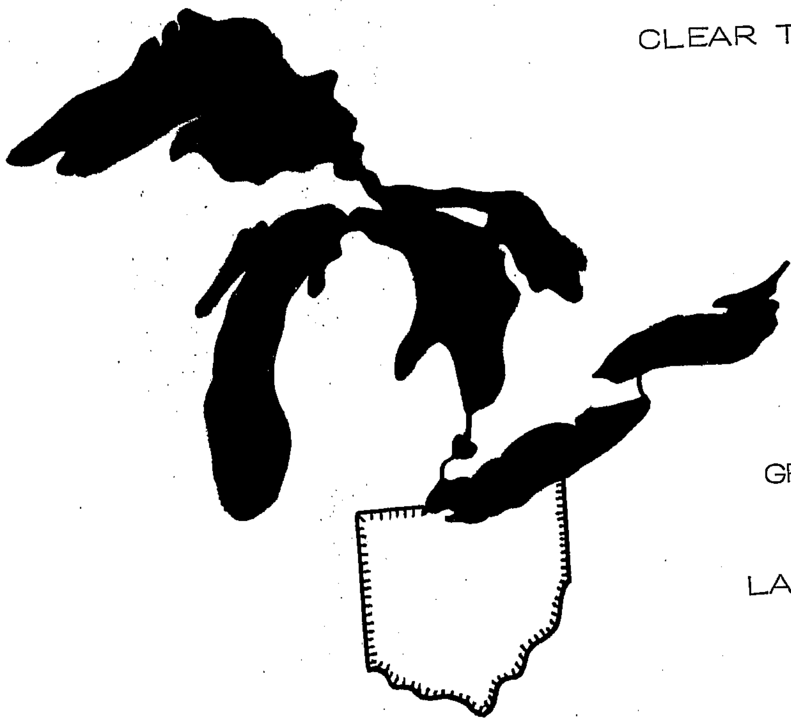

CLEAR TECHNICAL REPORT NO. 43

GREAT LAKES SURVEILLANCE DESIGN SYMPOSIUM

LAKE ERIE AND DETROIT RIVER PROGRAM ASSESSMENT

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Introduction

On January 20-21, 1976, the Surveillance Subcommittee of the Great Lakes Water Quality Board, International Joint Commission held a surveillance design symposium in Windsor, Ontario for the purpose of formulating the 1976 and future monitoring efforts on the Great Lakes and connecting waterways. The symposium was attended by 40 representatives of federal, provincial and state agencies with an on-going IJC monitoring program and seven university scientists who have been engaged in research and/or monitoring efforts on the Great Lakes.

Appendix B of the 1974 Report of the Great Lakes Water Quality Board lists three primary problems that the surveillance programs of each lake must address:

1. acceleration of eutrophication or maintenance of a particular trophic state
2. concern for the presence and impact of toxic substances in the system
3. the impairment of water quality by total dissolved and suspended solids introduced into the lake by man's activities

In response to these problems, pollution abatement programs have as their objectives the control of the loadings of (1) nutrients which relate to eutrophication, (2) toxic substances and (3) suspended and other dissolved materials. To monitor the lakes effectively three surveillance goals have been established by the Water Quality Board:

1. to measure directly the loading from sources affected by remedial programs
2. to monitor in the receiving water the frequency and intensity of violations of water quality objectives in both localized areas and in the open lake where changes in problem conditions are to be established.

3. to provide sufficient data to permit valid interpretation of water quality conditions in order to distinguish the impact of remedial programs from natural changes, both near to and remote from sources (entails documentation of the loadings not under control of present remedial programs as well as monitoring ambient water quality or impacted biota in the system in order to distinguish the impact of controlled loadings from impact from other causes).

With these guidelines as a framework, the group was subdivided by lake to consider the design of a set of priorities for surveillance activities. The design components considered for each lake included: (1) material loadings, (2) nearshore, (3) open lake, (4) intakes, (5) special problem areas, (6) studies in support of surveillance and (7) data management/quality assurance.

Surveillance Plans

Prior to the symposium, each government agency or contractor participating in a phase of the IJC surveillance network for Lake Erie prepared a draft plan which was circulated to all the participants in the Lake Erie work-group. The following plans for 1976 were considered:

A. Lake Erie/Tributaries
   1. Corps of Engineers/Buffalo District
   2. Pennsylvania Department of Environmental Resources
   3. Michigan Water Resources Commission
   4. Ohio Environmental Protection Agency
   5. Ontario Ministry of the Environment

B. Lake Erie/Water Intakes
   1. Pennsylvania Department of Environmental Resources
   2. Michigan Water Resources Commission
   3. Ohio Environmental Protection Agency
   4. Ontario Ministry of the Environment

C. Lake Erie/Nearshore
   1. Canada Centre for Inland Waters
   2. Pennsylvania Department of Environmental Resources
   3. Ohio State University/USEPA
   4. Ontario Ministry of the Environment

D. Lake Erie/Open Lake
1. Canada Centre for Inland Waters
2. Pennsylvania Department of Environmental Resources
3. Great Lakes Laboratory/USEPA
4. Ohio State University/USEPA

E. Detroit River
1. Michigan Water Resources Commission
2. Ontario Ministry of the Environment
3. USEPA/Grosse Ile Laboratory

The frequency of measurements and the parameters to be measured vary considerably among the agencies (Tables 1 - 5). A brief description and assessment of surveillance plans proposed by each agency follows.

The U. S. Army, Corps of Engineers, Buffalo District plan calls for monitoring of water quality near the mouths of four tributaries in northwestern Ohio (Maumee, Portage, Sandusky and Huron Rivers) during the period January - June 1976 (Figure 1). Sampling will be conducted at 6-hour intervals during peak flow periods and once per week during low flow. Nutrients and solids will be determined. This program is specifically designed to provide reliable tributary loading for runoff events. The major criticism of this study lies in the fact that the monitoring stations are up to 20 kilometers inland from the lake.

The Pennsylvania Department of Environmental Resources', in cooperation with the Erie County Department of Health, plan includes seven stations in Lake Erie and two in Presque Isle Bay which are monitored by boat, one station in Lake Erie which is monitored through the city water intake at Erie and three stations which are located on tributaries (Sixteen Mile, Walnut, and Elk Creeks) to Lake Erie (Figure 2). Because the Pennsylvania plan contains tributary, water intake, nearshore and open lake components, it is the most comprehensive state program. In addition to a wide range of water quality parameters, biological surveillance will be conducted in 1976.

The Michigan Water Resources Commission monitoring plan includes three tributaries to Lake Erie/Detroit River (Rouge, Huron and Raisin Rivers) and five water intakes (Detroit-Jefferson Avenue, Detroit-Wyandotte, Detroit-Allen Park, Monroe, and Enrico Fermi Power Plant) (Figure 3). These locations are sampled monthly with no specific attempt to obtain samples during peak flow conditions. There appears to be considerable controversy between Michigan WRC, Corps of Engineers/Buffalo, and IJC/Windsor over the statistical method for calculating loadings to Lake Erie from the Michigan tributaries.

The Michigan Water Resources Commission and the Ontario Ministry of the Environment jointly conduct a monitoring program of the Detroit River from its head at Lake St. Clair to its mouth at Lake Erie. The two agencies alternate monthly sampling at 54 stations on 10 ranges across the river (Figure 4). Michigan WRC is responsible for computing nutrient loadings to Lake Erie. A model developed by the Lake Survey Center, NOAA is used for this purpose. This approach appears to be adequate and is generally accepted by the scientific community. Monthly sampling is appropriate for this stream because of the fairly uniform flow throughout the year. In addition to this program, the USEPA, Grosse Ile Laboratory plans to continue daily monitoring of phosphorus in the Detroit River at the Free Bridge to Grosse Ile (Figure 4).

The Ontario Ministry of the Environment plan, in addition to Detroit River monitoring, calls for monitoring of six tributaries (Grand River, Kettle Creek, Lynn River, Big Otter Creek, Big Creek and Catfish Creek), three water intakes (Kingsville, Blenheim and Dunville) and 108 nearshore stations along the Ontario shore of Lake Erie (Figure 5). In 1976 emphasis will be placed on the eastern basin of Lake Erie because of the significant urban and industrial development underway in that part of the lake. Thirty additional stations in this area will be sampled during spring runoff events for five consecutive days. In addition, the impact of improved water treatment of municipal and canning wastes at Leamington will be assessed in Pigeon Bay of western Lake Erie. The Ontario plan appears to be adequate with exception of the water intake surveillance, which only includes five water quality parameters.

The Ohio EPA monitoring program for the Lake Erie basin consists of monthly measurements at 12 tributaries (Maumee, Portage, Sandusky, Huron, Vermilion, Black, Rocky, Cuyahoga, Chagrin, Grand and Ashtabula Rivers and Conneaut Creek) and four water treatment plant intakes (Oregon, Sandusky, Cleveland-Crown, and Painesville) (Figure 6). This plan calls for a comprehensive list of parameters. The major shortcoming of this plan is that there is no provision for peak runoff sampling. Another criticism of the Ohio program is that many of the tributaries are not, in actuality, sampled on a monthly basis due to a variety of reasons.

No plans were received from the State of New York for monitoring tributaries, water intakes, nearshore or the Niagara River. This is the only jurisdiction which was not included in the surveillance plans developed at the symposium for Lake Erie and its connecting waterways.

The Canada Centre for Inland Waters and the Grosse Ile Laboratory, USEPA (in conjunction with the Ohio State University, Center for Lake Erie Area Research and the New York State University College at Buffalo, Great Lakes Laboratory) plans call for extensive investigations of the nearshore and open lake portions of all three basins of Lake Erie. CCIW will visit 106 stations (Figure 7) and CLEAR/GLL will visit 80 stations (Figure 8) on a monthly basis during the ice free period of the year. In addition to routine surveillance the goals of these efforts will be to (1) determine the extent and duration of dissolved oxygen conditions less than IJC objectives and the oxygen depletion rate, (2) estimate biomass (3) provide measurements of nutrients to be used for calculating quantities in the lake to be compared with loading records (4) determine the amount of nutrients regenerated from the sediments and (5) estimate the magnitude of resuspended sediment in the western basin of Lake Erie. The surveillance plans appear adequate to achieve these objectives.

