOUTH SHORE
URBAN DAMAGES

ORLPD-E AUGUST 1981



TOTAL AVERAGE ANNUAL DAMAGES = $150,000
1979 CONDITIONS AND PRICE LEVELS
$20,000
FREQUENCY %
100
80
60
40
20
0
0
100
200
300
400
500
600
DAMAGES IN $1,000
GRANDLAKE ST. MARYS, OHIO
SOUTH SHORE
DAMAGE-FREQUENCY
ORLPD-E
AUGUST 1981



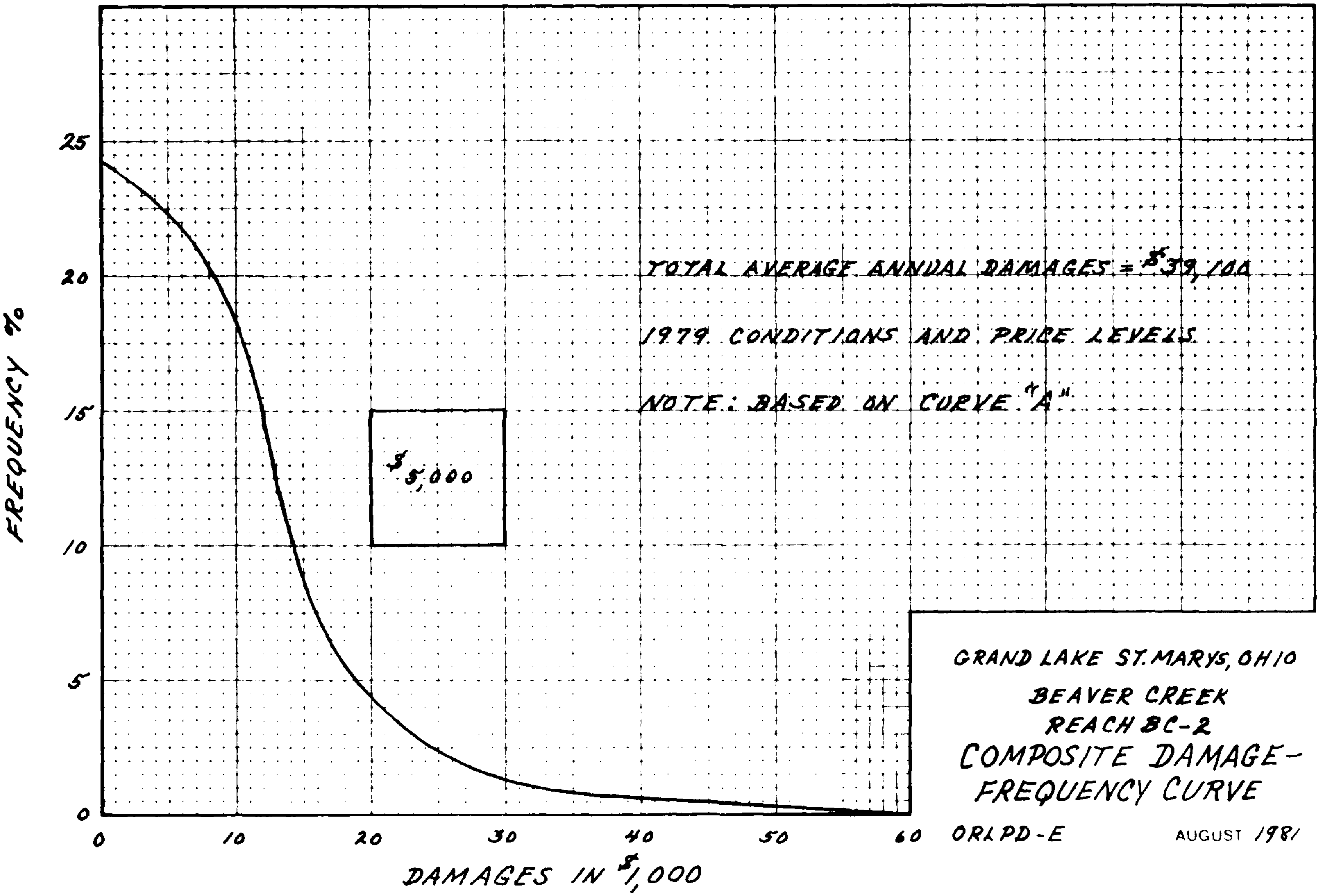
GRAND LAKE ST. MARY OHIO

BEAVER CREE

REACH BC-1

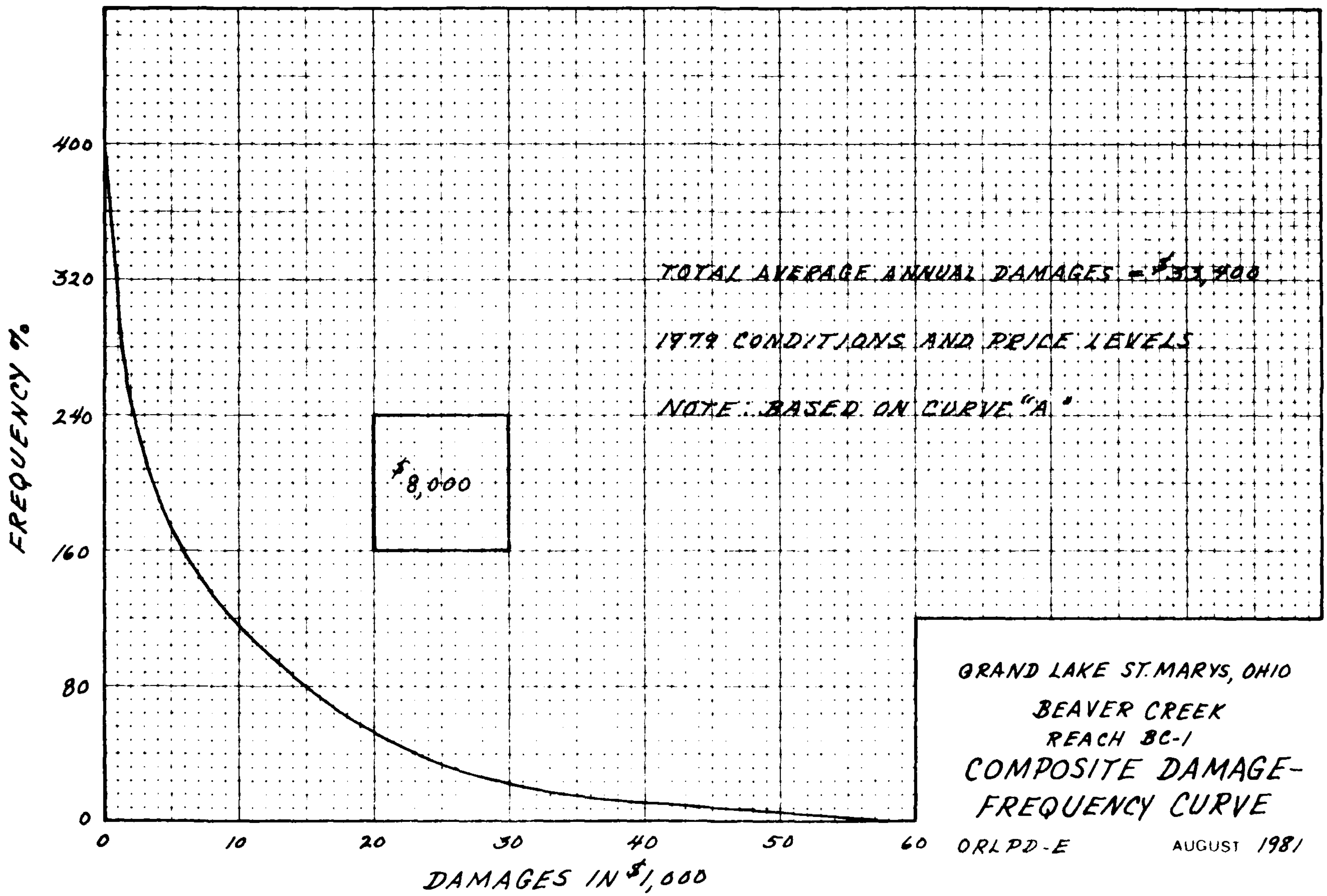
COMPOSITE DAMAGE-FREQUENCY CURVE

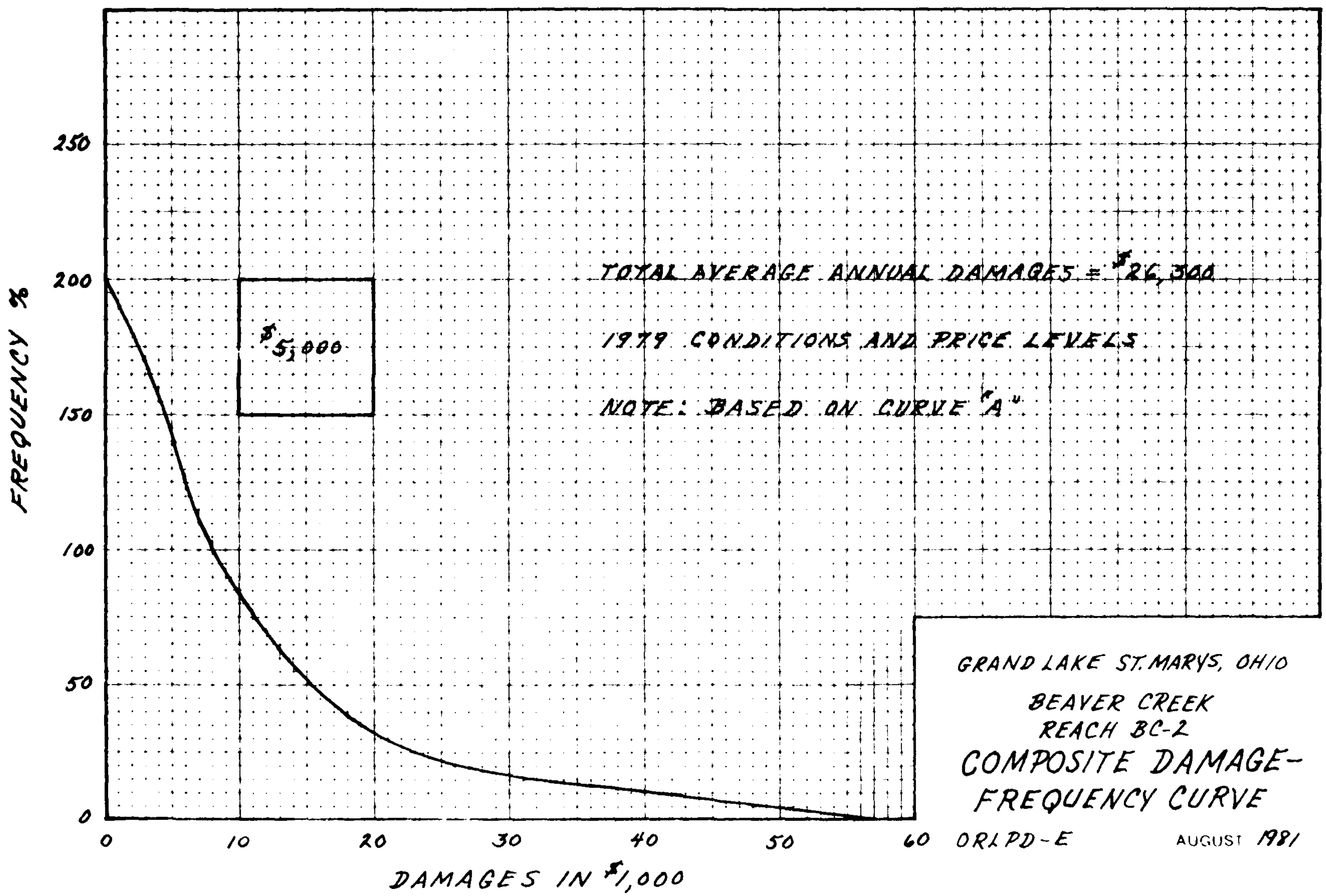
ORLPD-E AUGUST 1981



GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK
REACH BC-2
COMPOSITE DAMAGE-FREQUENCY CURVE

ORLPD-E AUGUST 1981


TOTAL AVERAGE ANNUAL DAMAGES = $33,400
1979 CONDITIONS AND PRICE LEVELS
NOTE: BASED ON CURVE "A"
$8,000
FREQUENCY %
400
320
240
160
80
0
0
10
20
30
40
50
60
DAMAGES IN $1,000
GRAND LAKE ST. MARYS, OHIO
BEAVER CREEK
REACH BC-1
COMPOSITE DAMAGE-
FREQUENCY CURVE
ORLPD-E
AUGUST 1981



GRAND LAKE ST. MARYS, OHIO

BEAVER CREEK
REACH BC-2

COMPOSITE DAMAGE-FREQUENCY CURVE

ORLPD-E AUGUST 1981

APPENDIX 2

PUBLIC VIEWS AND RESPONSES

APPENDIX 2

PUBLIC VIEWS AND RESPONSES

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

SECTION A

PUBLIC INVOLVEMENT

SECTION A

PUBLIC INVOLVEMENT

GENERAL

The public involvement activities for this study are described below with comments on the objective emphasized at each meeting.

NOVEMBER 1978 - INITIAL COORDINATION MEETINGS

This meeting was held in Columbus, Ohio with personnel of the Ohio Department of Natural Resources. The purpose of the meeting was to inform attendees of the initiation of the Grand Lake St. Marys Survey Investigation, present a tentative study schedule, discuss the study efforts, invite comments on water resources problems in the study area, and obtain contacts for obtaining available information concerning the study area.

This meeting was held in Celina, Ohio with local officials and representatives of local, civic, and private organizations from various communities for the purpose of introduction and to inform attendees of the initiation of the survey investigation. A tentative study schedule was presented and a general discussion of study efforts. Local perceptions of water and related resources problems were presented. Lake water quality, flooding, sedimentation, and erosion were cited as major concerns in the area. (Exhibit A-1)

APRIL 1979 - LOCALLY SPONSORED PUBLIC MEETING

A locally sponsored public meeting was held in Mercer County, Ohio at the Western Ohio Branch Campus, Wright State University. This meeting was attended by approximately 55 persons comprised of local, state, and Congressional officials, representatives of Chambers of Commerce for the Cities of Celina, and St. Marys, private interests, and the general public. The Louisville District was invited to make a presentation on study background, water resource problems and needs, study efforts, coordination efforts, and obtain local views concerning water resources problems. (Exhibit A-9)

DECEMBER 1978 - COORDINATION MEETING

The meeting was held in Columbus, Ohio with representatives of the Ohio Department of Natural Resources. The main purpose of the meeting was to: (1) update study progress, (2) reconfirm problems, study direction and scope, (3) introduce alternatives being given consideration, and (4) present remaining study schedule.

SEPTEMBER 1980 - COORDINATION MEETING

A meeting was held in Columbus, Ohio with representatives of the Ohio Department of Natural Resources and Ohio Environmental Protection Agency. The purpose of the meeting was to update study program and purpose, field questions and comments on the Stage 2 report previously submitted for review, and discuss conclusions and recommendations for inclusion in the final report.

NOVEMBER 1980 - LOCALLY SPONSORED COORDINATION MEETING

A locally sponsored quasi-public meeting was held in Mercer County, Ohio at Wright State University, Western Ohio Branch Campus. This meeting, arranged by the Lake Development Corporation, was attended by approximately 30 persons comprised of local, state and public and private interests. The Louisville District was invited to make a presentation of study findings. All problem areas were addressed as to alternatives investigated, costs, impacts and feasibility. A public information brochure was prepared and distributed at this meeting. (Exhibit A-10)

NEWS ACCOUNTS

Exhibits A-1 through A-10 illustrate various news articles concerning the Grand Lake St. Marys study.

Federal Study To Begin In 1979

Corps Seeks Lake Overview

By MAC McFARLIN

Representatives of the Louisville district of the U.S. Army Corps of Engineers met Wednesday with members of the Lake Development Corporation of Grand Lake St. Marys (LDC), representatives of the Lake Improvement Association (LIA), chambers of commerce of St. Marys, Celina and Coldwater, and governmental officials from Auglaize and Mercer Counties, to get an overview of the problems of the 13,500-acre (12,000 acres, according to the Ohio Division of Fish and Wildlife) lake from a local point of view.

Corps officials on hand included Jim Duck, chief plan formulation branch, planning division, of the corps' Louisville district, and Al M. Scalzo, who will be in charge of a federally-funded study of the local lake scheduled to get underway next Jan. 1.

Duck [illegible] study, originally approved by Congress as part of a 1970 flood control act but not funded until 1978, will take at least three years including the "plan of study" phase which he said would take four months to complete.

Scalzo and Duck noted that Congress has appropriated $70,000 to pay for the study but that Wednesday's meeting was scheduled before that funding was finalized, and for this reason they had not notified the press of the meeting and asked those who were invited to attend not to publicize it.

The corps officers stressed that local help would be needed not only for information about the lake and its problems — "we'd rather not reinvent the wheel" — but also in convincing Congress that the study is needed as a first step toward saving and enhancing a valuable community resource.

"We do not control or direct decision making on these projects," Duck explained. "The corps only [illegible] where we are told by Congress and carry out the orders [illegible] within the framework approved by the government."

Furthermore, Duck said, "we have never before been involved in a project like this one," a statement that sparked several comments of understanding from the audience.

Duck explained that the meeting was part of "a pre-authorization study," which could help to determine the direction and scope of the study. Also planned is a public meeting — "I refuse to call it a hearing" — tentatively scheduled for "late winter or early spring," he said, which probably will terminate the planning phase of the study.

The planning period is necessary, Duck said, because a study of materials gathered by local government agencies, sportsmen organizations and business groups "may show engineers they need only to evaluate and synthesize existing data to accomplish goals of the study."

The length of the study itself, [illegible] determined by the need to include an environmental impact statement (EIS), "[illegible] makes it pretty hard to complete a study such as this in less than three years."

However, he added, "if there is no construction by the corps as a result of our study then there will be no EIS although all environmental impact data collected during the study will be included in the final report and that becomes the property of the local communities."

Duck also said that although the scope of the study would depend upon what the corps determines is necessary as the project progresses, local communities could be certain of a comprehensive study "that could be followed by a construction detail plan," when and if the community decides to proceed with a lake improvement project.

That could eliminate two costly steps for which communities normally have to employ a private consulting engineer, he said.

It is too early to speculate about the extent of the corps study and the amount of corps involvement after the study is complete, Duck explained, because he will need to know what the Ohio Department of Natural Resources (ODNR) wants for the lake and to study recommendations coming out of the ongoing around-the-lake sewage disposal study before "we would know enough to make a projection."

He did say however that it was possible as a result of the study for the corps to be in control of an ensuing construction project and "if that [illegible] corps money but only for those aspects of the project we have recommended."

Among those in attendance at Wednesday's meeting, held at the Western Ohio branch campus of Wright State University, were Grand Lake St. Marys State Park Manager Rex Wallace, St. Marys Safety-Service Director Ken Heeman, LIA President Jack Esselman, WOBC Assistant Dean Tom Knapke and biology professor B.L. Norris, Tom O'Brien, operator of Ohio Marine Sales Harbor Point, and LCD representatives Phil Conradc of the Celina retail merchants committee and Dennis Gebele of the Celina Area Chamber of Commerce.

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CELINA, OHIO

23 November 1978

EXHIBIT A-1

THE DAILY STANDARD
CELINA, OHIO
4 March 1980

Initial Corps Lake Report Cites Complexities

(Editor's Note: Following is the first in a four-part series concerning the U.S. Army Corps of Engineers' reconnaissance report, which is, the first component of a three-year overall survey of Grand Lake St. M— Today's article deals with report's "problem identification" section. Subsequent articles will address the report's water quality analysis, a preliminary study submitted as part of the report by the U.S. Fish and Wildlife Service, and the corps' preliminary formulation of alternative solutions to the various lake problems.)

By STEVE FOUGHT

While noting the "complex interrelationships" involved, the U.S. Army Corps of Engineers nonetheless has identified four broadly-defined major problem categories as part of its reconnaissance report on Grand Lake St. Marys.

The four categories are water quality, water-related recreation, flooding, and physical drawbacks.

But in the introduction to its reconnaissance report, the corps emphasizes that "the water resource problems associated with the existing lake system have complex interrelationships that may be difficult to quantify. While solutions to individual problems may seem apparent, it is anticipated that it will be difficult, also, to find solutions to each of the problems which would not adversely affect other water resources uses and which are justified economically."

Water Quality

"The primary water quality problem in the Grand Lake St. Marys study area," the report notes, "is the eutrophication of the lake" that is, deprivation of the lake's oxygen supply.

"The main water quality problems are associated with nuisance algae blooms ... Taste and odor problems have been linked to the algae blooms, which also interfere with recreation and water supply uses."

Each year the lake experiences several algae blooms, the report notes, with accompanying fish-tainting, taste and odor problems. Odor levels in finished water, for example, have been reported occasionally *to exceed four times the level* "detectable to the customer."

The report also notes evidence of "significant bacterial pollution," a development attributable both to human and animal wastes. "It is probable *that a large part of the lake's* microbiological contamination is due to human waste," the report states, referring to the "extensive use of septic tanks in many unsuitable areas along the south shore," while bacterial pollution from animal wastes apparently is tied to the presence of the waterfowl refuge on Montezuma Bay.

Taste and odor problems are *especially noticeable in Celina,* the report states, since the city draws its water supply from the lake. While the water supply is more than ample to meet the city's growing needs, "the quality of finished water has generally deteriorated in regard to flavors, tastes and odors."

Past studies, the report notes, have concluded that algae are the prime source of taste and odor problems; chemical treatment costs for raw lake *water are comparatively high* and still rising; available well water is limited in quantity and high in objectionable mineral content; and, the city's daily per-capita water consumption is increasing at an increasing rate.

"The cost and technical feasibility of removing tastes and odors, sometimes without great success, is a major reason *for improving the raw water* quality," the report states.

Water-Related Recreation

Of course overall water quality carries with it almost unlimited ramifications, but it is related in large part to use *of the lake* 's a *recreational* resource.

Referring to the state of Ohio's Comprehensive Outdoor Recreation Plan, the corps report notes "*significant* deficiencies in realizing the recreational potential of the lake."

EXHIBIT A-2
Sheet 1 of 3

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CELINA, OHIO

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Grand Lake St. Marys attracts fewer human visitors per surface acre (129), than either Indian Lake (221) in Logan County or Lake Loramie (457).

Interestingly, the local lake experienced a decline in the number of "visitor days" per surface acre in the period 1970-76. In 1970, visitor days totaled 1.7 million, rising to 2.4 million in 1973 before dropping to 1.5 million in 1976.

"The comparison of visitor numbers generally indicates that Grand Lake is underutilized," the report states. "The reasons for this are many and varied, since several water-related problems exist . . (including) extreme shallowness, siltation, submerged tree trunks and stickups which interfere with boating, water pollution, water odors, and wind and wave problems," along with winter freezes and fluctuation in water levels which can cause damage to boat ramps, docks and marinas.

"All the above cited problems. . . create difficulties with existing and potential recreation; **however, when con**sidered simultaneously, the overall effect (is) massive. A smaller than usual amount of boating occurs for such a volume of water, and this is attributed to problems associated with the lake."

The report forecasts that if the lake were free of its problems, 1980 visitation would approach 2.7 million days, climbing to three million "visitor days" in 2000 (or double the current figure), and to 3.5 million in 2020.

Such expansion, however, might have adverse effects on the lake's fish and wildlife population, the report points out, and these "resources must be protected, if not enhanced."

Fishing remains excellent the year round, the report states, "but fluctuating lake water may affect fish habitats along the shoreline . . Low water in the winter has an adverse effect on the large gamefish. (And) low water in the spring also effectively eliminates some traditional fish spawning areas."

Physical Problems

Erosion and sedimentation are the main physical problems presently confronting the lake, according to the report, citing six categories of erosion: farm drainage, streambank, channel, lake shoreline, island, and dredge spoil.

Farm drainage erosion "has been taking place since the native forests of the area were extensively stripped in the late 1800s and early 1900s for farming." The displacement and washoff of agricultural soil and farm chemicals "creates economic and environmental problems" including not only loss of valuable topsoil, but also the deleterious effects of suspended and dissolved solids on lake water quality.

"In this case, much of the erosion. . . creates further complications as a potential cause of sedimentation and shallowing of Grand Lake, with attendant effects on lake circulation, aeration, water quality conc[illegible]tions, and navigation."

Also the report states, "siltation action and the resultant high turbidity (cloudiness) are probably the greatest single factors in controlling the life and productivity of the lake."

The reasons for sedimentation, however, "are not well documented, and there are conflicting viewpoints in the absence of good data."

Traditionally, the report notes, it has been assumed that Grand Lake St. Marys received tremendous silt loads from its tributary streams in the contributing watershed, an assumption based on the lake's high turbidity, the need for continuous dredging activity, and the predominantly agricultural nature of the watershed, where 87 percent of the acreage is under cultivation.

"On the other hand, there are factors which suggest that Grand Lake does not receive a high sediment input from its basin, as previously thought," the report states, noting specifically that absence of relief in the basin, extremely low stream gradients, and no

(Continued on page two)

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Lake Complexities

(Continued from page one)

visible evidence of excessive erosion. Furthermore, the lake is located in an area designated by the U.S. Geological Survey as "moderately low" in sediment yield, and basin soils consist mainly of clays and silts which are not particularly susceptible to high erosion.

"The source of the deposited material appears to be the main question. If the main source is material eroded by wave action, then additional bank protection measures would be helpful.

If the main source is inflow from the drainage basin then soil conservation practices would be more beneficial."

But the most important statistic relating to sedimentation the report states, is "net trap efficiency," or the rate at which the lake catches and retains sediment from inflowing water. And in this respect, "the small contributing drainage area and large surface area of Grand Lake make it a nearly-ideal sedimentation basin."

Channel erosion seems to be a widespread problem, the report indicates, judging from the extent of dredging necessary to keep channels open.

Lake shoreline erosion is exacerbated by "unusual wave and ice action" which often breaks down rock riprap and concrete walls and other protective structures. "The condition and effectiveness of these protective measures is a matter of concern," the report states. "In addition, many areas, both public and private, are unprotected."

Streambank erosion is considered "moderate," while islands are judged to be particularly susceptible to ice and wind-induced erosion.

Also dredge spoil material "placed in unprotected rows and left unprotected erodes quickly back into channels and into other parts of the lake." Containment of dredge spoil is necessary, the report states, since "dredged rows (currently) are suspected of contributing a great deal of sediment back into the lake and channels where turbidity is increased for long periods of time."

According to the report, "sedimentation does not appear to be seriously depleting lake storage. The main problem is that the material accumulates in places where it is especially noticeable and troublesome..."

The report also stresses that further investigation of the sedimentation problem is needed. "Any plans to improve the conditions in Grand Lake cannot be considered completely reliable or quantifiable until more current sedimentation data are available."

Flooding

Federal Insurance Administration flood hazard boundary maps, the report notes, "show moderate flood hazard potential on the northern and eastern sides of the lake except for the area along (Ohio) 703 near Four Turkey Rd. and Harris Rd."

Flooding also has been reported, the report notes, along Beaver Creek, which runs for 10.7 miles from the west bank of Grand Lake St. Marys until it meets the Wabash River in western Mercer County.

Flooding is caused in part by "restricted channel conditions and the lack of flood control storage in Grand Lake, poor surface drainage, low creek gradient (1.5 feet per mile) and high creek stages that prevent adequate outlet for numerous artificial drains to Beaver Creek."

There is limited data regarding the "frequency of flooding along Beaver Creek," the report states, as well as "concern for what is really the substantial problem."

The report does note, however, that the soil type along Beaver Creek is Defiance Wabash Association, which is somewhat poorly drained. Also adequate artificial drainage "is commonly difficult to establish because of the nearly flat topography and low grade to tile outlet.

"Additionally, extensive spoil banks along the creek tend to further confine surface runoff." Preliminary field inspections by the corps indicate that "the few tile drains observed may not be functioning properly," and that the "reservoir operation may also further impede drainage by releasing flows that possibly cover the tile outlets," although uncertainty exists because "records are vague in regard to the flows released."

Periodic flooding also occurs along the lake's southern shore, the report notes, "where the shore topography and the development are generally at a low elevation."

The problems on the south side are numerous: recreation-oriented developments around the lake "tend to make any lowering of the water surface undesirable"; soils in the upland watershed are poorly drained; poor drainage plus a high water table causes most soils to be seasonally wet; fluctuating lake water levels cause localized and widespread flooding, and, "wave runup along the south shore occurs from frequent wind-induced wave action."

However, the report notes, "there is no evidence of damage to buildings or homes due to flooding on the south shore."

Tomorrow: the water quality analysis.

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Eutrophication Termed Main Lake Problem

Algae, Nutrients Cut Quality

(Editor's Note: Following is the second in a four part series concerning the U.S. Army Corps of Engineers' congressionally-authorized three-year study of Grand Lake St. Marys. Today's article deals with a water quality analysis attached as an appendix to the main body of the corps' stage one reconnaissance report.)

BY STEVE FOUGHT

Eutrophic: An adjective describing a lake or body of water as rich in mineral and plant nutrients, but often deficient in oxygen.

In the eyes of the U.S. Army Corps of Engineers, following the first phase of a three-year study of Grand Lake St. Marys, there is little question about the major problem with the lake's water quality.

To quote from the corps' stage one reconnaissance report: "The primary water quality problem in the Grand Lake St. Marys study area is the eutrophication of the lake."

The problem is not so much a lack of oxygen — in fact the local lake is well oxygenated — but rather, an abnormally high concentration of algae and undesirable nutrients.

The report also cites higher than acceptable concentrations of bacteria from human and animal wastes at the mouths of tributaries and on the lake's south shore, but adds that "no known water-borne diseases have affected bathers or other local recreation seekers."

"The term 'eutrophic' covers a wide range of water quality conditions, from very desirable lakes which support excellent warmwater fisheries (and which may also experience occasional algae blooms) to the lakes which are in essence comparable to pea soup and are of no value except, perhaps, as sources of irrigation water," the report [illegible]

Grand Lake St. Marys, the corps report seems to indicate, falls between those two extremes. Despite its algae problems, "which are certainly more than occasional ... Grand Lake has remained a valuable resource."

In one respect, Grand Lake St. Marys is typical of other lakes in the corps' Louisville district, its water having been characterized by the U.S. Geological Survey as "moderately hard magnesium calcium sulfate bicarbonate."

The difference is found in the local lake's extreme shallowness, its high capacity-to-inflow ratio and its relatively high degree of commercial and residential development along the shorelines.

While dissolved oxygen, or lack of it, "does not limit the lake as aquatic habitat," the almost-continual algal blooms during the summer months adversely affect the lake's value as a fishery, recreational resource and source of Celina's municipal water supply, according to the report. "The Celina public water supply develops taste and odor problems. The algae [illegible] ... affects the aesthetic [illegible] of the lake [illegible]

The most important factor contributing to Grand Lake St. Marys' eutrophic condition, the report states, is a high concentration of nutrients, specifically nitrogen and phosphorus, which encourage algae growth.

State water quality standards, which require that "total phosphorus shall be limited to the extent necessary to prevent nuisance growths of algae ..." obviously are not being met at

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Grand Lake St Marys, the report notes

Nitrates, meanwhile, are a "potential problem" with samples taken near the south shore indicating a possible health hazard. But near the northwest corner, from which Celina's water supply is drawn, "sources indicate that no nitrate problem exists ..." according to the report.

Nutrients enter the lake through sewage and surface runoff, and primarily from shoreline development and tributaries on the southern end.

In its National Eutrophication Survey in 197[illegible] the Environmental Protection Agency estimated that 92 percent of the phosphorus entering Grand Lake St Marys came from non point sources cropland feedlots and barnyards for example. ... point sources also contributed the source of most nitrogen entering the lake EPA concluded.

Industrial effluents — in this case Avco New Idea's use of Coldwater Creek for cooling water — "do not affect the lake," the corps report states. Likewise, the waterfowl refuge on Montezuma Bay has only a minor effect on nutrient loads.

Domestic human wastes, however, contain high levels of phosphorus therefore, construction of the Grand Lake sanitary sewer system "should produce some improvement in trophic conditions."

"The effect of the nutrient levels on algae production is compounded by other factors," the report states including a long hydraulic residence time (1.3 years) that makes the lake more susceptible to increased [illegible] loading as well as "shallow, warm nature" of the lake which contributes to increased plankton production.

According to the report, Grand Lake St Marys experienced three stages in relation to biological productivity. The first stage began during the lake's formation and ended near the turn of the last century. The lake at that time supported "an extraordinary fishery" with up to 100 commercial fishermen employed, the dominant fish being black bass, sunfish, perch and catfish.

"In the decade of 1890-1900, several changes occurred which apparently greatly affected the water quality, productivity and the fishery of the lake," the report notes. A drought exposed the lake bottom and much of the remaining standing timber and logjams were removed, with 200 to 300 oil wells taking their place and resulting in oil spills and leaks.

When the lake was refilled after the drought wave action increased as a result of the lack of lake-bottom vegetation in turn increasing turbidity cloudiness. "In a very short time the lake was converted from a relatively clear [illegible] body of water to a turbid warmwater area with much increased wave action," the report notes. Carp and white crappie became the dominant fish.

"The lake remained in this turbid relatively unproductive condition for the next six or seven decades," the report states. The lake had become nutrient deficient with relatively spare plankton population. Green algae and diatoms were abundant with a low percentage of blue-green algae.

But in the past 20 to 30 years "another major change has occurred in the productivity of the lake. Nutrient concentrations have increased dramatically and the lake has become a classic example of a culturally eutrophic impoundment," the report states.

This development, concurrent with the increased south-shore development and greater use of fertilizer in farming has resulted in blue-green algae becoming dominant.

The blue-green algae not only

(Continued on page two)

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Lake Quality Impaired

(Continued from page one)

produce "obnoxious blooms," but also alter the base of the normal food chain. "The blue-greens are not utilized to a great extent as a food source by the higher life forms in the food chain, this can lead to production of less valuable fish species and the accumulation of [illegible] because of reduced grazing [illegible] bacteria, vegetation [illegible]," the report states. "The exact reason blue green algae become dominant in [illegible] lakes is not known. It is a common occurrence and is quite often accompanied by the taste, odor and aesthetic problems encountered at Grand Lake."

Also, two organic compounds, 2-methylisoborneol and geosmin, which are known to produce the earthy-musty odors characteristic of Grand Lake St. Marys have been isolated locally, the report reveals. "The growth of (such bacteria) normally depends on the presence of algae for a food supply, so the ultimate source of the taste and odor appears to be the heavy algae bloom."