Surveillance Priorities

The Lake Erie/Detroit River work-group considered the plans of each agency in terms of a uniform set of design objectives provided by the Surveillance Subcommittee. The objectives were established in order to comply with the assessment provisions of the Great Lakes Water Quality Agreement:

1. Compliance with objectives
2. Determine trends
3. Determine material loadings
4. Determine impact of remedial programs
5. Determine cause-effect relationships

The surveillance programs were also considered by geographic segments (tributaries, intakes, nearshore, open lake and connecting channels). As a result of discussions the following consensus of priorities for a Lake Erie/Detroit River Surveillance Program was developed:

1. Oxygen depletion problem, particularly the anoxic region of the central basin.

2. Phosphorus loading from all sources, including tributaries, municipal/industrial and atmosphere.

3. Nearshore localized problem areas, including bacterial contamination, Cladophora, radionuclides and turbidity.

4. Fish contamination by organic compounds and metals.

5. Long-term trend assessment of water quality, particularly continued monitoring of water intakes.

The Lake Erie work-group recommended that these priorities be incorporated into an overall surveillance plan for the lake and associated waterways. The parameters listed in Appendix B of the 1974 Report of the Great Lakes Water Quality Board were judged to be generally acceptable by the various agencies. The frequency and period of sampling proved to be a controversial issue which was not resolved by the work-group. The first four items on the priority list are considered the minimum for a satisfactory surveillance program for Lake Erie.

Surveillance Assessment

Tributaries. The tributary monitoring programs proposed by Michigan, Ohio, Pennsylvania and Ontario appear to be adequate to determine compliance with IJC standards. No information is available on the New York plan. However, there is considerable controversy on two issues: (1) calculation from surveillance data of annual loading to Lake Erie and (2) spring runoff event sampling versus uniform monthly sampling. The calculation question could be resolved as a staff function of the IJC, Great Lakes Regional Office. Mr. John Clark of that office has made some progress in this direction, but his latest attempt is not acceptable to the Corps of Engineers or the Michigan WRC. More effort and additional staff should be concentrated on the problem of developing a universally acceptable approach.

The problem of event versus monthly tributary sampling seems to be revolving around the biological availability of the phosphorus which is carried to the lake during spring runoff. Special research efforts are needed to resolve this question. The Grosse Ile Laboratory presently has a research project underway which will provide an impartial answer to questions on a case by case basis. Each stream will require separate testing. Another approach to this problem is contained in the proceedings of the IJC "Workshop on Cladophora in the Great Lakes." It appears that the state agencies are unlikely to convert from a monthly sampling schedule to spring effect sampling unless it can be shown that a significant amount of the spring phosphorus load is available for biological production.

Another issue which requires attention is the use of surveillance data to assess the impact of remedial programs in improving water quality. Some work of this nature has been attempted by the Corps of Engineers in northwestern Ohio. A more general use of surveillance data for this purpose will provide useful information on the effectiveness of various remedial actions.

The estuary-type mouths of most of the Lake Erie tributaries present a particularly difficult problem in calculating reliable loadings to Lake Erie. Special research projects are required to develop a model which will permit accurate estimates of loading within an estuary with a minimal number of samples.

Water Intakes. The Lake Erie work-group established a low priority for continued monitoring of water intakes. However, water intake data, because of their long and continuous nature, provide one of the basic tools for long-term assessments of water quality trends. It is important that this activity be continued and that the data are analyzed periodically to determine the impact of remedial measures.

Nearshore. The Ontario and Pennsylvania nearshore areas appear to be adequately monitored, but similar coverage is not planned for Michigan and Ohio. No plans were presented for New York. USEPA sponsored projects will provide some general information on the nature of the nearshore water on the American side, but specific problem areas will not be routinely monitored. Results of recent research projects in the vicinity of Cleveland and Toledo could provide the information necessary to develop effective surveillance plans for nearshore problem areas. Surveillance of specific problems, such as the impact of tributary runoff during peak spring flow, could be facilitated with remote sensing techniques developed by NASA, Lewis Research Center. The cost of remote sensing will be greatly reduced in 1978 when Nimbus G satellite is launched. This satellite will be equipped with an ocean color scanning system and will provide every-other-day coverage of the Great Lakes. NASA is presently undertaking studies with a similar scanning system aboard aircraft in order to perfect assessment techniques which can be utilized once the satellite is in position. It is desirable that total suspended and volatile solids data be gathered as often as possible during all ongoing surveillance programs to provide ground truth for satellite imagery.

The Cladophora problem is extensive in Lake Erie but not as serious as in Lake Ontario. The development of a detailed surveillance program appears unnecessary at the present time. If and when the costly techniques used in Lake Ontario are perfected on an economical basis, then they should be considered for Lake Erie.

The radiological surveillance program proposed by the Radioactivity Subcommittee appears in some aspects to be redundant with the monitoring program presently being conducted by Nuclear Regulatory Commission, particularly in regard to samples taken along a one kilometer arc at the perimeter of active nuclear power plants. The recommendation of this subcommittee should be given careful review in light of existing programs before they are implemented.

Open Lake. The open lake plans proposed for Lake Erie are the outgrowth of research projects designed to study the effectiveness of nutrient controls in limiting lake eutrophication. Technique development has proceeded to the point where routine surveillance measurements of the annual oxygen depletion rate is possible. Because of the seriousness of this problem and the wide variability of the area affected, an annual monitoring effort of modest intensity should be continued. The plans proposed for 1976 will satisfy this need.

Because of its relatively small volume, Lake Erie has a water retention time of less than three years. For this reason intense monitoring programs should be instituted every five years.

Dr. Nelson Watson, CCIW, suggested that for open lake surveillance it is important to establish a few intensive stations where water quality and biological parameters are monitored on a daily or at least weekly basis. Such surveillance would not be intended for the purpose of obtaining data for balance calculations, but it would produce a valuable record of change.

Detroit River. The sampling plan proposed for the Detroit River has a long historical basis. Comparable monitoring which was initiated in 1966 has continued to the present. This joint US/Canadian program appears to be working well and provides the loading information necessary to determine if the water quality is in compliance with the IJC objectives for the Detroit River. No plan was submitted for the Niagara River, but a similar approach should be considered.

General Assessment. Each agency involved in Lake Erie surveillance programs would be able to do a better job in designing and coordinating their programs if the Water Quality Board would provide a better definition of the IJC objectives. State programs need a clearer direction and identity with the IJC master plan. More effort should be spent showing the various state and provincial agencies how their programs fit into the overall scheme for Lake Erie, or better still, giving them an active role in developing that scheme.

Presently, biological indicators are not extensively used in surveillance programs. The use of such indicators is costly and time consuming. However, data on the appearance or disappearance of sensitive fish species in the fishery are readily available from most wildlife agencies on both sides of the boarder. These agencies routinely develop year class strength indices for many species. Coordinated through the Great Lakes Fisheries Commission such indices could be integrated into the total Lake Erie surveillance effort. The fish contamination surveillance program could also be coordinated through this Commission.

Data management and quality assurance are cronic problems which can always be expected in a large, multi-agency surveillance program. Consideration should be given to a task force to develop data handling and quality control procedures. The composition of the task force should include at least one representative from each agency involved in the surveillance programs. A surveillance manual could be produced and updated periodically. Funds would be needed to provide for uniform logging of the data. These steps will not resolve all of the inherent problems but they could provide a common basis for standardizing data outputs.

TABLE 1

LAKE ERIE TRIBUTARY MONITORING PROGRAMS
1976

Parameters	COE/ Buffalo	DER Penn.	Mich. WRC	Ohio EPA	OME
Flow	C		M	C	M
Iron		M	A	M	M
pH		M	M	M	M
Coliform, total		M			M
Coliform, fecal			M	M	M
Dissolved oxygen		M	M	M	M
BOD_5			M	M	M
Silica	D		M	M	M
Conductivity/TDS	D	M	M	M	M
Turbidity		M	M	M	M
Total phosphorus (unf.)	D	M	M	M	M
Sol. react. phosphorus	D		M	M	M
Ammonia	D	M	M	M	M
Total Kjeld. nitrogen			M	M	M
Nitrate & nitrite	D	M	M	M	M
Temperature		M	M	M	M
Suspended solids	D		M	M	M
TOC		M	M	M	M
Chloride		M	M	M	M
Oil and phenols			A	M	M
Cadmium		A	A	SA	Q
Chronium		A	A	SA	Q
Copper		A	A	SA	Q
Lead		A	A	SA	Q
Nickel		A	A	SA	Q
Selenium			A	SA	
Zinc			A	SA	Q
Arsenic			A	SA	Q
Barium				SA	
Mercury		A	A	SA	Q
Fluoride			A	SA	
Sulfate		M	A	SA	Q
Pesticides				SA	Q
PCB		M		SA	Q
Chlorophyll series			MS		
Asbestos					
Alkalinity		M	M		
Particulate C and N					

TABLE 2

LAKE ERIE WATER INTAKES MONITORING PROGRAMS

Parameters	DER Penn.	Mich. WRC[1]	Ohio EPA	OME
Flow				
Iron		A	M	
pH	M	A	M	
Coliform, total	M	A		
Coliform, fecal		A	M	
Dissolved oxygen	M		M	
BOD_5			M	
Silica		A	M	W
Conductivity/TDS	M	A	M	
Turbidity	M	A	M	W
Total phosphorus (unf.)	M	A	M	W
Sol. react. phosphorus		A	M	W
Ammonia	M	A	M	
Total Kjeld. nitrogen		A	M	
Nitrate & nitrite	M	A	M	
Temperature	M	A	M	
Suspended solids		A	M	
TOC		A	M	
Chloride	M	A	M	
Oil and phenols		A	M	
Cadmium		A	SA	
Chronium		A	SA	
Copper		A	SA	
Lead		A	SA	
Nickel		A	SA	
Selenium		A	SA	
Zinc		A	SA	
Arsenic		A	SA	
Barium		A	SA	
Mercury	M	A	SA	
Fluoride		A	SA	
Sulfate		A	SA	
Pesticides		A	SA	
PCB	M		SA	
Chlorophyll series				W
Asbestos	M			
Alkalinity	M	A		
Particulate C and N				

1. Detroit River – Jefferson Ave. W.W. sampled quarterly

TABLE 3

LAKE ERIE NEARSHORE MONITORING PROGRAMS

Parameters	CCIW	DER Penn.	OSU/ USEPA	OME
Flow				
Iron	A	Q		Q
pH	M	Q	M	Q
Coliform, total	A	Q		Q
Coliform, fecal	A	Q		Q
Dissolved oxygen	M	Q	M	Q
BOD5		Q	M	
Silica	Q		M	Q
Conductivity/TDS	M	Q	M	Q
Turbidity	M		M	Q
Total phosphorus (unf.)	M	Q	M	Q
Sol. react. phosphorus	Q		M	Q
Ammonia	Q	Q	M	Q
Total Kjeld. nitrogen	Q		MS	Q
Nitrate & nitrite	Q	Q	M	Q
Temperature	M	Q	M	Q
Suspended solids		Q	M	QS
TOC				Q
Chloride	M	Q	M	Q
Oil and phenols				Q
Cadmium	AS	Q	A	
Chronium	AS	Q	A	
Copper	AS	Q	A	
Lead	AS	Q	A	
Nickel	AS		A	
Selenium	AS			
Zinc	AS		A	
Arsenic	AS			
Barium	AS		A	
Mercury	AS	Q	A	
Fluoride				QS
Sulfate	A		M	Q
Pesticides	AS			
PCB				
Chlorophyll series	M		M	Q
Asbestos				
Alkalinity		Q	M	Q
Particulate C and N	M		M	

TABLE 4

LAKE ERIE OPEN LAKE MONITORING PROGRAMS

Parameters	CCIW	DER Penn.	GLL/ USEPA	OSU/ USEPA
Flow				
Iron	A	Q	M	
pH	M	Q	M	M
Coliform, total	A	Q		
Coliform, fecal	A	Q		
Dissolved oxygen	M	Q	M	M
BOD5		Q		
Silica	Q			M
Conductivity/TDS	M	Q	M	M
Turbidity	M			M
Total phosphorus (unf.)	M	Q	M	M
Sol. react. phosphorus	Q		M	M
Ammonia	Q	Q		M
Total Kjeld. nitrogen	Q			MS
Nitrate & nitrite	Q	Q	M	M
Temperature	M	Q	M	M
Suspended solids		Q		M
TOC				
Chloride	M	Q		M
Oil and phenols				
Cadmium	AS	Q	M	AS
Chronium	AS	Q		AS
Copper	AS	Q		AS
Lead	AS	Q		AS
Nickel	AS			AS
Selenium	AS			
Zinc	AS		M	AS
Arsenic	AS			AS
Barium	AS			AS
Mercury	AS	Q	M	AS
Fluoride				
Sulfate	A			
Pesticides	AS		M	
PCB			M	
Chlorophyll series	M		M	M
Asbestos				
Alkalinity		Q	M	M
Particulate C and N	M		M	M

TABLE 5

DETROIT RIVER MONITORING PROGRAM

Parameters	Mich. WRC	OME	USEPA
Flow			
Iron	M	M	
pH	M	M	
Coliform, total	M	M	
Coliform, fecal	M	M	
Dissolved oxygen	M	M	
BOD_5	M	M	
Silica	MS	MS	
Conductivity/TDS	M	M	
Turbidity	M	M	
Total phosphorus (unf.)	M	M	D
Sol. react. phosphorus	M	M	D
Ammonia	M	M	
Total Kjeld. nitrogen	M	M	
Nitrate & nitrite	M	M	
Temperature	M	M	
Suspended solids	M	M	
TOC	M	M	
Chloride	M	M	
Oil and phenols	M	M	
Cadmium	A	A	
Chronium	A	A	
Copper	A	A	
Lead	A	A	
Nickel	A	A	
Selenium	A	A	
Zinc	A	A	
Arsenic	A	A	
Barium	A	A	
Mercury	A	A	
Fluoride	A	A	
Sulfate	A	A	
Pesticides	A	A	
PCB	A	A	
Chlorophyll series	MS	MS	
Asbestos			
Alkalinity			
Particulate C and N			

KEY

C - Continually
D - Daily
W - Weekly
M - Monthly
Q - Quarterly
SA - Semi-Annually
A - Annually
S - Selected Stations

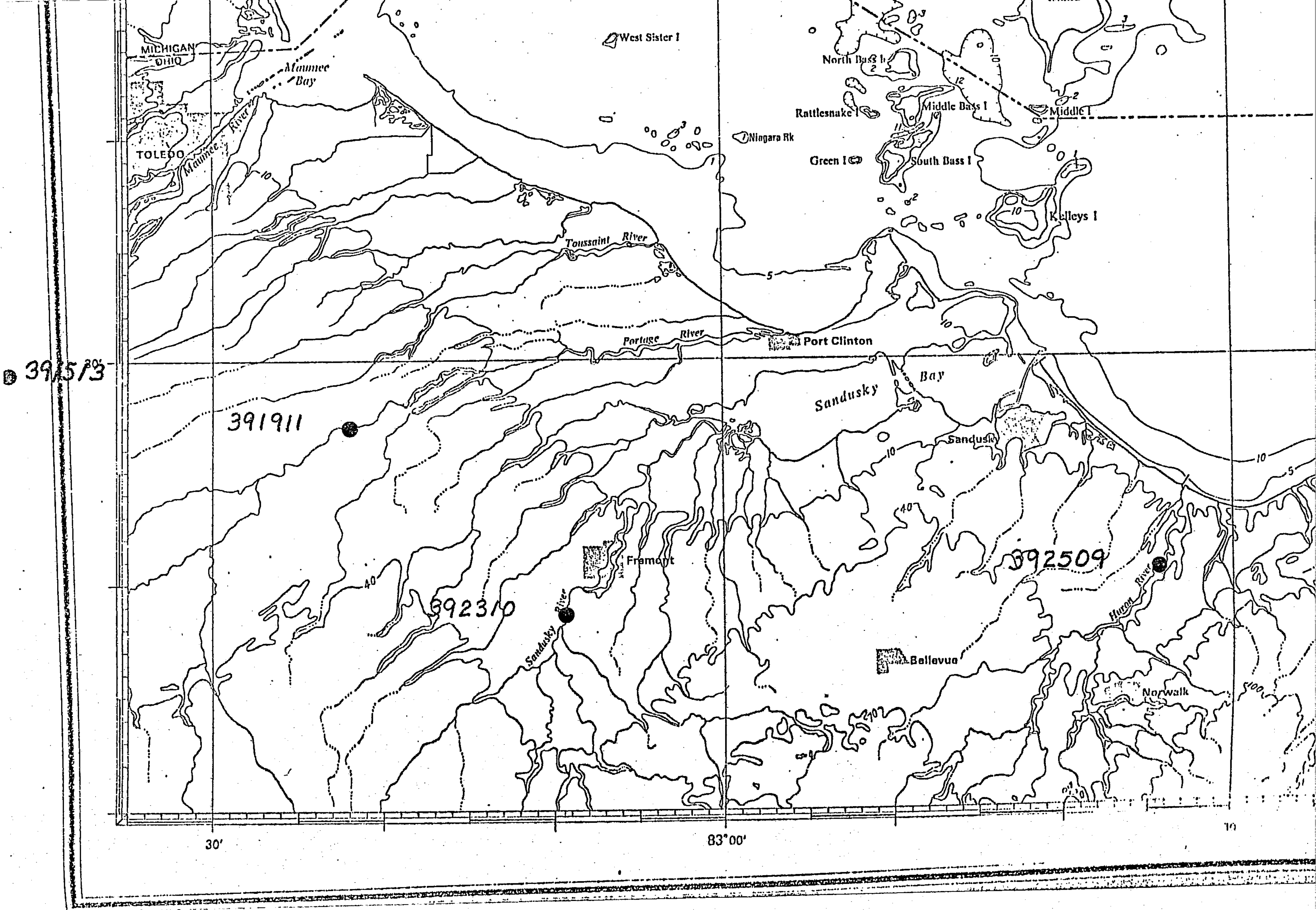


FIGURE 1. U.S. Army, Corps of Engineers Monitoring Stations in Northwest Ohio.