Another contributor to pollution is the presence of fecal coliform (or generally speaking, bacteria from human or animal waste). "Fecal coliform are of course only indicator organisms," the report notes, "and show only the potential for existence of pathogens [illegible] no known water-borne diseases have been attributed to the lake."

Still, bathing waters and primary contact recreation standards are based on fecal coliform content, and data indicates "Grand Lake would not meet the primary contact criterion much less the bathing waters criterion."

The high readings for fecal coliform probably are attributable, the report says, to the "proximity of sampling stations to the south shore and tributary mouths," as is the case with nitrates. And while the readings "may not be representative of the whole lake, they do illustrate the effect of [illegible] and other [illegible] on the south shore [illegible] another problem which should be [illegible] by [illegible] system."

The unknown factor in any analysis of Grand Lake St. Marys remains the overall effect of sedimentation and turbidity.

The corps report acknowledges that information on sedimentation is [illegible] and [illegible] question. It has not been determined, for example, whether the primary [illegible] of sediment input is the lake's watershed basin or dredge spoil [illegible].

Turbidity apparently limits the quality of a lake habitat, the report notes, specifically through [illegible] effect or the weight of sediment that might settle out or accumulate.

"The material in suspension in Grand Lake is most likely a [illegible] from the [illegible] area. As such it could limit the ability of the water to transmit light."

Referring to EPA studies, the corps report notes that turbidity can affect a lake fishery by acting directly on fish swimming in water where solids are suspended, preventing the successful development of fish eggs and larvae, modifying natural movements and migrations of fish, reducing the food available to fish, and affecting the efficiency of catching fish.

Indirect effects would include inhibiting the penetration of sunlight and increasing water temperatures as well as affecting photosynthetic activity.

"These effects are important at Grand Lake," the report states, "because the character and quality of its fishery began to deteriorate, at least in the opinion of many [illegible] [illegible] ap[illegible] the [illegible] and [illegible] and the loss [illegible] 1958. The [illegible] noted the [illegible] p[illegible] [illegible] [illegible] The [illegible] of [illegible] at Grand [illegible] because of human [illegible]."

In conclusion, the report notes that Grand Lake St. Marys water quality "has been monitored sufficiently to identify its problems and their probable causes. Further monitoring [illegible] does not appear necessary."

"The sediment problems of the lake have not been as well documented. That sediment [illegible] causes problems is apparent from the amount of dredging done by the State of Ohio. However, [illegible] is known about the [illegible] and source of sediment, or the extent of deposition in areas that are not dredged. A survey to determine these unknown factors would be helpful in determining if remedial action would be beneficial and economical."

The report also notes that the chemical properties of lake sediment have not been identified. A sediment survey dealing with quantity and quality is recommended at a projected cost of $[illegible].

Tomorrow: the U.S. Fish and Wildlife Service report.

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EXHIBIT A-3
Sheet 3 of 3

Lake Wildlife Imperiled

(Editor's Note: Following is the third in a four-part series on the U.S. Army Corps of Engineers' reconnaissance report on Grand Lake St. Marys. Today's installment concerns a companion report submitted to the corps by the U.S. Fish and Wildlife Service).

By STEVE FOUGHT

Man's activities are threatening Grand Lake St. Marys' value as a habitat for fish and wildlife, and the pressure will continue to increase.

The lake area still provides "a good warmwater fishery," sanctuary for 46 species of mammals, 23 species of reptiles, and 14 species of amphibians, "adequate wetland habitat to make it important for waterfowl production," as well as "one of the best locations in Ohio" for bird-watching.

But continued commercial and residential development along lake shorelines, along with intensive agriculture practices, have jeopardized the lake area's future as a fish and wildlife "resource base."

That is the rather sobering assessment offered by the U.S. Fish and Wildlife Service, a branch of the U.S. Department of the Interior, in its preliminary report to the U.S. Army Corps of Engineers, which is conducting a three-year, congressionally-authorized study of the local lake.

"Natural productivity of desirable fish and wildlife resources has declined at Grand Lake St. Marys over the last 75 years," the Fish and Wildlife (FWS) report notes. "With continued development around the lake, the quality and quantity of the existing resource base will continue to erode. The problem is complex, however, degraded water quality and degraded fish and wildlife habitat are two key factors which account for the resource loss."

Environmental factors, and particularly nuisance algae growths, drastically have changed the nature of the fish population at Grand Lake St. Marys, while destruction of suitable habitat has precipitated a decline in the "numbers and diversity of wildlife," according to the FWS report.

With human encroachment in the remaining lakeshore wetlands, "populations of amphibians and reptiles will continue to decline while some species will be extirpated from the area."

Approximately 290 species of birds have been observed in the lake area, but "in recent years the quality of 'birding' has decreased somewhat due to destruction of habitat." An immature bald eagle was sighted last in 1966, the report notes, while more recent sightings of bald eagles have been "very rare," cormorants and white pelicans no longer are seen, heron rookeries "are no longer found around the lake and other wetland birds have become uncommon due to the reduction of wetland habitat."

The FWS report also notes that "a comprehensive study of zooplankton and benthos (lake-bottom flora and fauna) is needed, since recent data is not available."

Since other lakeshore areas have been developed, the south shore, largely because of its low-lying land, remains the major site of "natural areas" conducive to wildlife habitat. Development there has been limited mainly to seasonal residences and trailer courts, but "a housing development of year-round residences is currently under construction on lakefront property southeast of the lake. Also, the Ohio Department of Natural Resources is proposing several dredge spoil sites along the south shore. Thus the resource base of wetlands is under continual modification and-or destruction."

A Fish and Wildlife spokesman in Columbus said Wednesday, "I would even call those south-shore wetland areas 'unique.' It is extremely rare to find wetlands like that along an inland lake."

Thus, FWS has recommended that "remaining wetland habitat ... be protected by local land-use zoning." Since wetlands would serve as "an effective buffer to the eroding wave action of the lake," FWS has proposed extension and enhancement of these areas as a "viable project alternative."

Funding for marsh restoration, the FWS report notes, is available through the 1976 Water Resource Development Act.

Reviewing Grand Lake St. Marys' history, Fish and Wildlife notes changes in the fish population which have been "as drastic as the changes to its aquatic environment."

"When the lake was [illegible] in 1834," the report notes, "[illegible] such as [illegible] was not considered [illegible] sequently, trees and other vegetation were left in the basin." And prior to 18[illegible] the flooded forest apparently provided a haven for [illegible] and water-dependent wildlife.

More than a pastime, fishing comprised a major sector of the local economy, the report states. "In addition to providing food for local families and [illegible] patrons, where free fish were served with drinks, fish were shipped by the barrel to markets in Cincinnati and St. Louis."

Commercial fishermen told of catching [illegible] pounds [illegible] from 11 nets in 24 hours. One fisherman shipped six to eight barrels of dressed fish each week during the spring. Anglers reeled in as many as 50 or 60 bass a day.

As late as 1894, the commercial catch exceeded one-half million pounds of fish annually.

The most prized and abundant species were largemouth bass, bluegill and pumpkinseed, all of which no longer are abundant. Even though commercial and sport fishing was unrestricted and many fish-eating birds were present on the lake, there was no apparent depletion of the fishery.

"Those years were the beginning of the end of excellent fishing in the lake," the report states. Near the end of the last century, an oil boom hit the lake area. From 1890-1900 a severe drought lowered the water levels. Stumps, snags and logjams were removed. Corn was grown on the exposed lake bottom.

Massive mats of submerged aquatic vegetation disappeared, the FWS report notes, and carp were introduced. Intensive

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GRAND LAKE SAINT MARYS, OHIO, SURVEY REPORT FOR FLOOD CONTROL A--ETC(U)

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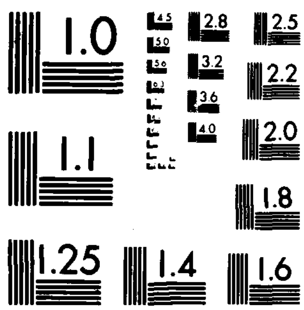

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(Continued from page one)

agricultural activity took root in the watershed. "All these factors contributed to a change of lake water quality from cool-clear to warm-turbid . . . This was followed by a corresponding change of the fish community to carp, crappies, channel catfish and bullhead. Populations of water-related avifauna (birds of the region) also decreased, while heron and cormorant colonies disappeared. . ."

And despite considerable effort, "the goal of returning the fishery population to its former condition has not been accomplished."

Since test-net data became available in 1932 from the Ohio Division of Wildlife, less desirable species such as "crappies, carp, channel catfish, bullhead, quillback and gizzard shad" have emerged dominant. Among the "considerable population fluctuations" recorded from 1932 through 1970 was evidence that black crappie and carp dominated in the first half of the period, with gizzard shad and quillback prominent from 1950-70.

More recent test-net data was not included in the report.

Shore seining data collected by the Division of Wildlife each summer at six sites (St. Marys state park beach, Windy Point Beach, Harbor Point, Scotty's Beach, Jack Oak Point and the backwater area of Montezuma Bay) indicate "considerable yearly fluctuation in catches of individual species . . . (although) the most dominant species was gizzard shad, followed by common shiner, hybrid sunfish and quillback."

The highest number of catches per hour in the test nets was recorded from 1946-55, the FWS report notes, from a high of 57.3 fish per hour in 1946 to a low of 7.1 in 1970 (the last available reporting period). Since 1932, the report states, Grand Lake St. Marys has been stocked with fish periodically, although the total number stocked "has decreased over sevenfold" from the 1932-55 period to the 1956-78 period. "Until 1955, the largest percentage of fish stocked was bluegill, which accounted for 58.6 percent of the total." But bluegill did not fare well in the lake, and the remaining members of the species usually were stunted.

Other stockings until 1955 included bullhead (25.1 percent), largemouth bass (5.6), crappie (3.8) and channel catfish (2.8). Northern pike were introduced to the lake in 1949 as a large predator fish. And, "it is interesting to note that gizzard shad (110,614 of them) were introduced into the lake via the stocking program in the 1930s and 1940s."

The emphasis in the stocking program has shifted from small predatory fish (bluegill, for instance) to large predators (northern pike and striped bass). From 1956-78, over 200,000 northern pike, 232,000 northern pike eggs, 134,800 largemouth bass and over 77,000 stripers were stocked in the lake.

Changes in the stocking program, the report notes, "are probably due to the availability of hatchery fish, placement of large predators to reduce populations of stunted bluegill and shad, and generally better knowledge of fish management and natural reproduction of desired species."

Population levels of game mammals, meanwhile, probably "are typical of many of the surrounding agricultural counties," the FWS report states. But intensive farming practices, including the removal of fencerows to make room for additional cropland, "has resulted in the destruction of the necessary habitat to maintain a high density of upland wildlife."

Some species remain common: muskrat, opossum, fox and gray squirrel, cottontail rabbit and whitetail deer. But residential development "has had adverse impacts on a number of mammalian species," the report notes.

The lake is part of a minor *flyway for geese*, and "thousands of migrating ducks and geese use the lake and St. Marys River as a resting area during spring and fall migrations."

The Canada goose management program at the Mercer County waterfowl refuge, started in 1956, produced 31,147 geese from 1957 through 1979. According to division of wildlife data, the refuge produces an average of 259 nests, 1,447 eggs, and 1,153 goslings (80 percent hatching rate) annually. Mercer County ranks 12th among Ohio counties in annual waterfowl "harvest," with 2,391 taken annually by hunters from 1966 through 1975.

Fish and Wildlife, however, has recommended that more extensive surveys of waterfowl other than geese be conducted in the future.

"In summary," the report states, "we believe the fish and wildlife resource base will continue to be adversely affected by individual, uncoordinated projects on and around Grand Lake. A corps project to correct existing problems, as defined by local community leaders, could be (either) detrimental or beneficial to fish and wildlife resources. We believe alternatives exist which would improve those resources, and we recommend the pursuit of those alternatives."

Tomorrow. Formulation of alternatives

THE DAILY STANDARD
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6 March 1980

EXHIBIT A-4
Sheet 2 of 2

Lake Alternatives Are Listed

(Editor's Note: Following is the last in a four-part series on the U.S. Army Corps of Engineers' reconnaissance report on Grand Lake St. Marys. Today's article concerns the report's section on formulation of alternatives.)

By STEVE FOUGHT

Having identified various problems with flood control, water quality, water-related recreation and physical dynamics, the U.S. Army Corps of Engineers study of Grand Lake St. Marys focuses on developing "a more definitive range of solutions . . . but at a gross level of detail."

If extended beyond next September and into "stage three," the study "would concentrate on developing an increased level of detail and refinement on a decreasing number of alternative plans."

At present, the corps' lake study has been funded through stage two, which will focus on specific improvement alternatives, but only in "gross detail." A third stage, if congressionally funded, would be aimed at providing greater detail of the alternatives.

According to the study's timetable, the completion of stage two — tentatively scheduled for September — represents a "potential stop." But local officials concerned with the lake are harboring high expectations for continuation of the study through all three stages, which would last through the end of 1981.

Stage two's current focus involves social, economic and environmental studies of the lake area, as well as an examination of cultural and fish and wildlife resources. Also underway is a study of the lake's hydrology and hydraulics.

Preparation of the preliminary stage two report will continue through the spring, with a public meeting on the formulation of stage two plans set for June.

As part of its reconnaissance report — or, stage one — the corps has listed a wide range of possible solutions to Grand Lake St. Marys' problems. The report emphasizes, however, that "no costs are included and none of these alternatives should be construed as recommendations."

All potential solutions to water quality problems are predicated on "restricting the amounts of available nutrients that contribute to undesirable plant growth."

External treatment measures, or those aimed at reducing pollution input in the watershed basin, include sewage diversion, runoff diversion and-or treatment, soil conservation, and chemical additive control.

The applicability of internal treatment measures, the corps report notes, might be limited by the large surface area of the lake. But possible internal techniques might include: plant harvesting to remove aquatic weeds and algae and reduce sediment; dredging to remove sediment and organic debris; bottom sealing to isolate sediment from the water column; treatment with flocculants, which perhaps would aggregate solids and nutrients into small lumps; and morphological modification, or changing the structural characteristics of pollution agents.

Another internal technique, the report adds, would be accelerating the outflow of nutrients, with the objective of artificially forcing nutrients from the lake at a faster than natural rate.

These alternatives could entail the following measures: encouraging farmers in the drainage basin to maintain vegetated buffer strips between cultivated areas and drainageways to restrict their time of use and method of application of phosphate fertilizers, and to plant winter cover crops to reduce barren-land soil loss; constructing sediment traps on drainage canals leading to the tributaries of the lake; deepening the lake; deactivating nutrients in major tributaries; prohibiting wastewater effluent discharge without nutrient removal; and, surveying the lake to determine exact sources of bacterial contamination.

Possible physical improvements to the lake might include wave-induced ero[...] control practices such a[s] riprap and other prote[ctive] structures, wave suppres[sion] via artificial islands, penins[ulas] and offshore breakw[aters]; deepening the lake; lake le[vel] stabilization; and modif[ication] and creation of lakeshore la[nd] forms.

Streambank erosion, the report notes, could be atta[cked] by revegetation with eros[ion] resistant plant species [or] fabric or solid mats on th[e] bank, or riprap. Boat-[...] and bay erosion could be ad[dressed] with similar techn[iques].

"Since the severity o[f] erosion damage varies a[c]cording to the underlying ca[use], each protection measure m[ust] be individually designed to f[it] the requirements of the p[ar]ticular situation," the rep[ort] notes.

Reducing sedimentation "g[oes] hand-in-hand with reductio[n of] erosion," the report st[ates]. "Stopping erosion comple[tely is] not always physically poss[ible] or economically feasible."

Possible methods of enh[an]cing recreational resou[rces] would include: providing ea[sier] public access; deepening th[e] lake in recreational area[s]; removing stumps for boa[ting] safety; constructing f[ish] habitats to replace those [lost] in stump removal; dredging a[nd] tributary channels and acce[ss] channels; identifying the bes[t]

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access channels and keeping them open; reducing wind-driven wave action; increasing the ratio of shoreline property to lake surface; and, creating limited stillwater areas with protective island or rock piers for boaters and skiers.

Flood control could be promoted by channel clearing and cleaning; channel modification (known in some quarters as channelization); levees; floodwalls; agricultural drainage improvements; upstream retention or detention of flood flows; and spillway modifications.

Non-structural alternatives include: development of flood-plain information to identify flood areas and warn of possible hazards; flood-plain zoning ordinances; development of open-space policies; posting warning signs; flood insurance; and, public-purchased land easements for flood-prone land.

Without lake improvement measures, the corps report notes, health hazards will increase if fecal pollution is not controlled; the summer population of Grand Lake St. Marys probably will continue to decline; property values around the lake might not improve; aesthetics are likely to decline because of water quality problems; and safety hazards due to stumps in the lake and great wave action will continue to exist.

Without improvement measures, the etrophication of the lake will continue. The musty odor will persist, as will water taste problems, high sedimentation, nutrient loads and bacterial contamination.

With improvements, population, particularly during the summer, will increase. Likewise, property values should benefit from lake improvements, which also probably would entail the use of the local labor force in physical projects.

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THE DAILY STANDARD
CELINA, OHIO

21 March 1982

On The Loose

By STEVE FOUGHT

A Rallying Point

Perhaps a word of praise is due the Louisville district of the U.S. Army Corps of Engineers, whose reconnaissance report on Grand Lake St. Marys was the subject of a recent four-part series in this newspaper.

The Louisville corps office is conducting a federally-funded study of Grand Lake St. Marys under Section 217 of the Flood Control Act of 1970. Stage two, formulation of alternative solutions as a "gross level" of detail, is in the works.