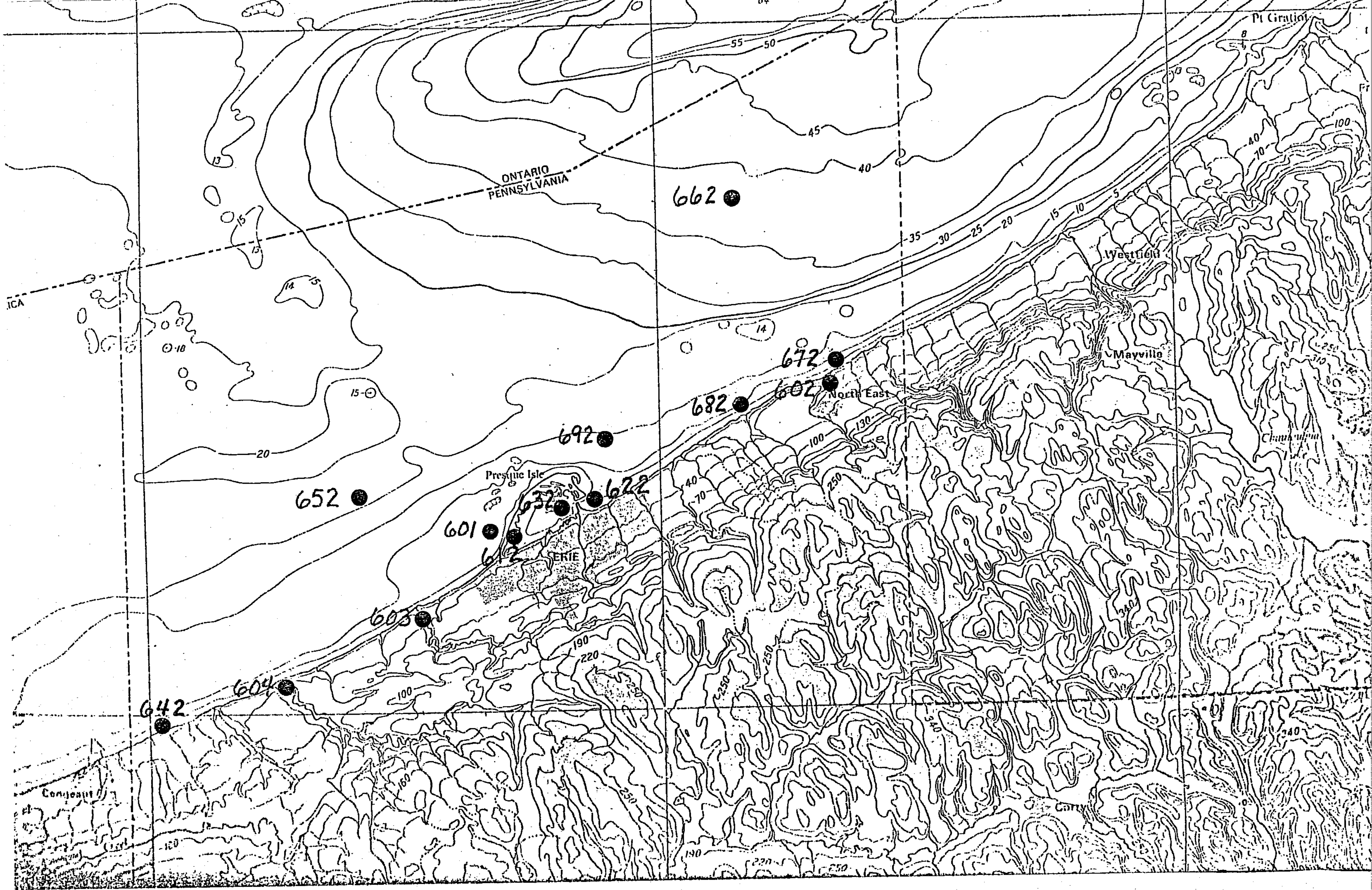


FIGURE 2. Pennsylvania Department of Environmental Resources Monitoring Stations in Northwest Pennsylvania and Lake Erie.

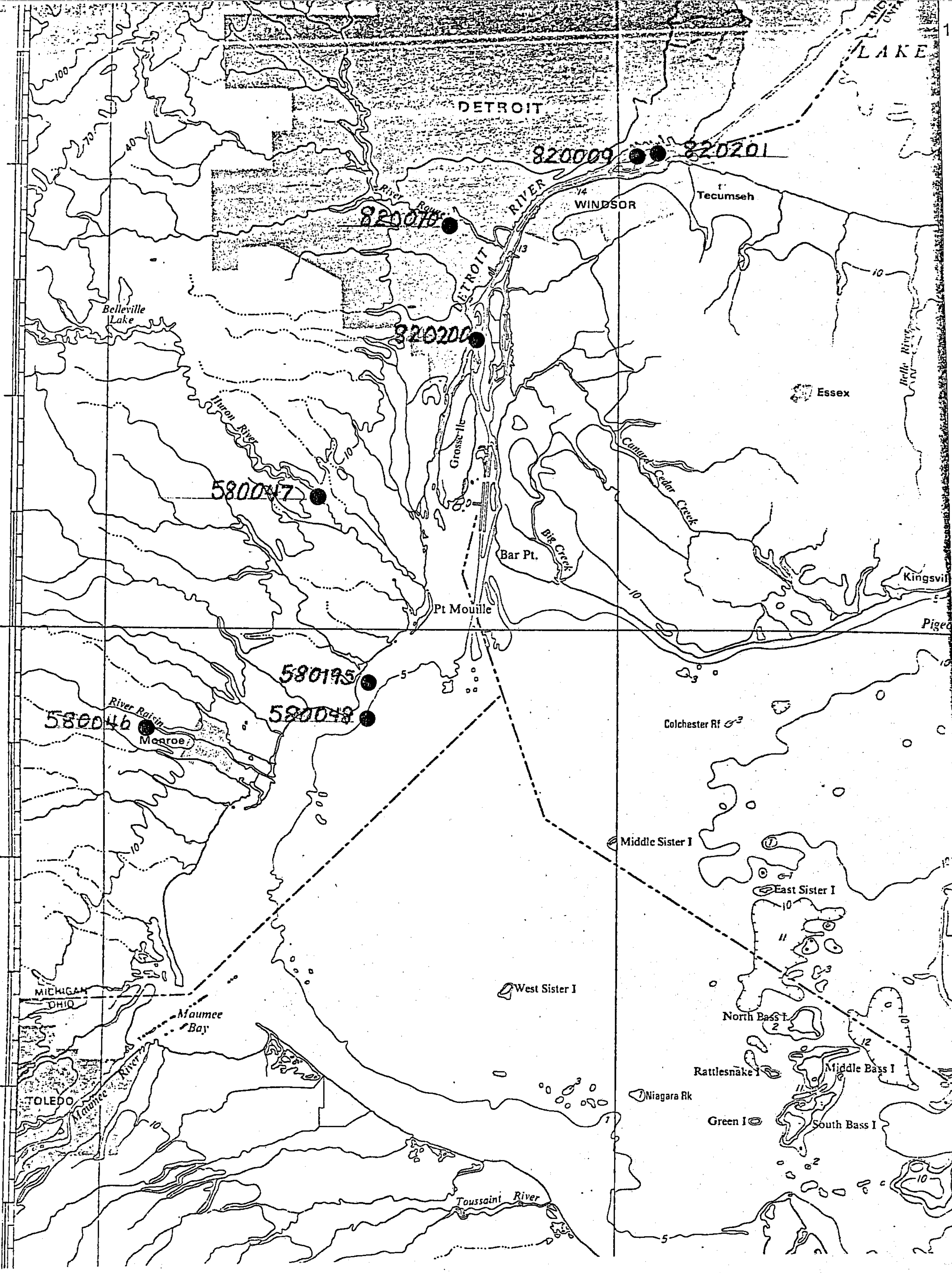


FIGURE 3. Michigan Water Resources Commission Monitoring Stations in Southeastern Michigan.

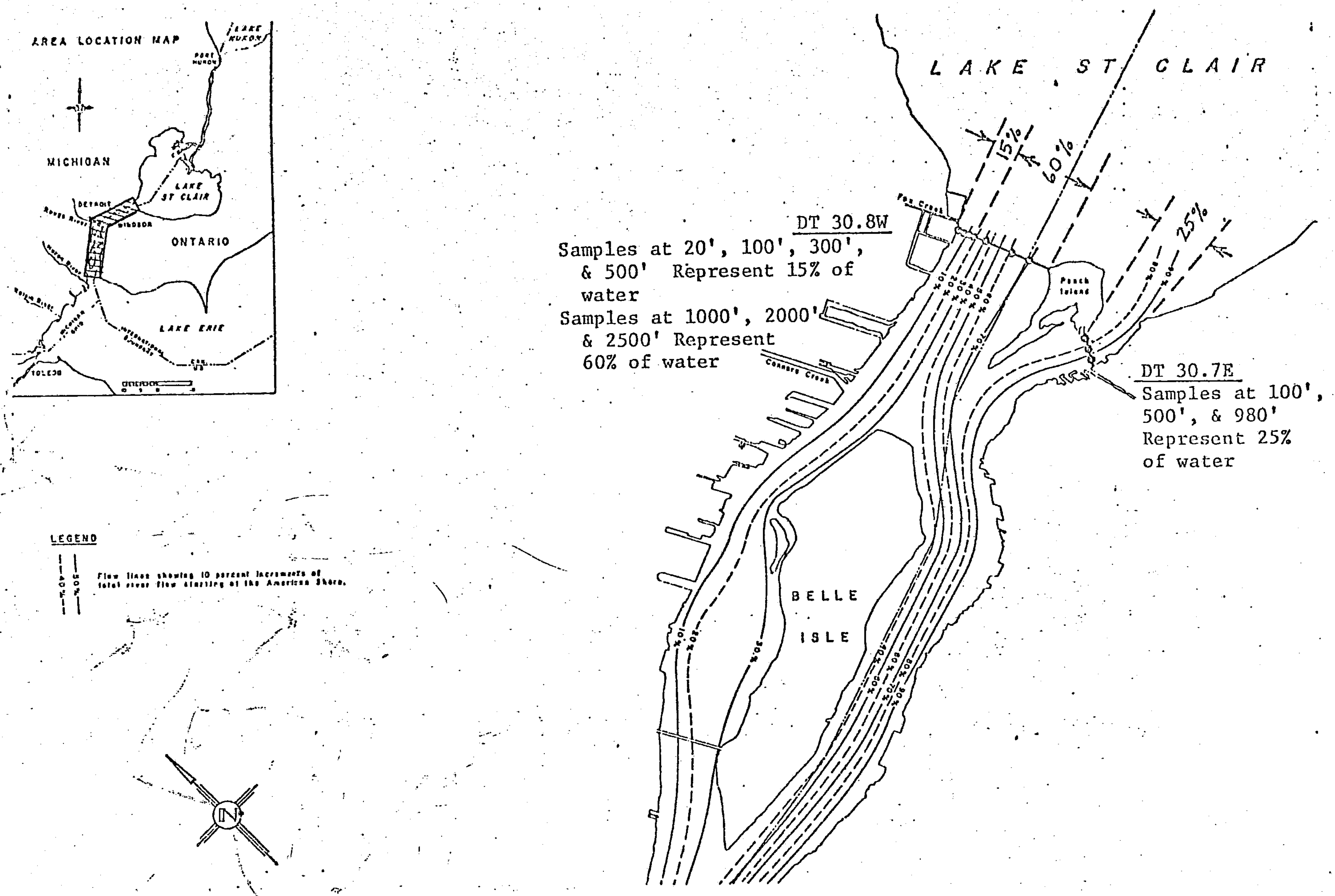


FIGURE 4A. Michigan Water Resources Commission, Ontario Ministry of the Environment and USEPA Monitoring Stations on the Detroit River.

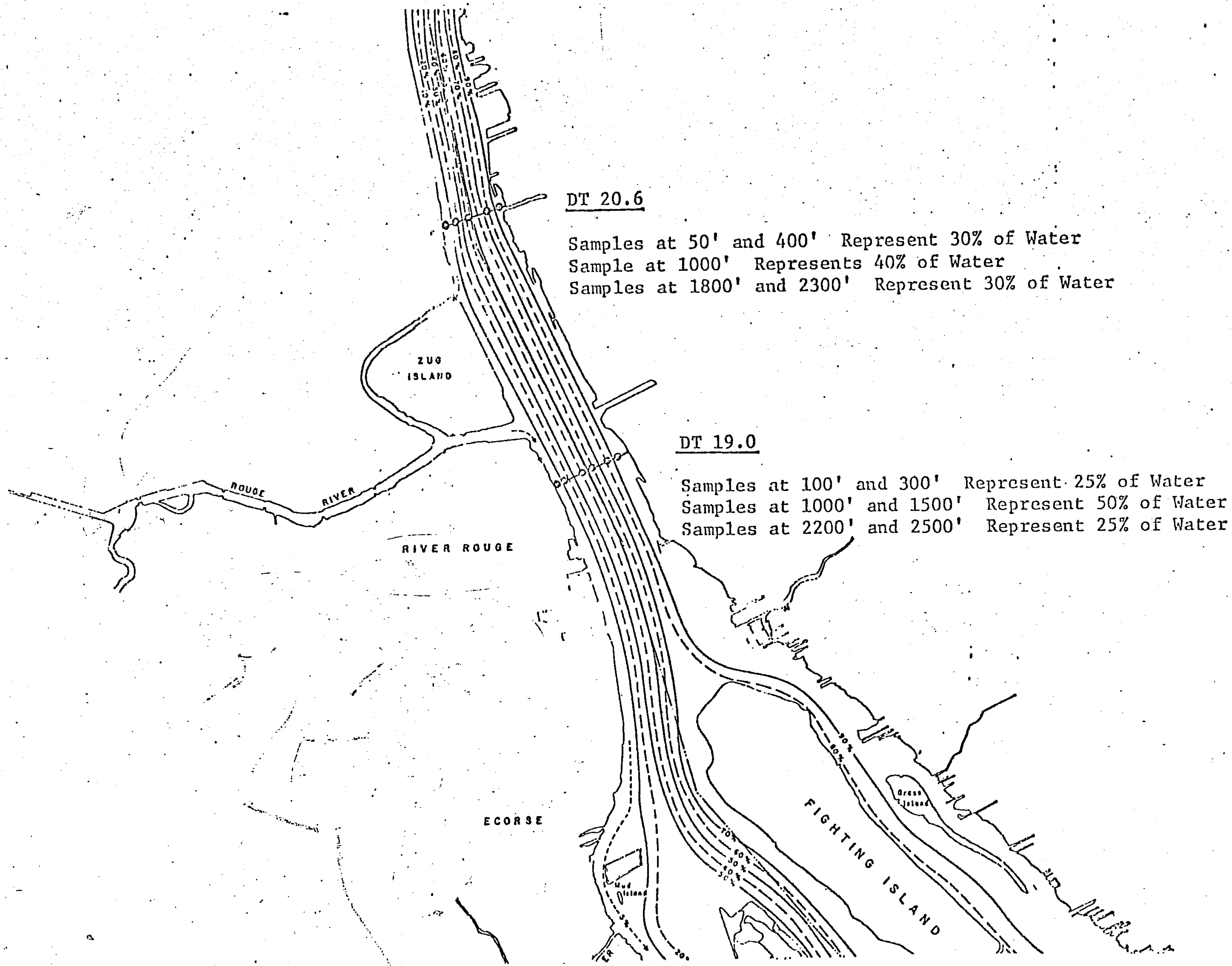

DT 20.6
Samples at 50' and 400' Represent 30% of Water
Sample at 1000' Represents 40% of Water
Samples at 1800' and 2300' Represent 30% of Water
DT 19.0
Samples at 100' and 300' Represent 25% of Water
Samples at 1000' and 1500' Represent 50% of Water
Samples at 2200' and 2500' Represent 25% of Water
ZUG ISLAND
RIVER ROUGE
ROUGE RIVER
ECORSE
FIGHTING ISLAND

FIGURE 4B

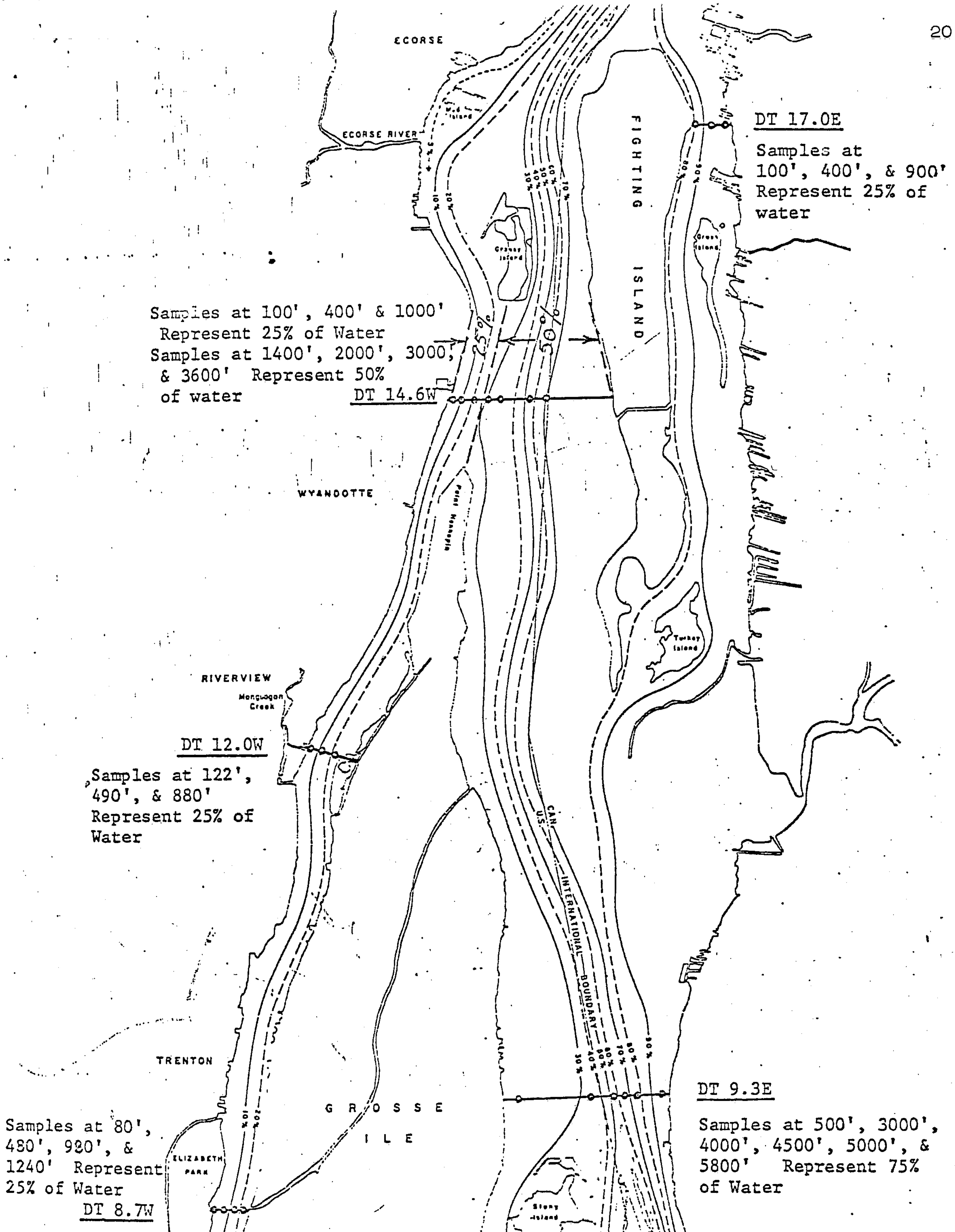

ECORSE
ECORSE RIVER
FIGHTING ISLAND
DT 17.0E
Samples at 100', 400', & 900' Represent 25% of water
Samples at 100', 400' & 1000' Represent 25% of Water
Samples at 1400', 2000', 3000', & 3600' Represent 50% of water
25%
50%
DT 14.6W
WYANDOTTE
RIVERVIEW
Monguagon Creek
DT 12.0W
Samples at 122', 490', & 880' Represent 25% of Water
CAN
US
INTERNATIONAL BOUNDARY
TRENTON
G R O S S E
I L E
DT 9.3E
Samples at 500', 3000', 4000', 4500', 5000', & 5800' Represent 75% of Water
Samples at 80', 480', 980', & 1240' Represent 25% of Water
DT 8.7W
ELIZABETH PARK
Stony Island
Turkey Island
Grassy Island