The study will continue at least through the fall of this year. And unless victimized by the budget-cutting hysteria currently weeping the land, the study well might extend through 1981 and even further.

Judging from the quality of the reconnaissance report, any funds allocated for continued study of Grand Lake St. Marys will be money well spent, something which cannot be said for all federal programs, certain corps projects included. Indeed, the authors of the reconnaissance report noted that, while not directly beneficial to this particular area, continued research into Grand Lake St. Marys might be valuable as a sort of pilot project for use at other lakes with similar problems.

Still, the reconnaissance report already has paid some rather handsome dividends to the local lake improvement effort. True, the report itself has not improved the water quality at Grand Lake; nor has it reduced sediment loads or algae concentrations or flood hazards.

What the report has accomplished, however, is nearly as important, if not as tangible. It has raised the level of public consciousness about the local lake, its makeup, its problems and its very much underestimated role in the life and economic health of the area.

For the first time ever, the myriad problems of Grand Lake St. Marys have been identified, catalogued and discussed intelligently in a single package.

To no one's surprise, the corps found Grand Lake's problems to be as massive as they are complex.

Drawing upon various historical sources, the report noted the evolution of the lake from a cool, clear body of water which supported a relatively huge commercial fishing industry and an abundance of bluegill, bass and perch into a mucky, turbid body of water with an underdeveloped tourist trade and a reputation for making carp feel very welcome.

With regard to water quality, obviously the main concern of local officials, the report identified in black and white the major problem as "eutrophication," a condition exemplified by high levels of unwanted nutrients.

Furthermore, the decline in overall water quality, the report stated, is at least partially responsible for the lake's failure to attract as many visitors per surface acre as other area lakes. And to this extent, the problem with water quality is related to the local economic well-being.

The important point is that Grand Lake's assets and drawbacks at long last have been quantified through intensive research. While actual improvement projects remain a distant hope, at least the mechanism for seeking assistance for such projects has been set in motion.

At the very least, the corps reconnaissance report should represent a rallying point for everyone concerned about Grand Lake St. Marys. It was only through the cooperation of federal, state and local agencies that the report became a reality.

Because of this rare display of unity, and thanks to the corps of engineers and the local officials who helped secure funding for the study, it is not as unrealistic today as it was in the past to hold out a measure of hope for the survival of Grand Lake St. Marys as a local resource.

EXHIBIT A-6

THE DAILY STANDARD
CELINA, OHIO

Tuesday Evening, March 25, 1980

Country Comforts

By J Swygart

A Stop To Pollution

The monsoon season officially has arrived in northwestern Ohio as the March rains have set in and are nearly a daily occurrence. Rivers and streams once again have left their banks, and as they recede, take some of Mercer County's precious topsoil with them. But how many other pollutants are accompanying the rainfall as it finds its way to various waterways around the county?

Deputy chief for state pollution abatement Robert Goettemoeller was in Coldwater last Thursday evening to outline the state's new pollution abatement standards, focusing mainly on animal wastes, and it was nice to see such a large crowd on hand (over 35) for the program.

But those in attendance were probably the ones who needed to be there least. Their problems were most likely not the serious type, while the few farmers around the county, and there are some, who have real problems in controlling animal waste were probably not there. I hope I'm wrong, but isn't that the way it usually works?

Until now, the responsibility for seeking out pollution violators has rested with the Division of Wildlife of the Ohio Department of Natural Resources, with the Mercer County Soil and Water Conservation District also doing what it could to prevent animal waste pollution. But the SWCD had neither the time nor the manpower to concentrate on that area alone.

But with the creation of the position of animal waste pollution abatement coordinator, to be manned by Dave Reichelderfer, a serious effort will be made to keep the county's streams and lakes free from flagrant dumpings of pollutants.

From time to time there have been news stories in the State Line Farmer describing fines levied by ODNR against farmers (or businesses) around the state for fish kills. We make an attempt to run each and every one of these that comes across the desk, and hopefully they are not taken in the wrong vein by the general public. They are not to make ODNR look like the bad guys who are looking to line their pocketbooks at the expense of farmers, but to stress that pollution is a serious problem, a problem that is being dealt with.

A close look at the location of the fines shows that the majority of violations have occurred in but a few counties. It's not that these counties have more instances of pollution, but rather that these counties have decided pollution is a serious enough problem and have provided the manpower to search out violators.

Now Mercer County is among that group, and hopefully if, or rather when, the abatement coordinator discovers a violation, he will not be met with a hard-core resistance but rather with a willingness to correct the problem.

Animal wastes are not the only type of pollution problem facing residents of Mercer County. Topsoil loss and sediment are also serious cases.

The recently released report by the U.S. Army Corps of Engineers on Grand Lake St. Marys offered a condensed list of possible actions that affect Mercer County farmers. They include:

— Encouraging farmers to maintain vegetated buffer strips between cultivated areas and all drainageways to help reduce sediment loads and reduce overload nutrient transport.

— Encouraging planting of winter cover crops to reduce barren land loss.

— Construction of sediment traps on main drainage canals leading to natural tributaries.

— Restricting the time of use and method of application of phosphorus fertilizers within the drainage basin to help reduce phosphorus loads in Grand Lake.

— Prohibiting direct discharge of wastewater effluent into Grand Lake without nutrient removal.

Not discussed in the report, but nonetheless a much talked-about subject, is legislation prohibiting the fall plowing of river bottomland.

In the next few years some important answers to serious questions must be tackled, and it is good to know that attention is already being paid in these areas.

EXHIBIT A-7

Corps Project Survives Budget Cuts -- So Far

Local Lake Study Still Alive

By STEVE FOUGHT

Federal funding for the third stage of the U S Army Corps of Engineers' study of Grand Lake St Marys appears to have survived cuts contained in President Jimmy Carter's revised fiscal 1981 budget

The local lake study, currently funded through fiscal year 1980 ending Oct 1, was not included in a list of corps projects scheduled to be deleted because of Carter's proposed federal budget cuts

"To be honest with you I'm surprised," said J C Duck, planning formulation chief for the corps' Louisville district. Early Thursday afternoon, Duck had said he "understood" funds for the local lake survey had been axed, although he had not received official confirmation.

But a spokesman at corps national headquarters in Washington later said Grand Lake St. Marys study monies apparently had not been affected by Carter's recommendation Monday for a $165 million reduction in the corps' budget.

A spokesman at the Office of Management and Budget in Washington confirmed that assessment. "I have a list of studies to be deleted," he said, "and I don't see Grand Lake among them"

A spokesman for U S Rep. Tennyson Guyer, R-Findlay, also said continued funding for the project seemed secure "It was not cut," the spokesman said. "and our office is very confident that it won't be."

An aide to U S Sen. Howard Metzenbaum, D-Ohio, said the $40,000 to complete the three-year study and prepare the final report indeed was included in Carter's revised budget. "It's pretty hard to find," he noted. "Forty thousand dollars doesn't even appear as a comma in the federal budget . . . But it's still there."

So far The budget still has to work its way through subcommittees of both houses, the House Appropriations Committee, budget committees, conference committee, and then the floors of both chambers.

But since the local lake survey needs only $40,000 ($280,000 has been appropriated by Congress in the past two years) for completion, and since it is already underway, chances for funding appear better than if the project still were on the drawing board.

Ohio Department of Natural Resources Director Robert Teeter testified before House and Senate appropriations subcommittees on energy and water development earlier this week Teater urged federal lawmakers to refrain from cutting water project allocations in Ohio, which totalled some $58.6 million in Carter's original 1981 budget.

Teater said water projects "are highly visible in the federal budget and therefore fall easy prey to the avowed inflation fighter," but argued that such projects are "fundamental to domestic health as well as to national defense."

He said if the subcommittee decided water project funding had to be reduced, "we would reluctantly accept cuts in the broad general investigation category where there are some regional studies underway in Ohio."

The Grand Lake St Marys study is classified by the corps as a "general investigation."

But Teater said this morning from Columbus that his remarks did not refer, even indirectly, to the Grand Lake St. Marys study. "I probably should have been a little more specific," he admitted.

Teater said the general investigation projects to which he had referred are located in central Ohio, in the Muskingum Basin, and along the Little Miami River and Mill Creek.

"We're fighting to keep going on the Grand Lake St. Marys project," he said "We fought hard for that project, and we're going to stick with it. We've gone to bat for it, and we're going to keep the pressure on them — with the help of the people in your area — to keep that in the budget."

Teater said, however, "we still don't know where the cuts are going to be . . . I was in Washington and I still can't figure it out . . . Everyone is nervous in Washington and fluttering around . . ."

Funding for the third stage of the corps' Grand Lake St. Marys study is necessary to complete the investigation and prepare the final report. Without the third stage and the final report, federal funding for any possible future improvements to the lake would be all but impossible.

"In short, the project would get laid on the shelf," Duck said. "We'd be in the position of saying to your local people, 'Here are a lot of solutions, and they cost a lot of money, but we can't do anything.' "

Duck said the study's stage two report, which will outline various solutions to lake problems "at a gross level of detail," is due in "a month or two." The report, he said, is highly technical and still under study by corps officials connected with the local lake survey. "We have a substantial amount of information on alternatives, and we'll be getting that put together here in the near future."

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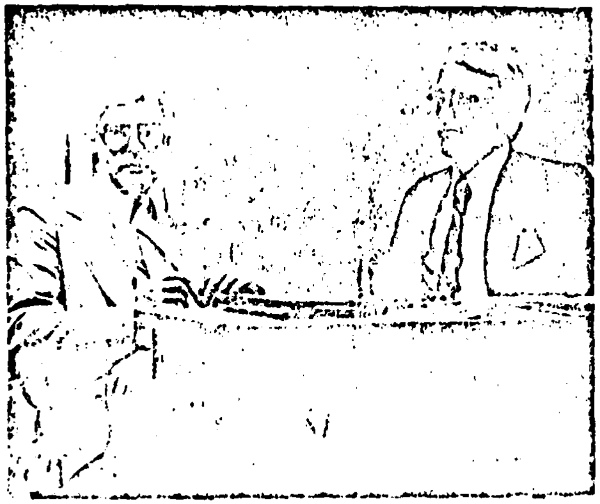
EXHIBIT A-8

Status Of US Lake Study Detailed



Lake Study...

... Al Scalzo, left, project manager for the U S Army Corps of Engineers Louisville district, and Dave Meyer, acting chief of planning, are pictured during Wednesday evening's public input meeting dealing with the now-underway corps study of Grand Lake St. Marys water quality. The session attracted more than 100 people, at the Western Ohio branch campus of Wright State University. (Staff Photo By Bob Bricker)

Corps Duo Seeks Local Input

By BOB BRICKER

Well over 100 persons, including representatives from the Ohio Department of Natural Resources, the Mercer County Soil and Water Conservation District, the Lake Improvement Association, the Lake Development Corporation, commissioners from both Mercer and Auglaize Counties, State Rep Dale Locker, D-Anna, and a staff member from the office of U S Rep Tennyson Guyer, R-Findlay, attended Wednesday evening's special community input meeting on the presently underway U S Army Corps of Engineers' Grand Lake St Marys water quality study.

On hand to explain the status of the study, at the Western Ohio branch campus of Wright State University were Dave Meyer acting chief of planning for the corps' Louisville district, and Al Scalzo, corps project manager.

The local study was authorized under Section 217 of the Flood Control Act of 1970, which directs the secretary of the army to conduct surveys for flood control and "allied purposes," including channel and major drainage improvements. Grand Lake St Marys was one of 23 studies authorized by the act, but the project remained unfunded by Congress until last year. The study, to be funded on a year-to-year basis, is expected to last for three years.

Purpose of the project, according to Meyer and Scalzo, is to seek ways to improve the overall quality of Grand Lake St Marys with particular emphasis on flood damage along Beaver Creek downstream from the lake to Beaver's confluence with the Wabash River, flood damage along the St. Marys River, poor agricultural drainage upstream from the lake along its south shore aggravated by fluctuating water levels, lake water quality problems including adverse odor and taste, submerged obstructions and sedimentation.

The allied purposes specified in the 1970 Flood Control Act cover enhancement of recreational facilities and a fish and wildlife study.

The study was initiated by the corps in December of 1978 and presently is in stage one of a reconnaissance report aimed at gathering information from federal, state and local agencies and individuals. The study's initial phase is expected to be completed in September.

The second stage of the study, the two officials said, will include specific problem identification and solutions, and is expected to be completed in May of 1980. If Congress continues to fund the study, the final report should be completed in November of 1981 with actual lake improvements hopefully to follow.

Scalzo said the purpose of the corps' study "is to recommend to Congress plans to solve Grand Lake St Marys water resource problems and to determine alternative feasibilities."

He presented a number of slides of the lake and addressed the findings thus far.

A major problem contributing to the lake's poor water quality, Scazlo said, "is the fluctuating water level and concurrent flooding problems along the west and east banks. The lake covers approximately 21 square miles, with only approximately 93 square miles of drainage. This fluctuation often leads to overloading Beaver Creek, because the west bank spillway is one foot lower than the east bank spillway."

Lake water odor and taste problems, Scalzo said, are aggravated by "agricultural phosphorous loading from upland tributaries feeding the lake." This phosphorous load, combined with the shallow lake depth and its resultant warm

(Continued on page two)

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Lake Study Detailed

temperatures, "leads to the formation of algae," he said, combined with pollution from agricultural wastes.

Silt deposited into the lake by feeding tributaries and distributed by wave action is another major problem. "Grand Lake has lost 18 percent of its original storage because of siltation," Scalzo said.

Erosion is still another problem: "There is intensive erosion on the south shore and the east bank. There also is much stream bank erosion on the south side, in the channels, and surrounding the islands. Soil erosion from upland agricultural land also is a problem.

"With this erosion, the turbidity of the lake is increased, aesthetic qualities are lost and fish and wildlife suffer."

Rip-rapping along the lake's shoreline has helped, Scalzo noted, but "because of the lake's length and depth, which leads to excessive wind aggravated wave action, rip-rap is beginning to be put back and over by wave action."

Scalzo noted that an environmental impact study will be conducted in conjunction with stage two of the lake study. The corps has contracted WAKPORA, a Cincinnati-based engineering and consulting firm, to conduct the impact study.

If the study is funded for the additional two years, he said, a final public meeting will be held in July of 1981 to present its results. Scalzo stressed, however, that local input is welcomed and needed during the entire study, and added that the upcoming federal budget should accommodate the cost of the study's second phase.

Following his address, Scalzo and Meyer fielded questions from the audience.

Dick Bruns, owner of Northmore Marina, asked for clarification on the need to request corps permits for individual shoreline rip-rapping, channel maintenance or widening.

"Yes," Meyer said. "As far as we know, improvement or modification of the shoreline should be reported to the Louisville branch of the corps and to the State Department of Natural Resources." Actual permits for the installation of fishing and boat piers, except along the west bank, are not required, he said.

Another questioner asked if Louisville corps members conduct field investigations following permit requests for shoreline alteration or improvement.

"We're not sure," Meyer said, "but we think field inspections are made."

Concerning a timetable for the issuance of such permits, Dr. Bill Norris, associate professor of biology at WOBC, said, "the university asked for permission to build a channel two years ago. We got the permits (from the corps) a year ago. I don't think I'd immediately go out and hire a contractor."

While Scalzo and Meyer admitted uncertainty about permit requirements and timetables — "this is sort of a gray area" — they urged anyone planning such improvements to check with both the corps and ODNR.

In response to a question concerning initiation of water quality improvements after the study is completed, Meyer said, "the benefit to cost ratio still will have to be measured before such work can begin. If the benefits do not exceed the costs, the study could possibly be terminated. However, we're talking about an extended period of time before anything happens."

Meyer added, however, that the local study has been given high priority by the corps.

In response to Scalzo's statement stressing the need for local input, Dr. Norris asked if the corps might authorize a local person familiar with the lake to issue permits for riprapping and other improvements instead of requiring permit-seekers to deal directly with the corps.

Scalzo said the corps does not hire persons for such purposes.

The corps officials were asked if they plan to contact farmers along Beaver Creek concerning the study's findings. "Yes," Meyer said, "we would like to."

Asked if the state or federal government sets water quality standards, Scalzo stated that standards are established by the state, but local input concerning water quality still is important.

Another audience member asked why the St. Marys River area north of St. Marys was excluded from the study.

Meyer replied that the area is under the jurisdiction of the Buffalo corps district, but stressed that if flooding in this area is found to be pertinent to the local study, it still can be included in the study. "Because it is in another district," Scalzo said, "would not preclude us studying it."

Asked about floating breakwaters designed to minimize wave action, Meyer said, "I don't know too much about them, but they are a good possibility. I read a report yesterday of putting old tires together and floating them out to break up wave action. There are advantages and disadvantages to this. We're talking about a large area, but we will study it."

Concerning local input, Locker asked, "are you talking about continual input? We have had problems in the past where we have talked the lake to death and meanwhile it keeps filling up with silt."

"We'd like to keep informed," Scalzo said. "I hope that this (the meeting) is not just a one-shot deal. But I don't think we need large demonstrations of concern during the course of the study.

"We think we've heard a number of things tonight. The quality of the water, fluctuating of water level, the flooding along Beaver Creek and the St. Marys River, and the need for enhanced recreation. We're not sure that silt is the lake's major problem."

An audience member concluded the meeting by stating "that if you give us just one inch of clear drinking water from the lake, we'll be satisfied."

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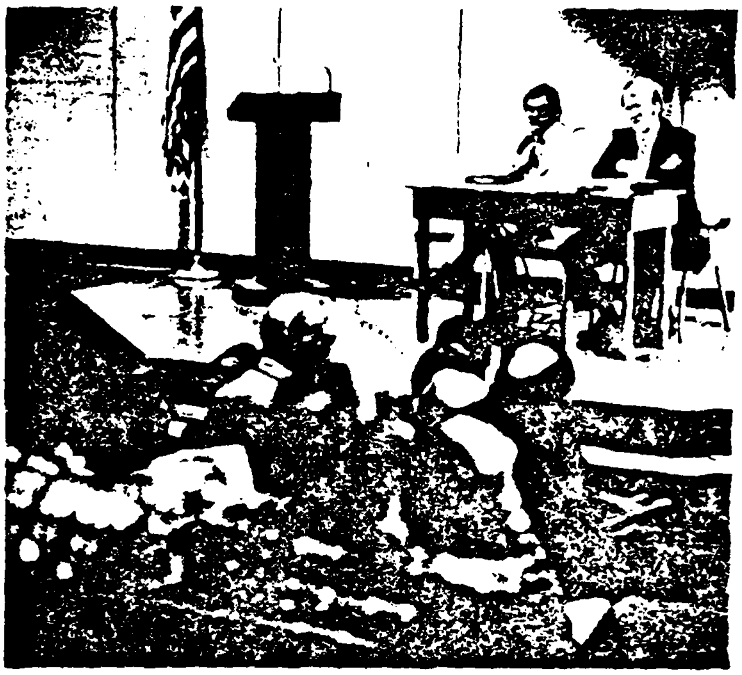

ARMY CORPS ENGINEERS AT LAKE MEET – Al Scalzo, P.E., left, and Dave Weyer, both of the planning division of the Army Corps of Engineers of the Louisville, Ky., district, discuss with interested citizens and local, state and federal officials, the results of their study of Grand Lake St. Marys with regard to forthcoming improvement plans for the local body of water through federal grants. The engineers were receptive to input and suggestions from local residents and knowledgeable lake enthusiasts, some of whom have conducted their own studies. The meeting was held this week at WOBC Branch Campus sponsored by the Lake Development Corp. of Grand Lake St. Marys. (Leader photo by Jimmy Sutton.)

Evening Leader
St. Marys, Ohio
27 April 1979

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The Daily Standard November 7, 1980

Lake Improvement Too Costly To Justify: Corps

By STEVEN FOUGHT

Grand Lake St. Marys' water quality problems "appear better resolved by reducing nutrient loads than by in-lake methods," according to a U.S. Army Corps of Engineers spokesman.

Al Scalzo, project manager for the corps' three-year, congressionally-authorized investigation of the local lake, made the announcement Thursday morning at a meeting arranged by the Lake Development Corporation (LDC).

None of the alternatives considered for resolution of the lake's water-related problems proved to be cost-effective, Scalzo said, which apparently rules out the possibility of a local improvement project by the corps.

According to a rough draft of the corps' local lake phase two report, "those alternatives subject to implementation by the Corps of Engineers were found to be economically unfeasible." But the final stage of the corps' study, which is expected to be completed by late summer of 1981, will include "some additional evaluation of alternatives (which) will then be coordinated with various state and federal agencies to seek interest and authority in the continuation of detailed studies and-or implementation."

LDC Trustee Dennis Gebele, a Celina businessman, said he did not perceive the corps' latest report as "totally negative...

"This is just a stopping-off place Even if the corps cannot make a project out of the lake, they can at least steer us in the proper direction."

The local lake study was authorized along with 22 other investigations by section 217 of the U.S. Flood Control Act of 1970 Its scope was confined by law "to evaluating the advisability and economic feasibility of providing flood control and related water and land resource improvements."

In determining the economic feasibility of any particular improvement alternative, because of that limitation, the corps measured its costs against only those benefits realized through flood control, and did not consider any indirect benefits associated with the enhanced economic, aesthetic or recreational potential of the lake.

Flood-control benefits were calculated for the 10.6 miles of Beaver Creek from its confluence with the Wabash River downstream to the West Bank spillway and also for the lake's south shore from west of Montezuma Bay eastward to Barnes Creek (Southmoor Shores).

The corps estimated average annual flood damages to residences along the south shore at $150,000 (for some 130 private properties), and for properties — principally farmland — along Beaver Creek at $85,000.

In examining lake water-quality improvement alternatives, the corps concluded that "to a large extent, the water quality problems in the lake are the result of intensive agricultural use within its watershed." The report said 23 tons of total phosphorus and 13 tons of sediment "reach the lake annually from agricultural areas.

"This phosphorus loading represents approximately 60 percent of the total annual load reaching the lake from all sources."

It said that "if all cropland in the watershed could be managed to satisfy Soil Conservation Service ... maximum allowable erosion rates," Grand Lake St. Mar[...] total sediment load would [...] reduced by 52 percent gr[...] erosion in the drainage ar[...] reduced by a like figure, a[...] the lake's total phosphorus lo[...] reduced by 40 percent."

But "in general, costs t[...] individual (farmers) excee[...] benefits derived from i[...]plementing the practices." T[...] report said cost-sharing by st[...] and federal agencies possi[...] "could shift the balance to fa[...] implementation and reduce t[...] economic burden" on individ[...] farmers

Other water-quality i[...]provement alternative[...] examined by the corps i[...]cluded: livestock wa[...] management; treatment o[...] tributary inflows; dredg[...] destratification and aera[...] nutrient inactivation; dilu[...] lake drawdown; bott[...] sealing; and, biotic harvest[...].

In each instance, costs we[...] found to be prohibitive w[...] weighed against estima[...] benefits.

Among the alternat[...] considered for control.... shoreline erosion were brea[...] waters: riprap, gabions (roc[...] filled wire baskets); bulkhea[...] and, concrete fabriform ma[...]

But "complete protection fo[...] 60,000 feet of curren[...] unprotected, irregular sout[...] shore areas," according to t[...] report, would cost $1.62 mill[...] for riprap; $2.5 million fo[...] gabions $3.6 million for bulkheads; and, $3.74 million fo[...] concrete mats.

Other erosion and sedimen[...]tion-control alternatives in[...]cluded protection of tributar[...] streambanks and sedimenta[...] ponds, both of which were als[...]

(Continued on page two)

Lake

(Continued from page one)

judged to be cost-ineffective

Alternatives to control lake shoreline flooding included breakwaters (permanent and mobile groins (breakwaters constructed prependicular to shorelines), and shoreline levees None were found to be cost-effective

Alternatives considered for reduction of flooding along Beaver Creek included detention basins, diversion of lake overflows to the St Marys River via Four-Mile Creek, a clearing and cleaning program for removal of flow-obstructing objectis, channel enlargement and agricultural levees

The corps estimated that to clean 9.8 miles of Beaver Creek would cost an estimated $1 million, far outweighing benefits The least-exvensive channel enlargement project considered would have cost an estimated $1.61 million, also cost-ineffective

Diversion of lake overflows to the St Marys River would entail the construction of a new outlet structure on the east side of the lake and a two-mile deep-cut channel to Four-Mile Creek at an estimated cost of $3.5 million, also cost-ineffective

The corps' draft report concluded that, given the availability of funds and the report's findings on cost-effectiveness current lake management practices with regard to dredging and control of the lake pool probably could not be improved upon

EXHIBIT A-10

SECTION B

PERTINENT CORRESPONDENCE

UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
REGION V
230 SOUTH DEARBORN ST
CHICAGO ILLINOIS

1 FEB 1979

Colonel Thomas P. Nack
District Engineer
U.S. Army Engineer District, Louisville
P. O. Box 59
Louisville, Kentucky 40201

Dear Colonel Nack:

Thank you for your letter of January 26, 1979, inviting us to participate in a study of flood control and related problems at Grand Lake St. Marys, Ohio.

We welcome the opportunity to participate in this study, and would like to designate Mr. Robert L. Kay of my Staff (312/353-2307) as our representative.

Thank you for offering us the opportunity to be involved in the discussion and coordination of this project.

Sincerely yours,

Barbara J. Taylor, Chief
Environmental Impact Review Staff
Office of Federal Activities

EXHIBIT B-1

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE 200 North High Street, Room 522
Columbus, Ohio 43215

February 2, 1979

Colonel Thomas P. Nack
Corps of Engineers
Louisville District
P.O. Box 59
Louisville, Kentucky 40201

Dear Colonel Nack:

We appreciate your invitation to participate in the survey investigation of Grand Lake St. Marys, Ohio. Earl V. Scott, District Conservationist at Celina, Ohio, has been selected to represent the US Soil Conservation Service in this study. his mailing address and telephone number is as follows:

301 North Riley Street
Celina, Ohio 45822
Telephone: 419-586-2548

Sincerely,

Robert E. Quilliam
State Conservationist

EXHIBIT B-2

246 N. High Street
Post Office Box 118
Columbus Ohio 43216

Telephone (614) 466 3543
If no answer (614) 466 8686

JAMES A. RHODES
GOVERNOR

JOHN H. ACKERMAN, M.D. M.P.H.
DIRECTOR OF HEALTH

February 6, 1979

Thomas P. Nack
Colonel, Corps of Engineers
District Engineer
Department of The Army
Louisville District Corps of Engineers
P. O. Box 59
Louisville, Kentucky 40201

Dear Colonel Nack:

Doctor Ackerman has asked me to reply to your recent letter. We certainly thank you for providing the Ohio Department of Health with the opportunity to participate in your study at Grand Lake St. Marys, Ohio.

Mr. Frank C. Petrie, Jr.. will represent the Ohio Department of Health and participate in your study. Frank is the Acting Sanitarian in Charge of the Department's Recreation Unit. I am sure he will do a fine job and provide you with assistance during the study. Frank may be contacted at (614) 466-5190 in Columbus. Ohio, or at (614) 385-6851 in Logan, Ohio.

In your letter you mentioned that coordination with other State and local agencies would be necessary. I hope you intend to include all the local health departments within whose jurisdiction your study will take place. Mr. Petrie will be of assistance in coordinating that activity.

Sincerely,

John Frazier, Chief
Bureau of Environmental Health

JF/cw

cc: John H. Ackerman, M.D.
Director of Health

cc: Joesph G. Laco, Chief
Division of PEHS

cc: Frank Petrie
Acting Sanitarian in Charge
Recreation Unit

EXHIBIT B-3

Ohio Department of
Administrative Services
30 EAST BROAD STREET
COLUMBUS, OHIO 43215

JAMES A. RHODES, Governor

RICHARD D. JACKSON, Director

February 6, 1979

Thomas P. Nack, Colonel
Corps of Engineers
District Engineer
Department of the Army
Louisville District Corps of Engineers
P. O. Box 59
Louisville, KY 40201

Re: File No. M-1159

Dear Colonel Nack:

In reference to your letter of January 26, 1979 concerning the proposed study of Grand Lake, St. Marys near St. Marys, OH, we welcome the interest of the Corps of Engineers.

We, of course, will participate in any way that we can. We are enclosing the "Scope of Services" of a contract which we currently have with Burgess and Niple, Limited, Consulting Engineers of Columbus, Ohio. Their report will be in our hands around May 1, 1979.

Mr. Ray Weisent of my staff, telephone number (614)466-4780 is hereby designated as my representative to work with you in any way that will be helpful to your comprehensive study.

Very truly yours,

RAYMOND R. KOHLI, P.E.
Deputy Director
Division of Public Works

RRK:acr

TU/1

EXHIBIT B-4

United States Department of the Interior

GEOLOGICAL SURVEY
Water Resources Division
975 West Third Avenue
Columbus, Ohio 43212

February 8, 1979

Colonel Thomas P. Nack
District Engineer
Corps of Engineers
Department of the Army
P. O. Box 59
Louisville, Kentucky 40201

Dear Colonel Nack:

We received your letter ~~of January 26, 1979~~ addressed to James F. Blakey concerning a survey in Grand Lake St. Mary's, Ohio. Please note our correct address and that ~~I have replaced Mr. Blakey as~~ District Chief.

We would be happy to participate in the study to the extent that our manpower resources will allow. Our capability would include: Measurement of discharge (momentary and/or continuous); measurement of most all aspects of water quality, including suspended sediment loads; limnological work; flood routing and frequency analysis; time of travel studies; and lake contents surveys, etc.

During the early planning phase of this study, either Richard Hawkinson, my assistant, or I will participate in any meetings. If we become substantially involved in the hydrologic work of this study, we will appoint a project leader.

If you have any questions, please call my FTS number, 943-5258.

Sincerely yours,

David E. Click

David E. Click
District Chief

DEC:jh

EXHIBIT B-5

United States Department of the Interior
FISH AND WILDLIFE SERVICE
Federal Building, Fort Snelling
Twin Cities, Minnesota 55111

IN REPLY REFER TO
AFA-SE

FEB 15 1979

Colonel Thomas P. Nack
District Engineer
U. S. Army Engineer District
Louisville
P. O. Box 59
Louisville, Kentucky 40201

Dear Colonel Nack:

In reference to your letter of February 6, 1979 regarding the impending study of Grand Lake, St. Marys, Ohio, we appreciate the early notification of your plans in this area.

The site falls within the summer range of the Indiana bat (Myotis sodalis) and lies along the migratory routes of the peregrine falcon and Kirtland's warbler. One proposed plant, the Plantain, heartleaf (Plantago cordata), has been recorded for Auglaize county, Ohio, which is within the area.

Merryll Bailey has plans in March with John Kessler of your biological staff to examine other potential CE project sites in Ohio and Illinois so will include Grand Lake in that field trip. It is difficult to ascertain potential problems and suggest necessary assessment studies without first examining habitat within the area. Hopefully his forthcoming trip will resolve this problem.

Your Stage 1 work plan which includes non-specific environmental (.05) and fish and wildlife (.06) studies should be useful in identifying problem areas and in designing surveys to investigate specific problem areas.

Hopefully, Mr. Bailey can discuss this proposed project in relation to the other projects during our March meeting and explore the cumulative, long range effects of the flood control projects as a unit.

Sincerely yours,

D.H. Rasmussen

D. H. Rasmussen
Assistant Regional Director

EXHIBIT B-6

Ohio EPA

Re: Grand Lake St. Marys Survey
Corps of Engineers Study

Colonel Thomas P. Nack
District Engineer
Corps of Engineers
Louisville District
P.O. Box 59
Louisville, Kentucky 40201

February 23, 1979

Dear Colonel Nack;

The Ohio EPA would be pleased to provide input for your study of the Grand Lake St. Marys area. We understand that your investigation is authorized by Section 217 of the Flood Control Act of 1970. Although your study proposal includes the areas of flood control, flood damage reduction, drainage, water quality, and water related outdoor recreation; our input would be limited to water quality and water related outdoor recreation. You may contact Mr. Gary Martin, Assistant Chief in our Division of Surveillance and Standards at (614)466-9092 for further assistance during your study.

You may wish to contact the Onio Department of Natural Resources if you have not already done so. Perhaps Mr. Pete Finhe at (614)466-6020 could provide input for your study in the areas of flood control and flood damage reduction. I believe Ohio DNR could also assist you in water related outdoor recreation.

Thank you for this opportunity to work with the Corps during this study of Grand Lake St. Marys.

Sincerely,

James F. McAvoy
Director

JFM:sam

cc: Gary Martin

State of Ohio Environmental Protection Agency
Box 1049, 361 E Broad St., Columbus, Ohio 43216 · (614) 466-8565

James A. Rhodes, Governor
James F McAvoy Director

EXHIBIT B-7

ODNR
Ohio Department of Natural Resources

April 9, 1979

Colonel Thomas P. Nack, District Engineer
U.S. Army Engineer District, Louisville
600 Federal Place, P.O. Box 59
Louisville, Kentucky 40201

Dear Colonel Nack:

Reference is made to your letter of 26 January 1979 concerning the Grand Lake St. Marys survey study.

In accordance with your suggestion, I am pleased to designate John Cousins, Chief of our Division of Water, to serve as your contact for the study. Mr. Cousins can be reached at (614) 466-4768.

As you are aware, the Grand Lake St. Marys study is one of our highest in priority. We are, therefore, vitally interested in assuring that viable alternatives are developed for resolution of the water problems.

Sincerely,

ROBERT W. TEATER
Director

RWT:dkc

cc: Wayne S. Nichols, Deputy Director for Resource Protection
John Cousins, Chief, Division of Water

ODNR
Ohio Department of Natural Resources

May 22, 1979

Colonel Thomas P. Nack
District Engineer
U.S. Army Engineer District
P.O. Box 59
Louisville, KY 40201

Dear Colonel Nack:

Thank you for the opportunity to review your proposed Stage I Work Plan for Grand Lake St. Marys, Ohio.

The Work Plan as proposed is quite acceptable to us and we look forward to working with you and your staff in this cooperative effort. Please keep us informed when we may be of assistance.

Sincerely,

Robert W. Teater

ROBERT W. TEATER
Director

RWT:ck

JAMES A RHODES Governor • ROBERT W TEATER Director

EXHIBIT B-9

ODNR
Ohio Department of Natural Resources
DIVISION OF WATER
Fountain Square · Columbus, Oh. 43224 · 614 466 4765

September 17, 1979

Mr. Neil E. Jenkins
Chief, Planning Division
U.S. Army Engineer District
P.O. Box 59
Louisville, KY 40201

Dear ~~Mr. Jenkins~~ Neil:

This is in response to your inquiry dated 7 September 1979 about fish and wildlife data and needs for additional studies.