FIGURE 4C

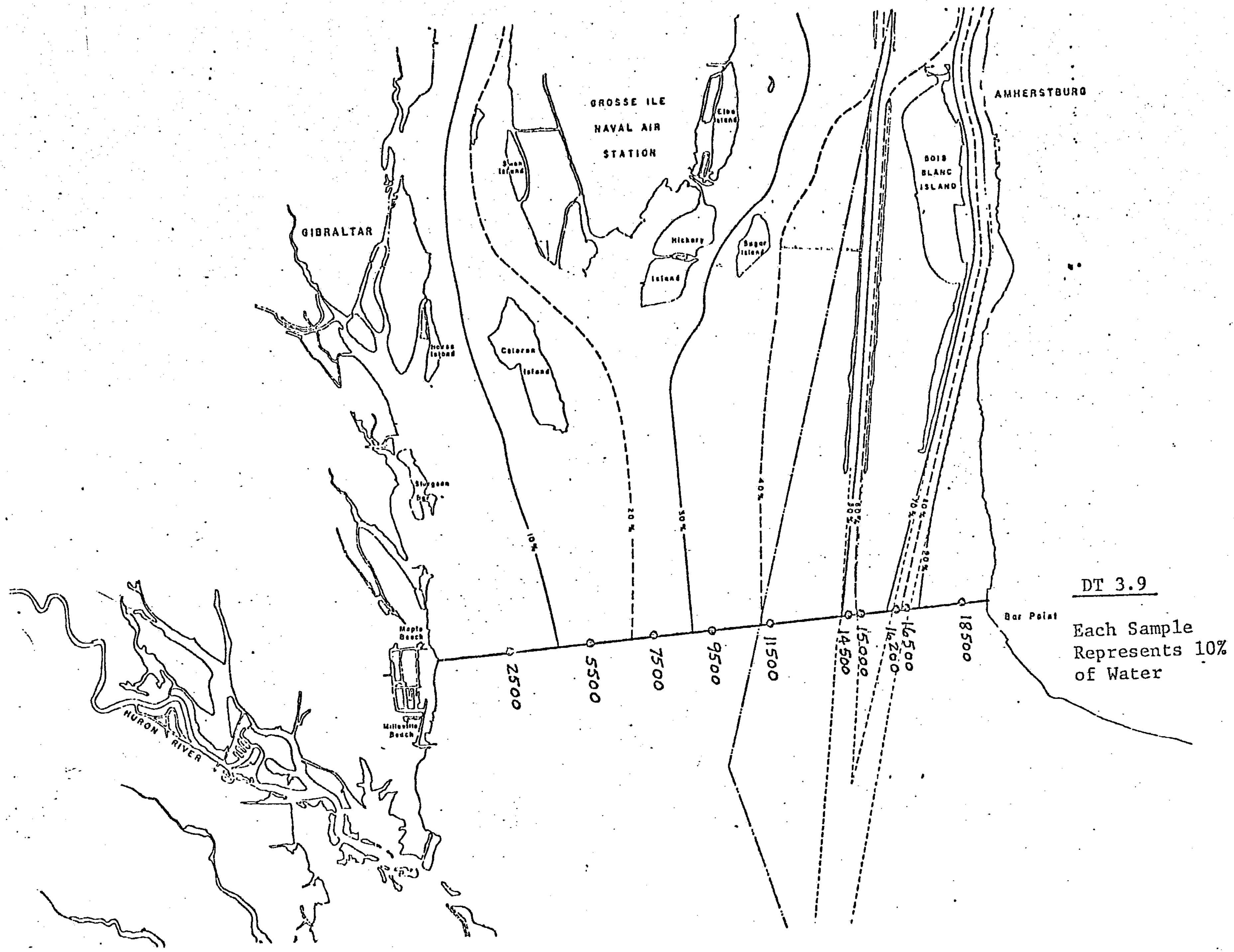

AMHERSTBURG
BOIS BLANC ISLAND
GROSSE ILE NAVAL AIR STATION
GIBRALTAR
HURON RIVER
Bar Point
DT 3.9
Each Sample Represents 10% of Water
18500
16500
16200
15000
14500
11500
9500
7500
5500
2500
10%
20%
30%
40%

FIGURE 4D

FIGURE 5A. Ontario Ministry of the Environment Monitoring Stations along the Northern Shore of Lake Erie.

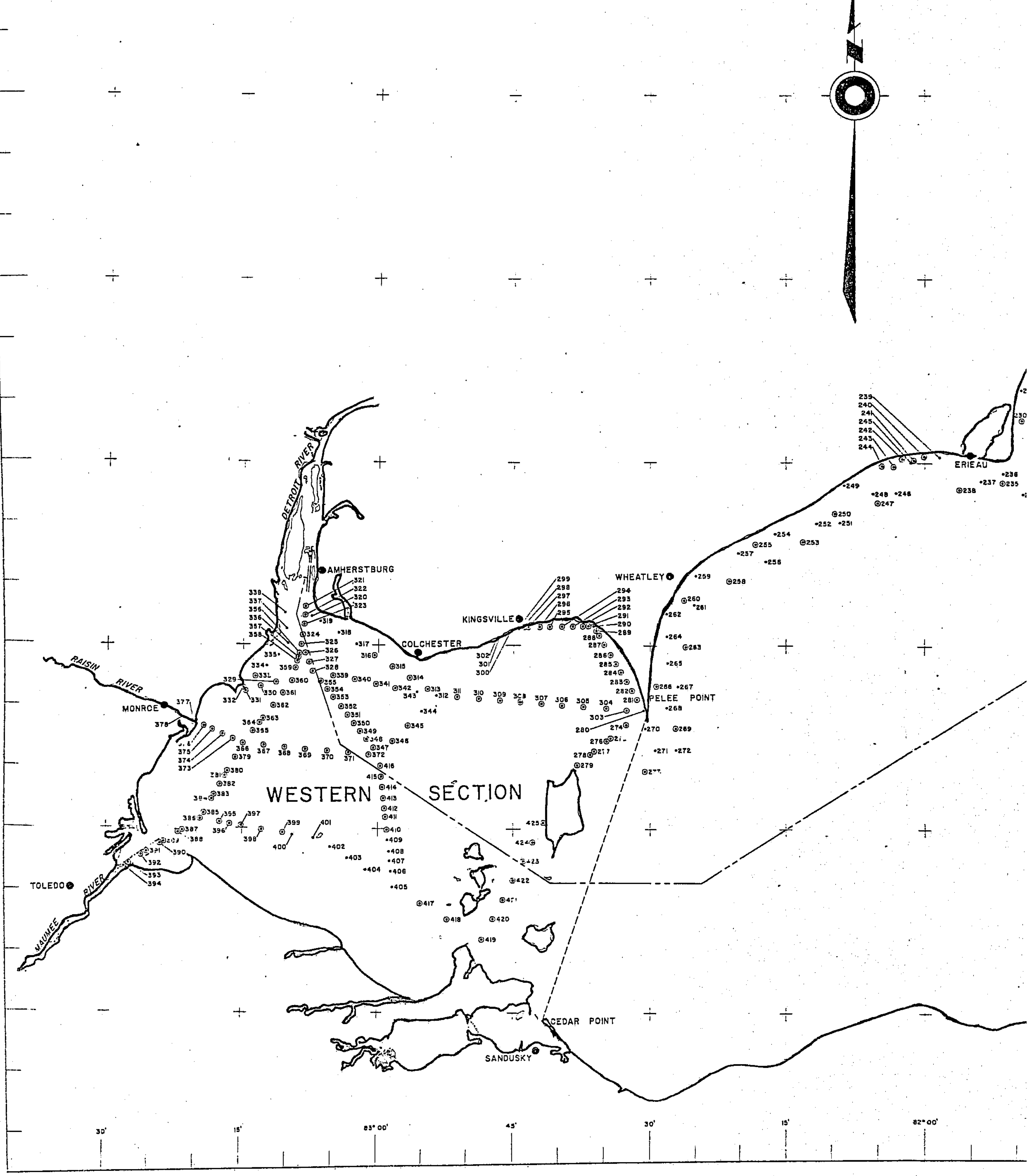
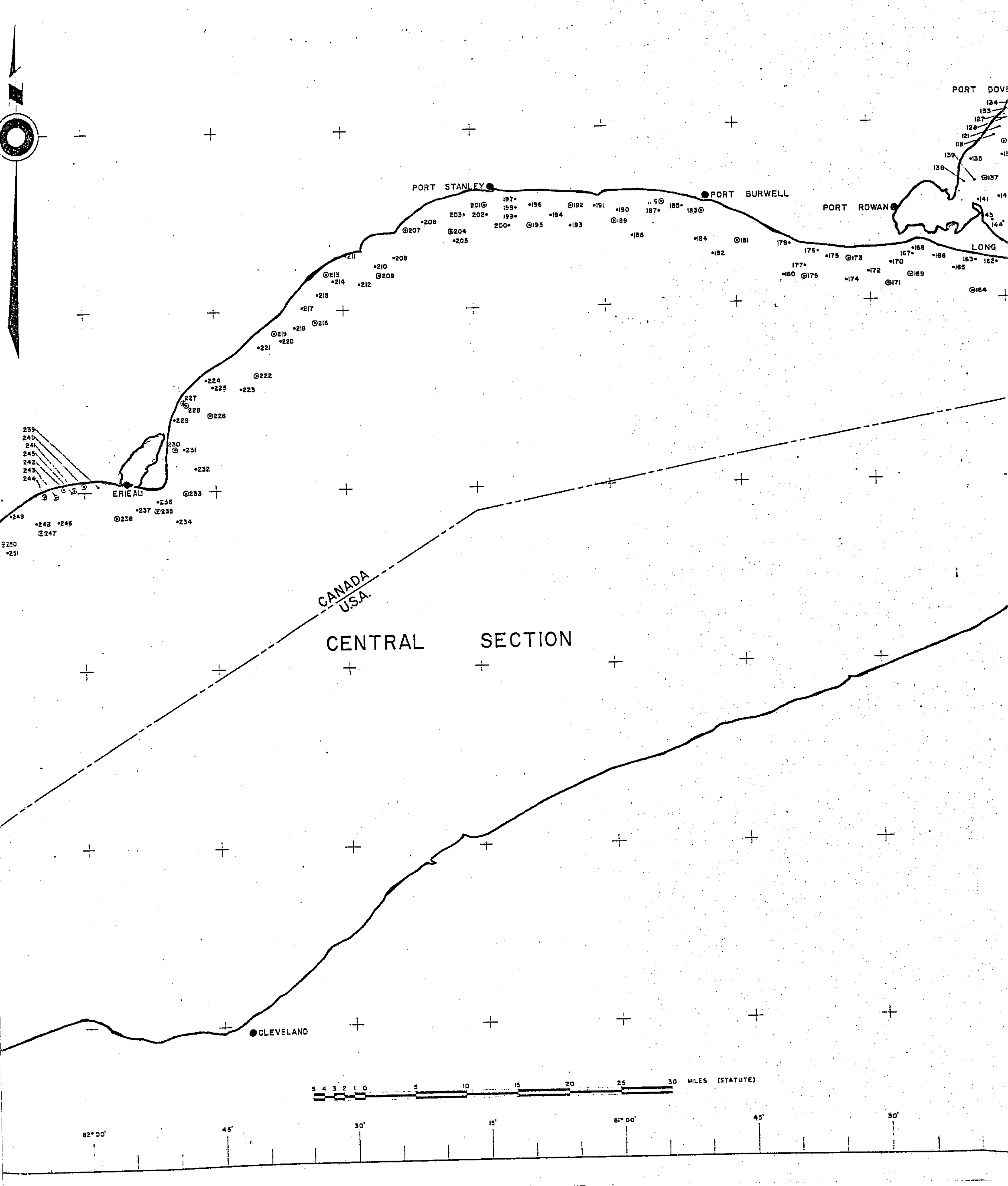
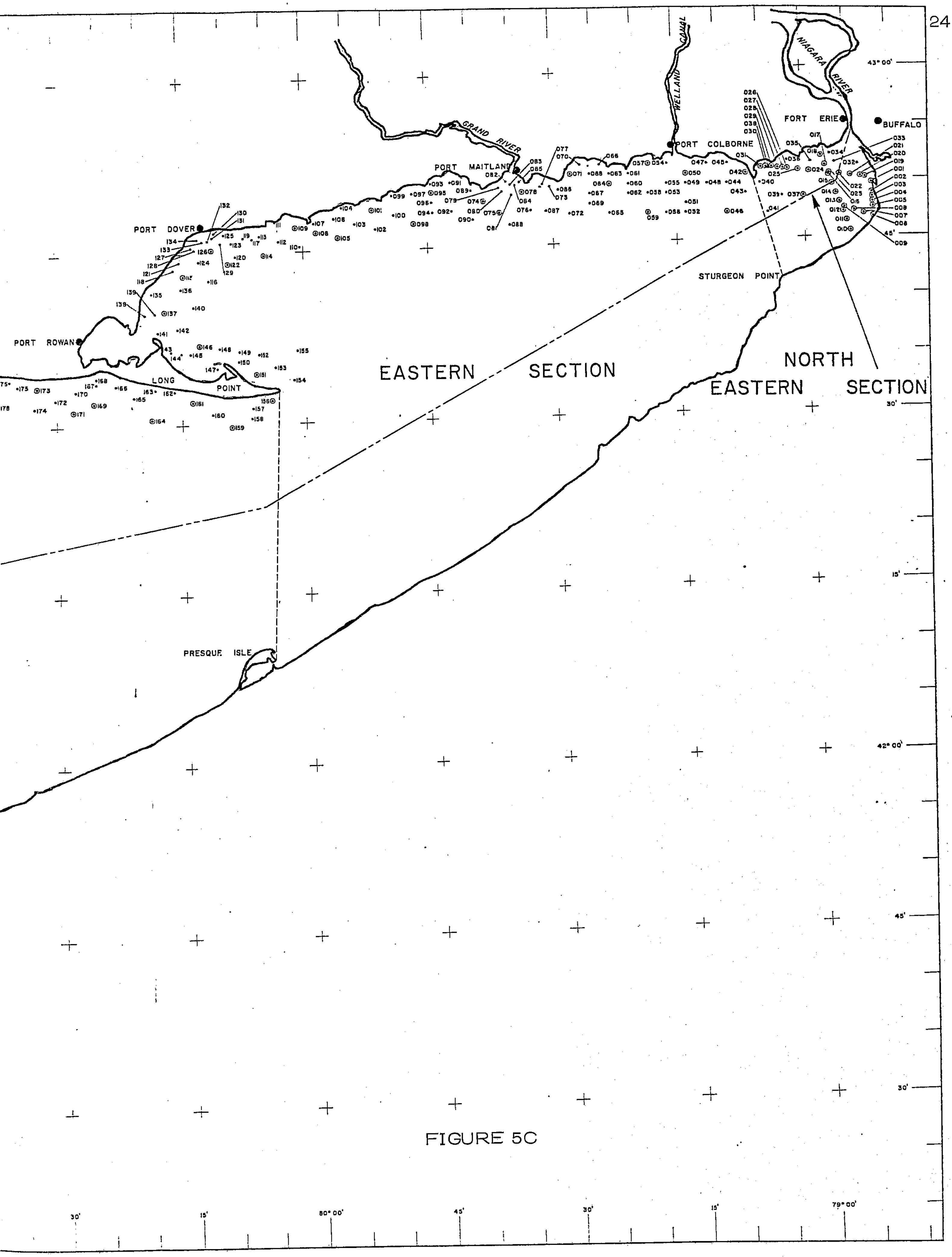