Please find attached copies of pertinent inservice documents, publications and/or reports, which may assist in providing the requested waterfowl, furbearer and game production information. In addition, a copy of the Grand Lake St. Marys 1978 Annual Fisheries Report is attached. It should be noted similar annual reports are available for several years between 1970 and 1978 but not refered to or considered on Table 1, page 6 of the preliminary Fish and Wildlife Report, submitted by the Fish and Wildlife Service. We recommend that you or your staff meet with our Wildlife staff to discuss this matter in greater detail. Much useful information is contained in file data which requires time and judgement to extract. Hopefully the data requirements can be made more specific.

We wonder whether the U.S. Fish and Wildlife Service staff is fully aware of the time and funding constraints on the Grand Lake Study. Given these constraints, we feel it is imperative that the study place major emphasis on evaluation and recommendation of specific solutions to the most urgent of the problems. These might include shore erosion control, pool level control and nutrient/algae reduction. Under separate and additional funding authorization, we would enthusiastically support the four-season biological study proposed by Mr. Oberst, although conclusions based upon a single year of study can be difficult to interpret. Under the existing circumstances, we concur in your proposal for more limited biological studies.

Sincerely,

John H. Cousins
Chief

JHC:ck

cc: Carl Mosley, Jr. - Robert Lucas

Enclosure

JAMES A. RHODES, *Governor* • ROBERT W. TEATER, *Director* • [redacted] *Chief*
John H. Cousins

EXHIBIT B-10

Ohio EPA Inter-Office Communication

TO: Al Scalzo, Army CoE, Louisville, Kentucky **DATE:** September 30, 198[illegible]

FROM: Carl A. Wilhelm by Jerry Wager, Chief, Division of Strategic Planning

SUBJECT: Review of State II Interim Report for Flood Control and Allied Purposes at Grand Lake St. Marys.

Thank you for the opportunity to review the Stage II Interim Report for Flood Control and Allied Purposes at Grand Lake St. Marys, Ohio, (May, 1980). While we would like to see some portions of the Report developed in greater detail; nevertheless, the Report does an excellent job of addressing the major issues, incorporating past studies and presenting the relative merits of various control measures. This information enables local, State and federal officials to make some sound policy judgements.

In our view, the Report makes a very significant finding:

> "..primary contributors to the decline in lake water quality are from phosphorus and sediment. As the water quality declines, the quality of the recreational experience the lake will support will also decline... Grand Lake St. Marys can be considered eutrophic... With these conditions the lake may become unacceptable as a source of water supply and recreation.... The most significant contribution of phosphorus to Grand Lake St. Marys appears to be from non-point sources or rural, primarily agricultural land."[1]

While this finding echoes that of past studies, it has not resulted in an alteration in basic governmental approaches to the Lake's problems. Past studies and current program emphasis appear to be on the flooding, dredging and bacterial problems in the Lake and its tributaries. As a result, public expenditures (current and proposed) appear to be directed at symptoms rather than long-term solutions.

Because of the large local and State capital investment in the Lake, (most of which is based upon its maintenance as a source of recreation and water supply), it would appear that future efforts should focus on the primary problems of agricultural runoff including animal feedlots, (contributing 74% of phosphorus load).

This study, as well as past studies, underscores the need to carefully assess the cost-benefit of future State and federal expenditures. For example, the Report currently estimates a 14% phosphorus contribution from urban and suburban runoff. Expanded development of the south shore, which may result if carrying capacities increase with construction of sewerage facilities, could worsen water quality problems and offset gains made by other capital expenditures.

[1] Grand Lake St. Marys, Ohio, Draft Public Information Brochure, pp. 9-10.

EXHIBIT B-11
Sheet 1 of 3

Based on the Report's results, several additional areas need to be looked at:

1.a. Because agricultural runoff has been identified as the primary contributor of phosphorus, additional analyses is needed to define critical problem areas in the watershed tributary to the Lake; initially for feedlots and secondly for farmland.

b. Cost estimations of changes in agricultural practices and feedlot improvements need to be refined. In general, existing cost estimates may be overstated (e.g. p. D-73) and do not consider the alternative of treating only critical areas as opposed to the total watershed.

c. Existing county agricultural programs need to be evaluated to determine the level of resources that can be directed to the problem and the additional funding and manpower needed. Existing funding/manpower levels of Mercer and Auglaize County Soil and Water Conservation Districts should be evaluated to determine their needs. County Extension and ACP programs need to be looked at to determine if their education and funding resources respectively might be better focused to help alleviate existing problems.

d. State and federal agricultural programs should give priority to this area of the State, specifically SCS, ASCS (Special Projects) and the Division of Soil and Water Districts, ODNR.

2. More analysis is needed to determine the cost/benefit and and environmental impact of the facilities recommended by the Grand Lake Regional Sewer System Facilities Plan, by Finkbeiner, Pettis, Strout. Local governments should take advantage of recent changes in the Clean Water Act which allow lower cost, more flexible ("innovative and alternative") solutions to water quality problems resulting from on-site sewage systems.

3. Additional study of in-Lake sediment and its impact on water quality should be done, particularly since it has implications for the cost-effectiveness of watershed land treatment and large scale Lake dredging.

4. The impacts on sediment transport to the Lake and the severity of flooding that might occur from a watershed land treatment program should be studied in greater detail.

5. Because of the shared responsibility for the quality of Grand Lake St. Marys, the rural, urban and suburban sectors of the community need to be equally involved in analyzing and choosing alternative control strategies.

6. Unfortunately, federal grant programs to control nonpoint source pollution are largely lacking. However, even in the face of this, State, federal and local agencies need to cooperatively devise a comprehensive funding program directly focused on the Lake's primary problems. This may involve non-traditional types of expenditures and vastly improving the financial status of local soil and water conservation programs. Local programs to reduce the problem of urban runoff should also be given priority since this source of pollution may be expected to increase in importance. In this regard, the Report could give more emphasis to the traditional community "house-keeping" and land use programs which help reduce urban runoff.

7. Because of local perceptions regarding the ineffectiveness of of in-Lake dredging operations (p. C-15), the localized nature of flood control improvements, controversy over the proposed wastewater facilities plan, and the need to involve more agricultural interests from the watershed, a greater public involvement effort may be necessary. Army CoE representatives have indicated that remaining project funds are limited (meeting 9/16/80) and therefore more in-depth analysis of subjects may not be possible. Given this, an expanded emphasis on public education through local meetings, etc., may prove to be the most effective route to take at present. A better understanding of the inherent costs and limitations of some controls and the discussion of a watershed treatment effort may result in more cost-effective approaches to mitigating the effects of the Lake's problems.

If your have any questions regarding our comments, please contact me.

cc: John Cousins, Chief, Division of Water, ODNR
Greg Binder, Chief, Office of Wastewater Pollution Control, Ohio EPA
Bob Goettemoeller, Division of Soil and Water Districts, ODNR
Reading
File

ODNR
Ohio Department of Natural Resources
DIVISION OF WATER
Fountain Square • Columbus Ohio 43224 • (614) 466 4766

October 3, 1980

Mr. James Duck, Chief
Plan Formulation Branch
US Army Engineer District - Louisville
P.O. Box 59
Louisville, KY 40201

Dear Jim:

Enclosed is a sheet of comments on the Grand Lake St. Marys study brochure draft. I believe Bob Goettemoeller;s points are well taken.

Sincerely,

Arthur F. Woldorf
Supervisor
Water Planning Unit

AFW:ck

Enclosure

EXHIBIT B-12
Sheet 1 of 2

Comment: Grand Lake St. Mary's Ohi

Draft Public Information Brochure

October 2, 198?

Robert L. Goettemoeller

Deputy Chief, Pollution Abatement

ODNR - Soil & Water Districts

Table 3 on page 10 reflects figures for phosphorus loadings from specific sources which seem much more realistic than previous draft. These new figures need to be reflected in the text on pages 25 through 27, however.

I am still a bit concerned about the low figure for waterfowl. If you total the animal units by Fed. EPA standards, there exists probably between 1000 and 3000 animal units of waterfowl based on the resident and migrant waterfowl. These animals are generally closely associated with water. Although the Division of Wildlife has done a good job of enticing the fowl away from the lake proper, this 1% figure may be challenged at the local level.

The text also needs to be clarified as to the contribution of domestic and municiapl sewage to Phos. loading. The text should indicate which category in Table 3, if any, includes these wastes.

RLG:lb

EXHIBIT B-12
Sheet 2 of 2

ODNR

Ohio Department of Natural Resources

DIVISION OF WATER
Fountain Square • Columbus, Ohio 43224 • (614) 466-4766

November 10, 1980

Mr. Al Scalzo
Chief, Planning Division
U.S. Army Engineer District, Louisville
600 Federal Place
P. O. Box 59
Louisville, KY 40201

Dear Al:

The public meeting in Celina went very well, I thought. The Lake Improvement Association seemed to have a very good understanding and acceptance of what you presented.

While talking with Soil Conservation Service people today, I realized one area of your draft report which I think should be clarified or strengthened. You make a good case for improved soil management practices to control sediment-borne phosphorus. SCS agrees that farmers need a bit of subsidy to justify no-till farming in poorly drained areas. But they also point out that no-till practices in the Grand Lake St. Marys area require improved soil drainage which, in turn, requires improved drainage outlets. It is quite important to us that the drainage outlet problem be pointed out in your comments. I understand SCS has pretty good field data on this. You might want to talk with Marshall Edens, Ohio SCS P.L. 566 and River Basin Planning Chief at (614) 469-6932.

Sincerely,

Arthur F. Woldorf
Supervisor
Water Planning Unit

AFW:ck

cc: Marshall Edens

United States Department of Agriculture

Soil Conservation Service

Room 522, Federal Building
200 North High Street
Columbus, Ohio 43215

December 8, 1980

Mr. Al Scalzo
Chief, Planning Division
U.S. Army Engineers District, Louisville
600 Federal Place
P.O. Box 59
Louisville, Kentucky 40201

Dear Mr. Scalzo:

This is to document our phone conversation of November 20, 1980 relative to no-till farming and sediment control.

As stated in our phone conversation, I feel, and so do others in SCS, that no-till or minimum till operations reduce erosion and the resulting sediment production. However, we have little or no hard data to support such claims. As I said, "we feel."

Contacts with Dr. Sam Bone and others at Ohio State University, whose names and phone numbers I furnished you, might be more helpful and considered more authoritative.

I apologize for my lack of assistance but not being a research organization, we have few licenses.

Sincerely,

Marshall D. Edens
Water Resources Planning Staff Leader

cc: Arthur Woldorf, ODNR, Columbus, OH

EXHIBIT B-14

ODNR
Ohio Department of Natural Resources

DIVISION OF WATER
Fountain Square • Columbus Ohio 43224 • (614) 466-4766

March 27, 1981

Mr. Neil E. Jenkins, Chief
Planning Division
U.S. Army Engineer District, Louisville
P.O. Box 59
Louisville, KY 40201

Dear Neil:

Thank you for the opportunity to review the preliminary drafts of concluding sections of your proposed report on Grand Lake St. Marys. Copies were shared with our Divisions of Outdoor Recreation Services, Parks & Recreation, Soil & Water Districts, Wildlife, and Engineering, as well as Ohio EPA and Ohio Water Development Authority. Our suggestions follow.

1) Sections on "Recommendations" and "Conclusions" should each begin with a short paragraph which defines the purpose of the section. It should be made very clear to the reader that the Conclusions present the Corps' judgements regarding desirable future actions and priorities, not necessarily limited by existing feasibility or authorizations. It should be overtly stated that Recommendations relate exclusively to Corps' comments to Congress about feasible federal action. Most readers will not understand that your report must be addressed to Congress.

2) The Ohio Public Works proposal to release increased flows out the east end of the Lake should be discussed in greater detail to enable reader understanding that the action will have negligible flood control impacts on Beaver Creek and the Lake, and unknown impacts on the St. Marys River flood plain. If you do have information on resultant impacts on the St. Marys watershed, the reader should be referred to it. We suspect that the impacts would be great and legally complex.

3) On page 13, next to last paragraph, add ODNR to cooperating agencies in dredging program.

4) On page 14, second paragraph, we would prefer to delete this paragraph due to conflict with an ongoing program.

5) Construction costs referred to in the report seem to be costs anticipated if the projects were federally built. Unit costs tend to be much lower

for locally sponsored projects. Item 6, top of page 2 should recognize this difference so as not to unduly influence existing discussions about county projects.

6) Item 1, page 1 should refer the reader to the more detailed discussion contained in the main report.

7) Item 3, page 1 would be more helpful if reworded positively, so as to clarify that the Lake does provide some limited flood control but extends the period of bankfull flow.

8) Item 18, page 8. We doubt that minimum-till agricultural practices will in all cases cost farmers more than his benefits despite recently published data. Would recommend you delete all words after the semi-colon.

9) 3rd paragraph, page 11, should also refer to ODNR state standards for erosion and sediment control.

10) Item 1, page 12. Substitute "efficient" for "minimum".

11) Page 12, next to last paragraph. Substitute "to enforce" for "establishing."

12) Phosphorus Reduction, page 10. We propose the following less specific wording be used.

<u>Phosphorus Reduction</u>

Continued efforts should be directed toward phosphorus reduction from sewage wastes. This can be accomplished by regional collection, treatment, and disposal outside the watershed or by improved on-lot and package plant alternatives or a combination of solutions. Because of the relatively high cost of installation of a centralized sewerage system, the Ohio Water Development Authority has received USEPA grant to do additional facility planning and consider alternatives to the centralized system. From the point of view of best lake quality management, discharge of all sewage effluent to some point outside the watershed would be the preferred alternative.

13) Several more specific suggestions from reviewers are provided in the sheets attached. Use your own judgement.

Sincerely,

John H. Cousins
Chief

JHC:ck

Enclosures

EXHIBIT B-15
Sheet 2 of 2

SECTION C

COMMENTS AND RESPONSES

SECTION C

COMMENTS AND RESPONSES

On 9 June 1981, drafts of the Main Report and Technical Appendix were sent to selected Federal and nonfederal agencies, local organizations and governments, and to individuals and groups that had expressed an interest in the study. The draft Main Report and Appendix were furnished to agencies and government entities for review. This mailing consisted of 30 copies of the report and appendix. All letters received as a result of the review of the documents are displayed in this section. Corps of Engineers responses to comments contained in the review letters are appropriately displayed.

ODNR

Ohio Department of Natural Resources

DIVISION OF WATER
Fountain Square • Columbus, Ohio 43224 • (614) 466-4959

July 2, 1981

Colonel Charles E. Eastburn
District Engineer
U.S. Army Engineer District, Louisville
P.O. Box 59
Louisville, KY 40201

Dear Colonel Eastburn:

Thank you for providing the Department of Natural Resources the opportunity to review the Draft Survey Report for Flood Control and Allied Purposes, Grand Lake St. Marys, Ohio. We suggest the following changes be considered:

page 70 -- The section headed "Phosphorus Reduction" should be changed to "Wastewater Treatment" and the first sentence should be changed to read, "Continued efforts should be directed toward reducing bacterial contamination and phosphorus loading introduced to the lake from sewage wastes."

The section has been revised accordingly.

page 71 -- In the first line, "Ohio Water Development" should be "Ohio Water Development Authority."

Comment noted.

page 75 -- We are in concurrence with the statements made in the "Conclusions" section and believe these could be formulated into a management plan for the lake, to be implemented by the various agencies identified--the report stops short of suggesting such a plan. While we realize that the report is being submitted to Congress and concerns only the Corps of Engineers activity, we feel it would have a more positive effect on local citizens in Ohio if mention were made concerning the possibility of a coordinated lake improvement plan. To achieve this aim, the following paragraph has been drafted as a possible replacement of the "Tentative Recommendations" section.

This paragraph has been incorporated in its entirety.

Based on the conclusions contained in this report and following coordination with pertinent Federal, State and local interests, whose comments and responses generally concur in the study conclusions, no further action by the Corps of Engineers is found feasible at this time in providing improvements in the interest of flooding, water quality, and other water and related resources at Grand Lake St. Marys, Ohio. However, an improvement plan for the area formulated using the management methods outlined in the forgoing "Conclusions" section of this report and coordinated among the specific federal, state and local interests identified, would produce positive impacts and thus enhance the recreational and aesthetic values of the Lake.

Sincerely,

John H. Cousins
Chief

JHC:ck

cc: Robert Lucas

United States Department of Agriculture
Soil Conservation Service
200 N. High Street
Room 522
Columbus, Ohio 43215

August 4, 1981

Colonel Charles Eastburn
U.S. Army, Corps of Engineers
Louisville District
600 Federal Place, P.O. Box 59
Louisville, Kentucky 40201

Dear Colonel Eastburn:

The Draft Survey Report for Flood Control and Allied Purposes, Grand Lake St. Marys, Ohio was sent to the State Conservationist, USDA, Soil Conservation Service, Columbus, Ohio. We have reviewed this report and have the following comments.

There are corrections needed in regard to the discussions of soils located in the area of this project. We suggest correcting the second paragraph, page 6, of volume 1 as follows:

Land adjacent to Beaver Creek is predominantly Defiance-Wabash Soils which are very poorly drained and occupy low lying, level and depressional positions on flood plains. Drainage is difficult to establish due to a lack of suitable outlets resulting from the nearly level topography and prolonged high flows in the main channel. Soils in the Grand Lake St. Marys Watershed are dominantly in the Blount-Pewamo and Blount-Glynwood soil associations. These soils are nearly level to gently sloping, somewhat poorly to very poorly drained silt loam-silty clay loam soils over loam or clay loam glacial till. They have poor bearing values in the subsoils and have severe limitations for septic tank systems. With a good drainage system and a high level of management these soils rank as one of the most productive of agricultural products.