FIGURE 5B


PORT STANLEY
PORT BURWELL
PORT ROWAN
PORT DOVE
LONG
ERIEAU
CANADA
U.S.A.
CENTRAL SECTION
CLEVELAND
MILES (STATUTE)
82° 00'
45'
30'
15'
81° 00'
45'
30'



PORT DOVER
PORT ROWAN
LONG POINT
PORT MAITLAND
GRAND RIVER
WELLAND CANAL
PORT COLBORNE
FORT ERIE
BUFFALO
NIAGARA RIVER
STURGEON POINT
PRESQUE ISLE
EASTERN SECTION
NORTH EASTERN SECTION
43° 00'
42° 00'
80° 00'
79° 00'

FIGURE 5C

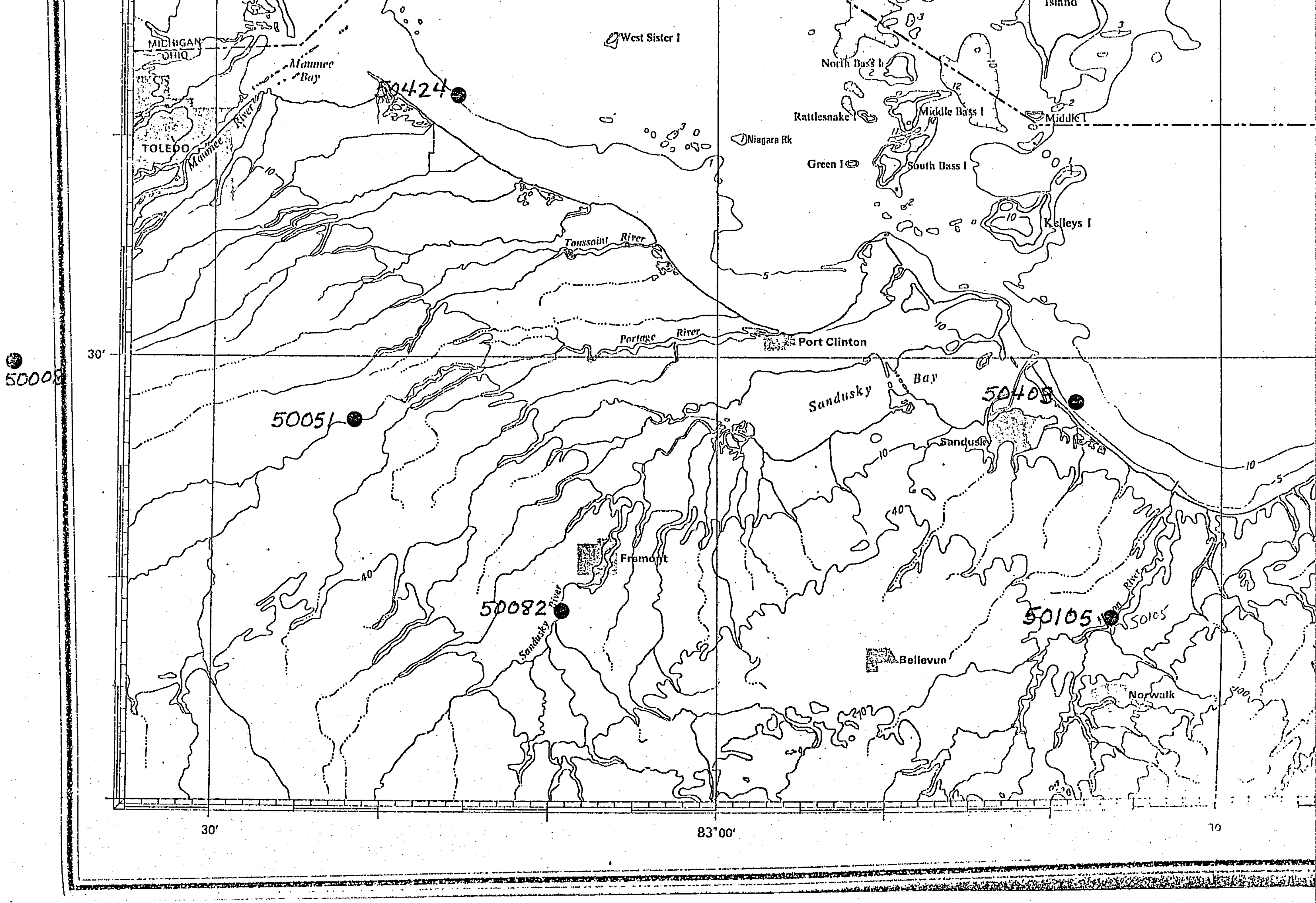


FIGURE 6A. Ohio Environmental Protection Agency Monitoring Stations along the Ohio Shore of Lake Erie.