This paragraph has been incorporated in its entirety.

We appreciate the opportunity to review and comment on this plan.

Sincerely,

Robert R. Shaw
State Conservationist

APPENDIX 3

REPORTS OF OTHERS

Section A	Fish and Wildlife Service Report dated 17 August 1979

United States Department of the Interior
FISH AND WILDLIFE SERVICE
IN REPLY REFER TO:
East Lansing Area Office
Manly Miles Building, Room 202
1405 South Harrison Road
East Lansing, Michigan 48823

Colonel Thomas P. Nack
District Engineer
U. S. Army Engineer District
Louisville
Post Office Box 59
Louisville, Kentucky 40201

Dear Colonel Nack:

This responds to your February 5, 1979, letter, requesting a preliminary Fish and Wildlife Report on The Grand Lake St. Marys project in Mercer and Auglaize Counties, Ohio. These comments have been prepared under the authority of and in accordance with provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) and in compliance with the intent of the National Environmental Policy Act of 1969. In accordance with the Endangered Species Act of 1973, as amended, the information you have provided has been forwarded to the Regional Director, U. S. Fish and Wildlife Service, Federal Building, Fort Snelling, Twin Cities, Minnesota 55111. Information regarding endangered species will be forwarded under separate cover.

INTRODUCTION

Grand Lake St. Marys is located in Mercer and Auglaize Counties in west-central Ohio (Plate 1). The lake was formed by placement of a dam on the headwaters of Beaver Creek in the Wabash River watershed and a dam on the Miami and Erie Canal which joins the St. Marys River in the Maumee River watershed. The two dams formed a shallow lake with approximately 21 square miles of surface area. The lake is approximately 8 miles long, 2 miles wide, and has an average depth of 8 feet. The total watershed draining into the lake is 114 square miles. The lake is owned and operated by the State of Ohio. Several lakefront parcels are managed by the Ohio Division of Parks and Recreation, which operates a state park, and the Ohio Division of Wildlife, which manages a fish hatchery and waterfowl refuge. Presently, the general study area is intensively farmed, with predominately row crops. Seasonal and residential dwellings surround the lake.

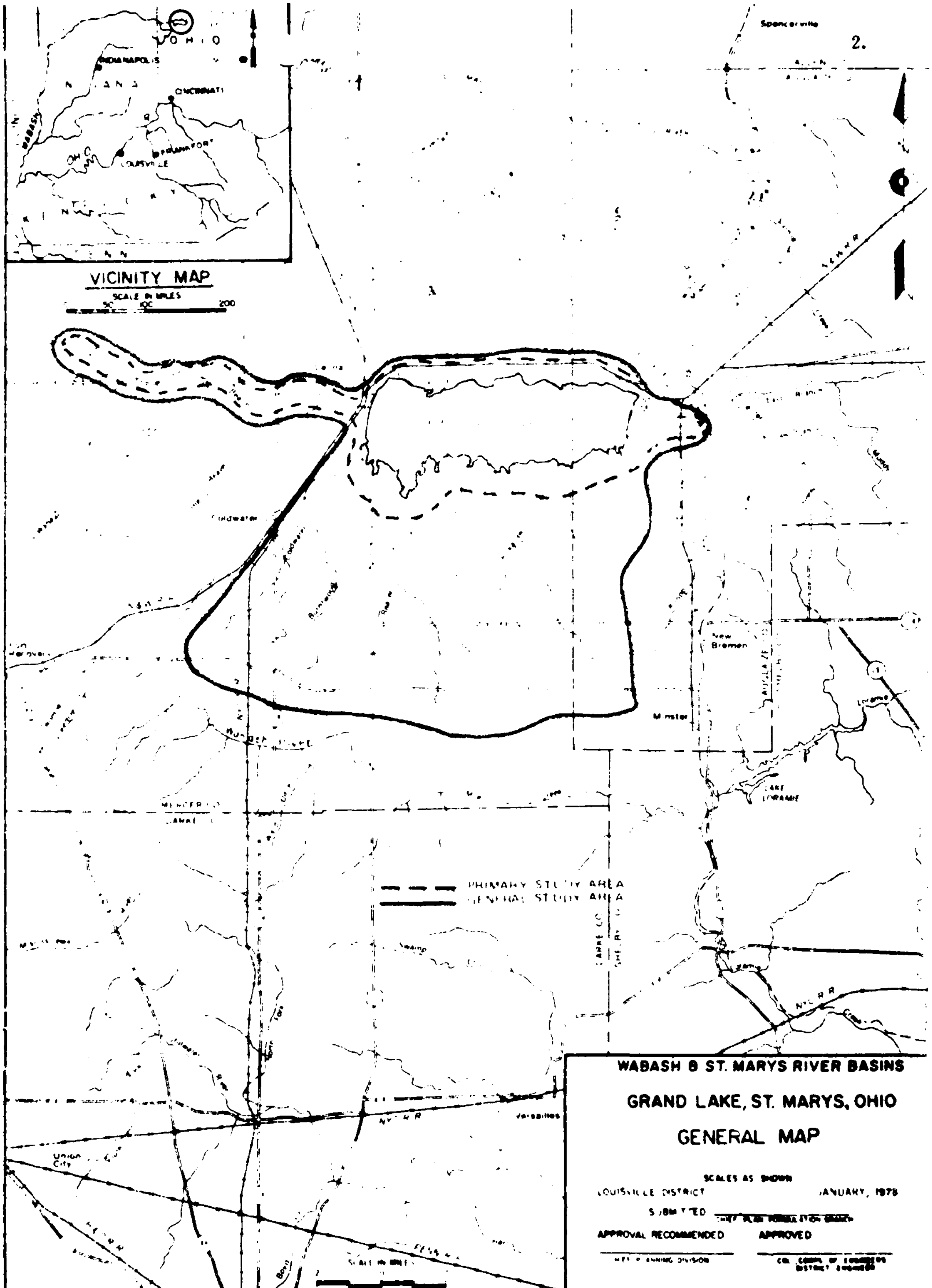
VICINITY MAP
SCALE IN MILES
OHIO
INDIANAPOLIS
CINCINNATI
FRANKFORT
LOUISVILLE
WABASH
Spencerville
2.
Coldwater
New Bremen
Minster
Versailles
Union City
LAKE LORAMIE
PRIMARY STUDY AREA
GENERAL STUDY AREA
WABASH & ST. MARYS RIVER BASINS
GRAND LAKE, ST. MARYS, OHIO
GENERAL MAP
SCALES AS SHOWN
LOUISVILLE DISTRICT
JANUARY, 1978
SUBMITTED
APPROVAL RECOMMENDED
APPROVED

PLATE 1

Based upon information from your Stage I Work Plan, local interests have identified the following water resource problems: flooding of farm land along Beaver Creek to its confluence with Wabash River; flood damage along the St. Marys River; poor drainage of agricultural land along the south shore; lake water quality problems due to eutrophic conditions; shoreline erosion due to fluctuating water levels and excessive wave action; degraded recreational use of the lake due to water quality, wave action, and underwater hazards; and influx of silt and chemicals (including nutrients) from farm, residential, and industrial activities.

Grand Lake St. Marys was created in the mid-1800's as a water supply reservoir for the canal system in the area, and secondary uses included residential and industrial water supply. Recreation, such as boating, was not considered in its construction; consequently, trees and other vegetation were left in the basin which included the southern edge of Ohio's Black Swamp. Clarence F. Clark (1951, 1960), a life long resident and naturalist of the lake area, provides a comprehensive natural history of the lake from its early years to the late 1950's. Prior to 1890, the flooded forest apparently provided a haven for both fish and water-dependant wildlife. Largemouth bass, bluegill and other sunfish, perch, bullhead, and frogs were caught in abundance by numerous commercial fishermen and private individuals. In addition to providing food for local families and bar patrons (where free fish were served with drinks), fish were shipped by the barrel to markets in Cincinnati and St. Louis. Commercial fishermen gave accounts of catching 300 pounds of bass from 11 nets in 24 hours. Another fisherman shipped 6 to 8 barrels of dressed fish per week during the spring. A sport fisherman reported taking 50 to 60 bass per day. "Fishing was excellent," and the fish populations apparently were not adversely affected by this uncontrolled fishing pressure. Clark surmised that the following factors led to this condition: the lake water was cool and clear; and stumps, snags, logs, and "moss" or submerged aquatic vegetation provided ideal habitat for fish and aquatic related animals, while buffering wave action on the shallow lake. The lake, likewise, provided quality habitat for large numbers of resident waterfowl, cormorants, and wading birds. These fish-eating birds had no apparent adverse effects upon the fishery resource, according to Clark.

Near the end of the century, the oil boom hit the lake area. From 1890 to 1900 a severe drought lowered the lake water levels, which resulted in removal of stumps, snags, and logs. Hundreds of acres of corn were raised on the cleared lake bottom. To supply water to the canal system a ditch was dug from the east outlet approximately one and one-half miles lakeward. The massive mats of submerged aquatic vegetation disappeared during the peak of the oil boom. At the same time carp were introduced, and intensive agricultural activity began in the watershed. All these factors contributed to a change of lake water quality from cool-clear to warm-turbid waters. This was followed by a corresponding change of the fish community to carp, crappies, channel catfish, and bullhead. Populations of water related avifauna also decreased, while heron and cormorant colonies disappeared from the lake area. Since the inception of the degraded conditions at Lake St. Marys, several decades of intensive efforts were made to replicate earlier conditions which contributed to the lake's excellent fishery resources. These methods included regulation of angling during spawning seasons, rough fish removal, stocking of fish, and habitat improvement. All these methods are discussed in detail by Clark (1960). Despite the large allocation of funds and man-power over the years, the goal of returning the fishery population to its former condition has not been accomplished.

Grand Lake St. Marys has always been a shallow lake, but it has become more shallow due to deposition of silt and organic material. Most of the substrate is composed of these materials, with few gravel beds remaining exposed for spawning purposes. The east and west shorelines were formed by dams which are presently riprapped to protect the shoreline. The north shoreline has a high bank with sufficient gradient going north from the lakeshore. Consequently, the lakefront property became developed with middle to upper priced residences, and some lakefront property is being farmed. A significant portion of the shoreline has been protected from erosion by land owners. Because of the development only small shoreline areas remain in their natural condition. The state park exists along the northeast and east shoreline. This park is currently being expanded to include the west shore between the Coldwater Creek entrance and Monroe Road. Ohio DNR was granted a Section 404 permit to complete the project which consists of eight fill areas totaling 90 acres adjacent to and near the west shore. To minimize adverse impacts to waterfowl, we recommended conditions to the filling and riprapping of the southernmost site. We also recommended the use of 10 percent, 14 to 18-inch riprap to improve catfish spawning sites and the expedient completion of riprapping to minimize erosion and turbidity.

The south shore has little relief above normal lake water levels. Because of this condition much of this shoreline is undeveloped, although a housing development is presently being constructed along the southeast shoreline. Most of the wetlands around Grand Lake are found along the south shore. During the early years of the lake, the south shore wetlands were shallow meadows, which were later replaced by vast cattail marshes, some being one-half mile in width (Clark, 1960). In recent years, cattail marshes have retreated and are now replaced by lotus, water lily, and arrowhead. Other aquatic plants include coontail, pondweed, water weed, duck weed, and bladderwort. The retreat of the cattail marsh was due to management efforts to remove the cattails with a vegetation cutter, dredging in the cattail marsh to provide deep open water for fishing and waterfowl hunting, and upheaving of ice which removed cattails from some areas. Also, we suspect that a change in water levels may have been a factor in the replacement of cattails. Based upon our Classification of Wetlands and Deep-water Habitats of the United States, these wetlands include Emergent Wetland and Aquatic Bed classes in the Lacustrine system and Forested Wetland class in the Palustrine system. These classes correspond to Types 3, 4, and 7, respectively, in Circular 39, Wetlands of the United States.

FISHERY RESOURCES

Phytoplankton studies of Grand Lake St. Marys were made by Roach (cited in Clark, 1960) during a four-year period in the 1930's. The next intensive sampling of phytoplankton was done in 1973 by Hilgert, et al (1978) as part of the National Eutrophication Survey conducted by U. S. EPA. General conclusions of these two studies are that the lake has become progressively more eutrophic, as indicated by a several fold increase of phytoplankton density and a change of dominant groups, from diatoms to blue-green algae. This change is exemplified by the odor and taste problems associated with the lake water.

Clark (1960) includes a summary of zooplankton and aquatic invertebrates found in Grand Lake St. Marys. Cladocerans are the major group of zooplankton found while midges (Chironomidae) are the most abundant benthic organisms. Other invertebrate groups found in the lake include crayfish, mussel naiads, leeches, fairy shrimp, freshwater sponges and bryozoans. A comprehensive study of zooplankton and benthos is needed, since recent data is not available.

Clark (1951, 1960) eloquently described the fishery conditions in the 1800's. At that time, the most prized and abundant food fish species included largemouth bass, bluegill and pumpkinseed. Other important species included bullhead and perch. Both commercial and sport fish harvest were unregulated; however, natural recruitment apparently sustained high yields. In 1894, the total commercial harvest was over one-half million pounds. Largemouth bass, catfish, sunfish, and perch comprised the major portion of the harvest while carp and frogs were relatively minor contributors of the total poundage. Those years were the beginning of the end of excellent fishing in the lake. The oil boom was nearing its peak, fishery habitat was degraded by removing stumps and snags during the drought years, the mats of aquatic vegetation disappeared from the near-shore areas, and the surrounding watershed was intensively cleared and farmed. The lake emerged with different physical and chemical characteristics which were reflected by a change in the fish fauna. The earlier, more desirable species were replaced by crappies, carp, channel catfish, bullhead, quillback, and gizzard shad as the dominant species. This group has basically maintained its dominance since 1932. Table 1 presents test net data at approximately 5-year intervals. The data illustrate population dynamics of the sport fishery from 1932 to 1970. The data indicate considerable population fluctuations throughout this period. Some generalizations are that the dominance of black crappie and carp during the first half of the period were replaced by gizzard shad and quillback during the second half. Populations of white crappie and channel catfish remained relatively stable. The period of highest catch per hour was from 1946 to 1955.

In addition to the test net data, shore seining data is collected each summer by the Ohio Division of Wildlife. Surveys are made at St. Marys Park Beach, Jack Oak Point, Scotty's Beach, Harbor Point, Windy Point Beach, and the back water area of the waterfowl refuge. These data also indicate considerable yearly fluctuation in catches of individual species. By far the most abundant species was gizzard shad, followed by common shiner, hybrid sunfish, and quillback. Clark (1960) includes a list of 51 species having been recorded in the lake and its watershed, with recent introductions of flathead catfish and striped bass.

Table 1. Summary of Ohio Division of Wildlife test net data of fish populations at Grand Lake St. Marys, 1932-1970.

YEAR	1932*	1938*	1940	1946*	1950	1955	1960	1965	1970
HOURS FISHED	136	144	203	565	397	92	348	144	120
CATCH/HOUR	22.0	13.8	9.4	57.3	41.1	39.5	18.7	22.8	7.1
SPECIES**									
Black crappie	32.5	10.6	24.8	39.7	52.4	5.3	4.3	6.8	9.4
White crappie	12.0	60.0	19.6	14.1	18.7	39.0	13.9	14.7	21.0
Channel catfish	1.0	1.5	37.3	14.1	6.9	10.5	6.7	33.0	2.1
Gizzard shad		4.9	0.2	24.8	16.0	41.1	6.1	8.3	31.8
Carp	52.3	10.1	6.9	2.6	2.7	2.4	13.3	7.7	4.3
Quillback	2.3	7.2	0.6	3.2	2.0	0.8	47.2	15.1	25.5
Bullhead		1.3	4.0	1.3	0.3		6.6	5.8	2.6
Bluegill	0.8	4.3	5.6	1.6	0.8	0.1	0.5	0.1	1.7
Largemouth bass	0.1	0.4	0.1	<0.1	<0.1		<0.1		0.2
White sucker			0.1	<0.1	<0.1	<0.1	1.2		
Pumpkinseed			<0.1		<0.1		0.1		
Yellow perch			0.1		<0.1			<0.1	
Goldfish				<0.1					
Golden shiner				<0.1				<0.1	
Northern pike							<0.1	<0.1	0.5
Other sunfish							<0.1		
Other species							<0.1		
Orangespotted *sunfish*								<0.1	
Common sucker								4.8	1.0

* Data not collected on 5-year *interval*.

** Percentages of total yearly catch are presented by species.

Considerable emphasis was placed on the fishery resources of Grand Lake in the mid- to late 1940's. An intensive creel census was taken from 1946 through 1950, with spot checks through 1955 (Clark, 1960). Maximum effort was extended in 1948 with 26,787 anglers contacted. Catch per hour ranged from 0.6 in 1949 and 1950, to 1.9 in 1951. From 1946 through 1950 the total estimated fish taken from the lake varied from 382,073 in 1949 to 1,806,755 in 1946. From the 10-year creel census data, an average of 67.1 percent of total harvest were crappies (black and white); 18.3 percent, channel catfish; 7.3 percent, bullhead; 1.4 percent, bluegill (only 1946 to 1950); 3.9 percent, carp; and 1.7 percent, largemouth bass. The results of the census clearly indicate the importance of the lake for sport fishing.

Clark (1960) includes a comprehensive review of fishery populations in Grand Lake St. Marys. Included are discussions of food and feeding of fishes, age and growth, fish parasites, and competition in fish populations.

Grand Lake St. Marys has never had large populations of minnows; yet it supports large numbers of crappies which typically feed on minnows. It is concluded that gizzard shad play an important role in supporting populations of crappies, as well as recent introductions of other predatory fishes.

Age and growth data of popular sport fish in Lake St. Marys are discussed by Clark. These studies indicate that the growth of black crappie, white crappie, and bluegill is slower when compared to the same species in other lakes. Black crappie experienced the most growth during the first year and white crappie, the second year. The slow growth rate of bluegill indicates that conditions at Lake St. Marys are not favorable for this species. Largemouth bass had a normal growth rate, but below the State average, until the fourth year when exceptional growth was noted, followed by growth comparable to the State average.

No known studies have been conducted on parasites and diseases of Grand Lake St. Marys fish. However, Clark includes a list of parasites and diseases which have been observed on fish in the lake.

Competition of fish populations exists at Grand Lake St. Marys, as in any body of water with aquatic biota. Clark suggests that "an understanding of the intricate food relationships might assist in unraveling some of the mysteries of changing fish populations in Lake St. Marys." Stocking of predatory fish has received new emphasis to control stunted populations of bluegill and crappies, as well as provides new opportunities for anglers.

Fisheries management efforts on Grand Lake St. Marys have been evident since the early 1930's. One of the first management techniques included stocking of fish, which began in 1932 (Clark, 1960). Until 1955, the largest percentage of fish stocked was bluegill which accounted for 58.6 percent of the total, followed by bullhead with 25.1 percent, largemouth bass with 5.6 percent, crappie with 3.8 percent, and channel catfish with 2.8 percent (Table 2). Northern pike was included in the stocking program in 1949. Pike were introduced to add a large predator fish to the lentic system. It is interesting to note that gizzard shad were introduced into the lake via the stocking program in the 30's and 40's.

From 1956 through 1978, major emphasis was placed on stocking of northern pike, followed by largemouth bass. During this period, two exotic species, striped bass and flathead catfish, were introduced into the lake via the stocking program. Significant changes have occurred in the fish stocking program in Grand Lake St. Marys. The total number of fish stocked has decreased over seven fold, and emphasis has gone from small predatory fish (bluegill) to large predators (northern pike and striped bass). Largemouth bass remained an important species throughout the total stocking period. Changes in the program are probably due to the availability of hatchery fish, placement of large predators to reduce populations of stunted bluegill and shad, and generally better knowledge of fish management and natural reproduction of desired species.

In addition to the stocking program, other fish management techniques included regulation and the closing of certain portions of the lake to fishing during the spawning season. Through comparative test seining, it was later found that the sanctuaries had no greater populations of young fish than other portions of the lake. From 1932 to 1955, rough fish were netted and removed from the lake. At first only carp were removed, but later gizzard shad, quillback, and suckers were removed as well. In later years, the total weight of shad caught exceeded the maximum poundage of carp netted in the 1930's. Rough fish removal was discontinued in 1958, since its results were negligible. Habitat improvement methods on Grand Lake St. Marys are described in detail by Clark (1960). They include placement of riprap along eroding banks, removal of cattails and dredging of backwater areas where submerged aquatic vegetation was planted, and placement of fish shelters, gravel beds, and spawning boxes.

Since the formation of Grand Lake St. Marys, the changes of the fishery population has been as drastic as the changes which occurred to its aquatic environment. With a more degraded condition of water quality and diminished fishery habitat, populations of more desirable sport fish have decreased. Nevertheless, a good warmwater fishery is maintained which provides fishing enjoyment for many thousands of fishermen.

WILDLIFE RESOURCES

Approximately 90 percent of land uses in the Grand Lake St. Marys watershed is agricultural, while less than 10 percent remains wooded (Ohio DNR, 1976). Most forest areas are small, isolated woodlots surrounded by corn-soybean dominated farming. The area is within the beech-maple climax forest type. However,

Table 2. Stocking of fish and fish food in Lake St. Marys, 1932-1978[a/]

GAME AND PAN FISH (1932-1978)

Species	1932-1955 Total Number	1956-1978 Total Number
Largemouth bass	243,503	134,800
Bluegill	2,546,409	1,719
Crappie (black & white)	144,204	271
Black bullhead	526,191	
Brown bullhead	501,706	731[/b]
Yellow bullhead	45,981	
Perch (yellow)	23,276	
Channel catfish	121,669	
Green sunfish	46,400	
Pumpkinseed	25,652	
White bass	2,400	
Rock bass	480	
Walleye	56	
Suckers	40	
Smallmouth bass	690	
Mixed fish	800	
Northern pike	829,333	208,809 232,000 (eggs)
Striped bass		77,832
Flathead catfish		9,000
Rainbow trout		500
TOTAL	5,058,790	665,662

FORAGE FISH AND FISH FOOD (1932-1955)

Minnows	2,928,299
Tadpoles	538,961
Crayfish	278,670
Shad	110,614
TOTAL	3,856,544

[a/] Taken from Clark (1960) and Ohio Division of Wildlife files.

[b/] Recorded as "bullhead".

densities and species composition of woodlots have been modified by logging and grazing. Many fencerows were removed to accomodate today's modern farming practices. Therefore, travel corridors for wildlife are, to a large extent, limited to stream corridors. Surrounding the lake, no significant forested areas exist along the north, east, and west shorelines, due to housing, commercial, and agricultural developments. Most woodland is found along the south shore. A more natural condition exists there because of the low, flat terrain which is very susceptable to flooding. Soils remain moist in this area as indicated by the species composition of the vegetation. Tree species are similar to those found along riverine wetlands. Specific vegetative survey data for the Grand Lake St. Marys watershed are not available. Information on vegetation species would be useful in completing an environmental assessment of the lake area.

Approximately 14 species from four families of amphibians and 23 species from eight families of reptiles have been recorded in the two counties comprising the Grand Lake St. Marys watershed (Conant, 1938; Walter, 1946; CE, 1979; Clark, 1960). The more common species include the cricket frog, striped chorus frog, green frog, leopard frog, and the bullfrog which was economically important during the commercial fishing years. The most common reptile is the snapping turtle. With continued encroachment of man's activities in the watershed and the lakeshore wetlands, populations of amphibians and reptiles will continue to decline, while some species will be extirpated from the area.

Since the lake's formation, most bird species found in Ohio have been recorded in the Grand Lake St. Marys area. Approximately 290 species have been observed in the lake and its watershed (Clark and Sipe, undated). The area has been one of the best locations in Ohio for observing a diverse group of birds. However, in recent years the quality of "birding" has decreased somewhat due to destruction of habitat. For example, an immature bald eagle was last sighted in 1966, and more recent sightings of migrating eagles are very rare. Cormorants and occasional flocks of white pelicans which formerly inhabited the lake area are no longer seen. Heron rookeries are no longer found around the lake, and other wetland birds have become uncommon due to the reduction of wetland habitat.

One of the most commonly observed and important groups of birds at Grand Lake St. Marys is waterfowl. Because of the lake's large surface area and the excellent wetland habitat surrounding the lake, it has become an important concentration area for waterfowl. The lake is also a part of a minor flyway for geese, as indicated by banding recovery data (Kauffeld, 1979). Thousands of migrating ducks and geese use the lake and St. Marys River as a resting area during spring and fall migrations. The area has had as many as 4,200 geese. Data on nesting and general use by waterfowl, other than Canada geese, in the lake are scant or not available. Some information is available on wood ducks along streams in the watershed, and the State has complete information on its Canada goose program. Waterfowl use on Grand Lake St. Marys as determined by 10 biweekly surveys conducted in 1972 and 1973, was 65,346 days of use for ducks and 28,877 days of use for geese (Weeks, 1978).

Annual wood duck surveys are conducted on a 10-mile reach of St. Marys River in Auglaize County. For the years 1974 through 1977, the survey indicates an average of 0.16 pairs per mile, 1.98 birds per mile, 0.30 young per mile, 0.03 broods per mile and a survey index of 2.47. The index indicates that St. Marys River is a nearly average wood duck stream. Other streams in the watershed having wood duck production, although undetermined, include Prairie Creek, Chickasaw Creek, Beaver Creek, and the back bay of the Mercer County Waterfowl Refuge.

The Canada goose management program began at the Mercer County Waterfowl Refuge in 1956. At that time considerable effort was made to increase Canada goose populations throughout the Midwest. The program at Grand Lake St. Marys, as in most locations, has been successful with 31,147 geese produced from 1957 through 1979. The present total population at the refuge is approximately 3,000 geese. Table 3 presents goose production data for the last six years. During that period, a yearly average of 259 nests were studied, with an average clutch size of 5.62. The success rate for eggs hatched averaged 80 percent, thus producing a yearly average of 1,153 goslings.

For waterfowl harvested from 1966 to 1975, Mercer County ranks 12th among counties in Ohio with an annual harvest of 2,391 waterfowl, and Auglaize County ranks 38th with an annual harvest of 763 (from Ohio Division of Wildlife files). Special teal season harvest for 1978 was 40 teal in Mercer County and 40, in Auglaize County (Miller, 1978). In 1976-1977, 167 Canada geese were harvested from the Mercer Wildlife Area. Of these, 101 geese were banded in Ohio (Bednarik, et al, 1977).

Mammals which have been recorded in the Grand Lake St. Marys area include 48 species from 14 families (Burt, 1957; CE, 1979). Residential development in the area has had adverse impacts upon a number of mammalian species. However, some species remain common, such as muskrat, raccoon, oppossum, fox and gray squirrel, cottontail rabbit and whitetail deer. The main factors causing a reduction of mammals are destruction of the lakeshore wetlands, and the removal of fencerows and large woodlots.

Little wildlife harvest data are available specifically from Lake St. Marys watershed. We suspect population levels of game mammals are typical of many of the surrounding agricultural counties. Since 1977, Mercer and Auglaize Counties

Table 3. Canada goose production at Mercer County Waterfowl Refuge, 1974-1979*.

Year	Number of Nests	Number of Eggs	Mean Clutch Size	Percent Eggs Hatched	Number of Goslings
1974	346	1768	5.13	72	1287
1975	275	1594	5.80	85	1367
1976	244	1364	5.59	87	1200
1977	206	1154	5.60	86	1000
1978	248	1467	5.92	74	1100
1979	234	1332	5.70	72	961
Average	259	1447	5.62	80	1153

* Data provided by Ohio Division of Wildlife.

have had a shotgun season for whitetail deer; previously, only bow hunting was allowed. In 1978, the total deer harvest was 31 in Mercer County and 30 in Auglaize County. Information on production of furbearers from the lake and feeder streams is needed.

Current wildlife populations in the Grand Lake St. Marys area are very much dependent on cover and nesting habitat. Intensive farming in the watershed has resulted in the destruction of the necessary habitat to maintain a high density of upland wildlife. The area still provides adequate wetland habitat to make it important for waterfowl production. This condition must be maintained or enhanced with project alternatives favorable to wildlife resources.

DISCUSSION

Natural productivity of desirable fish and wildlife resources has declined at Grand Lake St Marys over the last 75 years. With continued development around the lake, the quality and quantity of the existing resource base will continue to erode. The problem is complex; however, degraded water quality and degraded fish and wildlife habitat are two key factors which account for the resource losses.

As previously mentioned, the lake water was clear and cool in the 1800's. Farming in the watershed was not intensive and the small amount of silt from watershed streams was filtered out by the shoreline wetlands, principally along the south shore on which side the watershed exists. With today's farming practices which includes large fields of row crops, surface drainage, and channel cleaning, silt from eroded fields reaches the lake with little resistance. Excessive amounts of fertilizer and herbicides frequently accompany the silt-laden waters. Because of the shallow natural condition of the lake, wave action keeps the silt in suspension, and the turbid water acts as a solar heat trap. This condition, combined with unlimited nutrients (phosphates and nitrates), brings about the eutrophic conditions which result in algae blooms and anaerobic conditions during certain times of the year. Residential development surrounding the lake also adds to the eutrophication of the lake. We understand a regional sewage treatment system is proposed for the Grand Lake area which should eliminate most discharges of poorly treated sewage into the lake. Improvement of the lake's water quality should also eliminate the odor and taste problems experienced by the local community, which uses the lake as a water supply source.

Best management practices should be mandatory in cases where pollution or erosion problems exist on farmlands. Specific problem areas could be monitored by the Soil Conservation Service (SCS) and the agency could provide technical assistance to the farmer to correct the problem. SCS has technical information which includes solutions to most soil conservation problems. For example, all livestock should be fenced out of stream beds and banks, but watering access could be provided. Grass strips and buffers should be used in swales and along ditches and streams to trap silt. Fall plowing should be prohibited in "bottom" land which is very susceptable to flooding. Soil tests should be made to determine the need for fertilizers, rather than using the manufacturer's wholesale use recommendations. Likewise, the use of other farm chemicals, which are prone to be washed into the lake, should be limited. We believe the lake's watershed is small enough, and the need is sufficient to implement a program to monitor and regulate nonpoint source discharge from watershed activities. The discharge of any improperly treated sewage into the lake should be prosecuted. Treatment facilities should be provided for discharging sewage from boats with toilet facilities. Septic tank discharges should also be monitored.

One factor which is a major contributor to the decline of numbers and diversity of wildlife populations has been the destruction of natural areas along the south shore. Basically, other lakeshore areas around the lake have been developed; that is, wetlands have been filled in and converted to other land uses, and shorelines have been riprapped and/or concreted. Because of the low land along the south shore, development has been limited, for the most part, to summer cottages and trailer courts. Frequent flooding of the area has been a deterrent to widespread occupation. Normal lake water levels are only inches below the level of access roads to summer residences along the lake. Nevertheless, a housing development of year-round residences is currently under construction on lakefront property southeast of the lake. Also, Ohio Department of Natural Resources is proposing several dredge spoil sites along the south shore. Thus, the resource base of wetlands is under continual modification and/or destruction.

In addition to Federal regulation, we believe remaining wetland habitat must be protected by local land use zoning. Adequate coastal wetlands with submergent, floating, and emergent vegetation would be an effective buffer to the eroding wave action of the lake. An extension and enhancement of existing wetlands should be considered a viable project alternative. Funding for marsh restoration can be obtained through the 1976 Water Resource Development Act (P.L. 94-587, Section 150). To complete a lakeshore protection feature, we recommend offshore dredge spoil disposal sites. These islands should be located in near-shore areas to protect existing developments from the wrath of wind, wave, and ice action. The islands could be of irregular configuration and should be located and managed for waterfowl and other wetland inhabiting fauna. Technology developed by the Corps should be used in constructing non-erodable dikes and planting of wetland grasses and woody vegetation. Fish attractors should be placed in appropriate areas to provide cover for the fishery resource, while other channels could be deepened for boating access. We believe the lake is of sufficient size to have multiple recreational use. Open water with adequate depth is available (or should be made available) for skiers and power and sail boat enthusiasts. The amount of water surface to provide for disposal of unpolluted dredge spoil, protection of existing developments from wave and ice action, and enhancement of fish and wildlife resources would be minimal. To make this plan acceptable, we believe the local community must be informed of its attributes. With proper management of the offshore islands, the vista created could be aesthetically pleasing and could provide the desired privacy for residents.

Modification of the east outlet structure has been proposed to allow the discharge of additional water into the canal outlet (and subsequently St. Marys River), thereby reducing downstream flooding along Beaver Creek during flooding conditions. We have no objection to this proposal provided that instream uses are accommodated. Methodologies used for limited clearing and snagging to remove log jams from Beaver Creek should be similar to those used by the Indiana Soil Conservation Service and Mr. George Palmiter in northwestern Ohio. The Ohio Department of Natural Resources and U. S. Fish and Wildlife Service should review and concur with the work plan.

In summary, we believe the fish and wildlife resource base will continue to be adversely affected by individual, uncoordinated projects around and on Grand Lake St. Marys. A Corps project to correct existing problems, as defined by local community leaders, could be detrimental or beneficial to fish and wildlife resources. We believe alternatives exist which would improve those resources, and we recommend the pursuit of those alternatives.

RECOMMENDATIONS

1. Based upon our assessment of the Stage I Work Plan and our review of existing fish and wildlife resource information for Grand Lake St. Marys area, we recommend that a detailed four-season fish and wildlife study be funded and conducted prior to our preparation of the draft Fish and Wildlife Coordination Act report. Emphasis of the study should be placed upon the following specific resource elements for which more data are required:

   a. A comprehensive study of the aquatic and terrestrial vegetation in the watershed and lake area should be conducted to provide an adequate data base.

   b. A study of the lake's zooplankton and benthos should be conducted to provide additional information on fish food organisms in the lake.

   c. Waterfowl surveys, for species other than Canada geese, should be conducted to determine current use of the lake area by resident and migratory waterfowl species.

d. A survey of furbearer and upland game populations, and the harvest of those resources should be conducted.

At least 15 months would be required for completion and write-up of the four-season study prior to our initiation of the draft report.

2. We also recommend initiation of studies to address our following concerns:

   a. Site specific problem sources of silt and nutrient enrichment into the lake.

   b. The impacts of stream blockages to the flow of flood waters in the lake area.

   c. Alternatives to increase and enhance the wetlands of the Grand Lake St. Marys area. These alternatives could be developed with the additional objective of providing shoreline protection from wave action.

We appreciate the opportunity to provide these comments at this early planning stage.

Sincerely yours,

Raymond G. Oberer

Area Manager

cc: Director, Ohio Department of Natural Resources, Columbus, OH

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