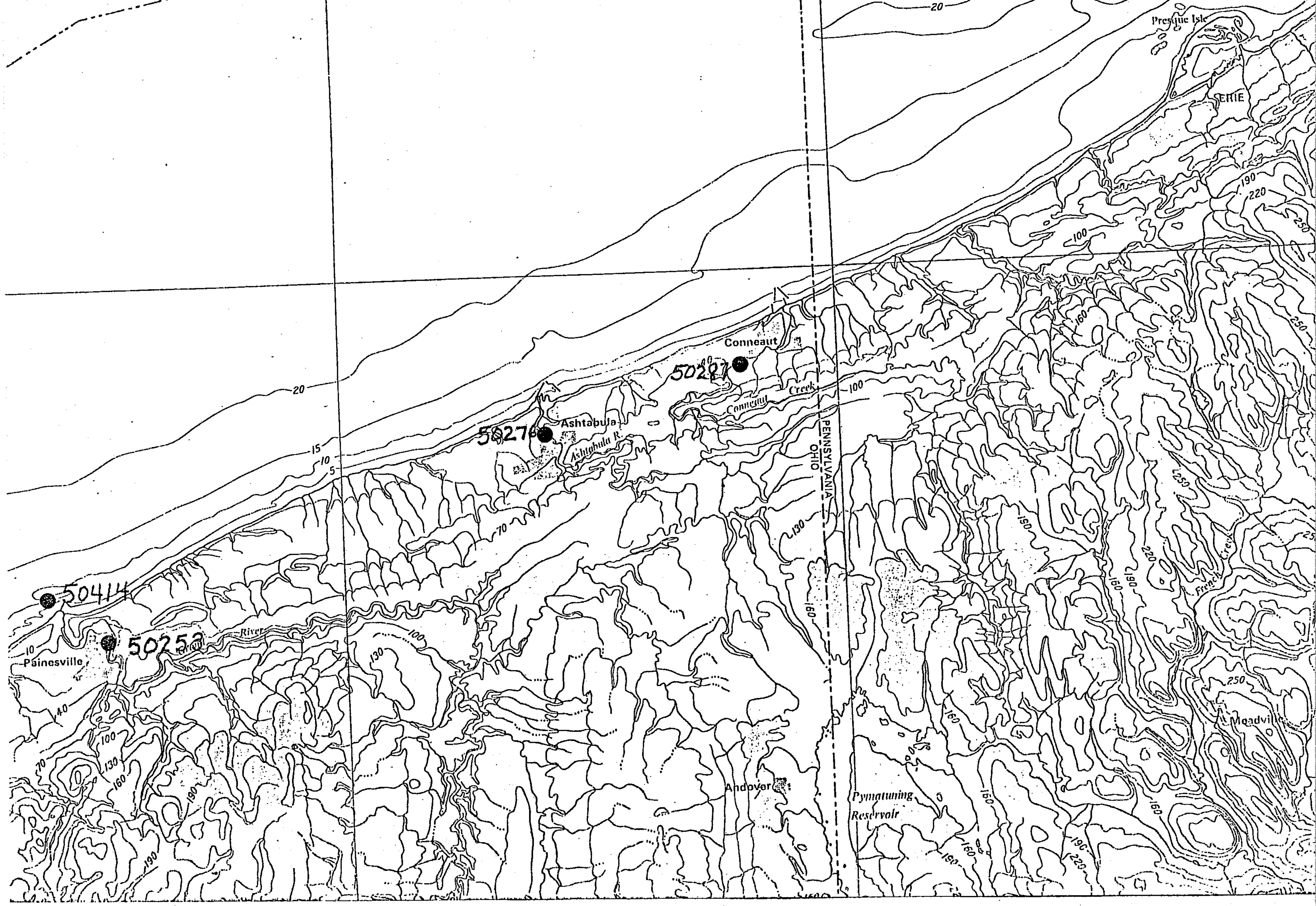

Presque Isle
ERIE
Meadville
French Creek
Conneaut
Conneaut Creek
PENNSYLVANIA
OHIO
Ashtabula
Ashtabula R.
Andover
Pymatuning Reservoir
Painesville
River
50414
50253
50276
50287
20
15
10
5
70
100
130
160
190
220
250

FIGURE 6B

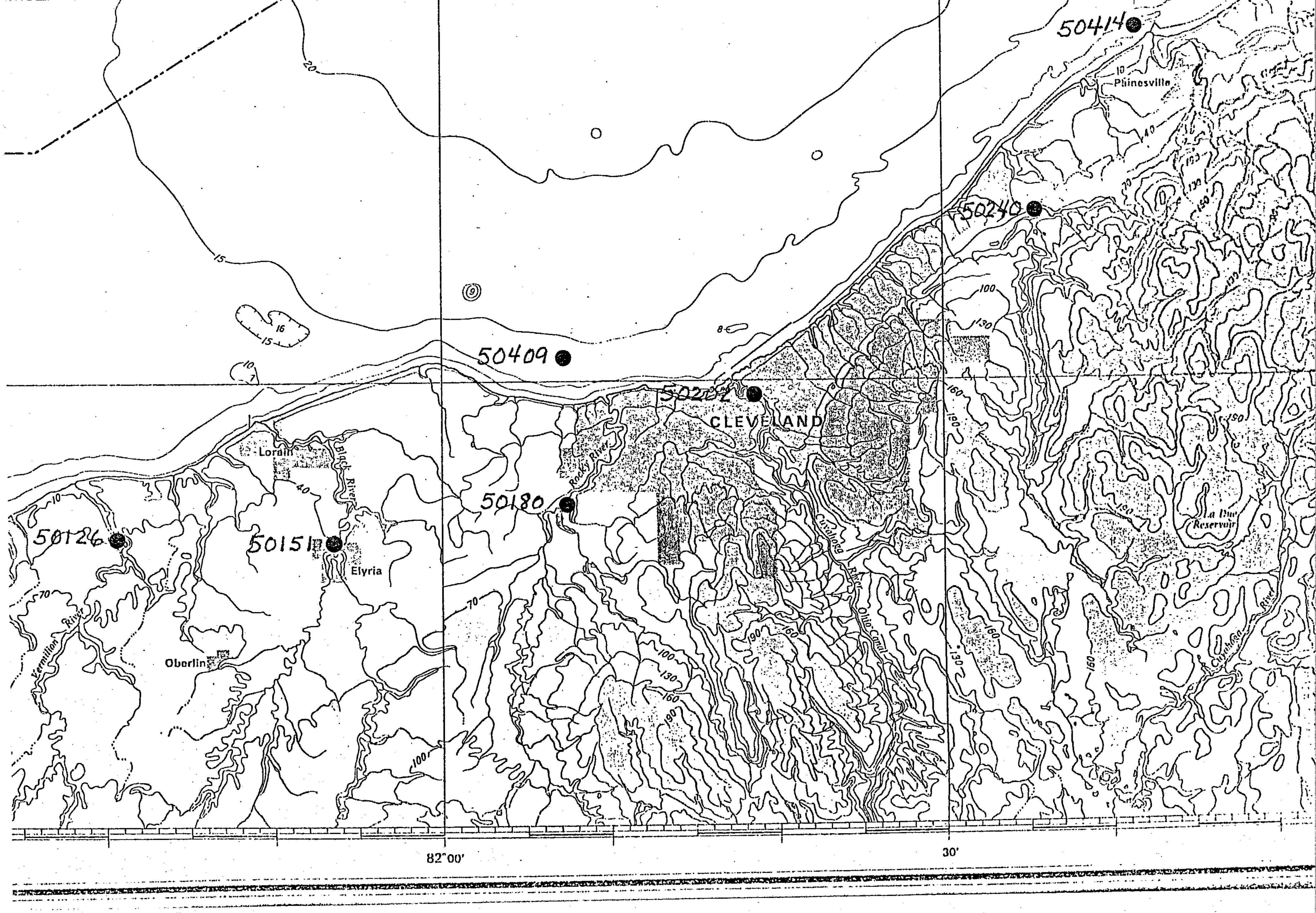

50414
Painesville
50240
50409
50282
CLEVELAND
Cuyahoga River
Ohio Canal
La Due Reservoir
Cuyahoga River
Rocky River
50180
Lorain
Black River
Elyria
50151
50126
Oberlin
Vermilion River
82°00'
30'

FIGURE 6C

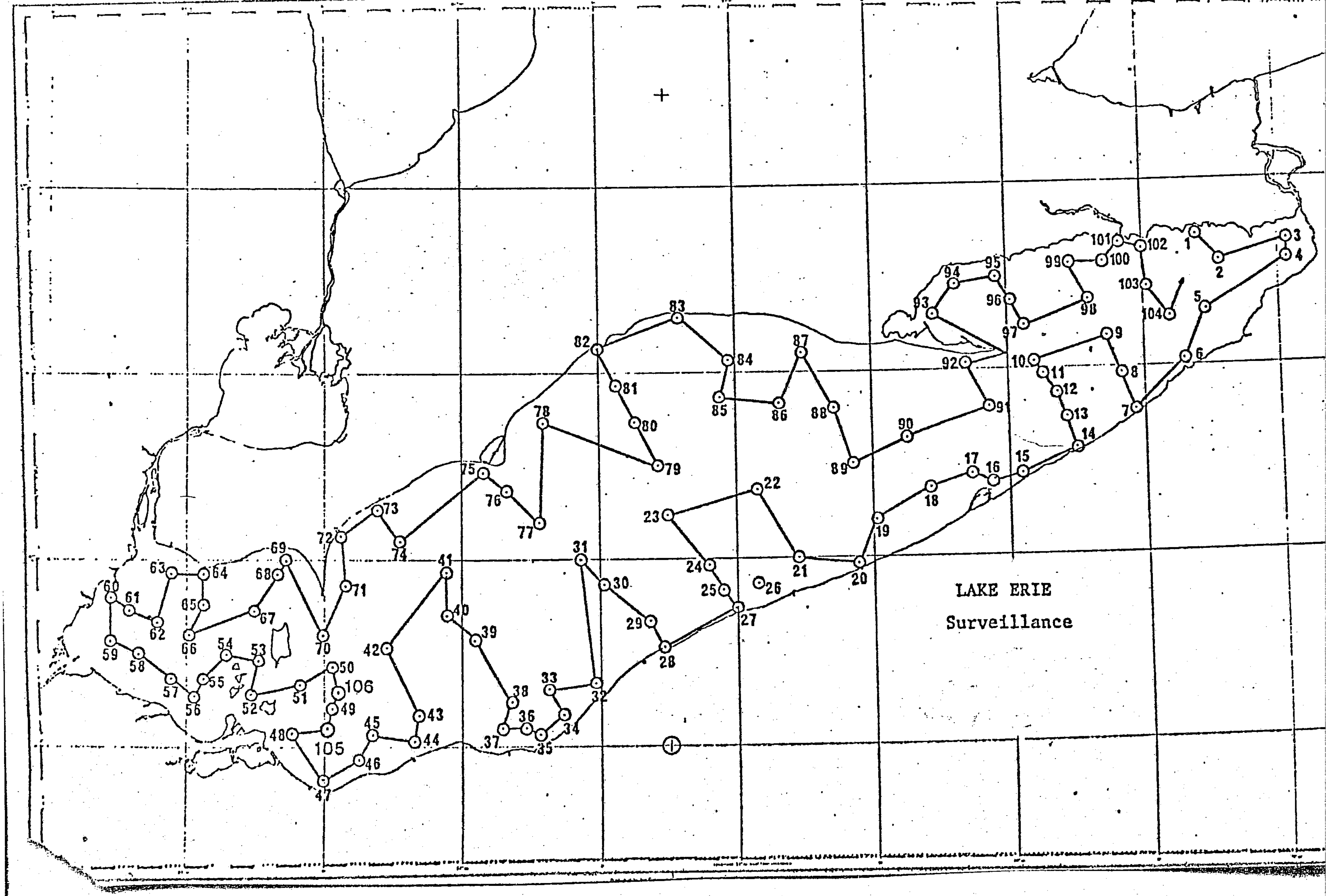


FIGURE 7. Canada Centre for Inland Waters Monitoring Stations in the Nearshore and Open Lake Portions of Lake Erie.

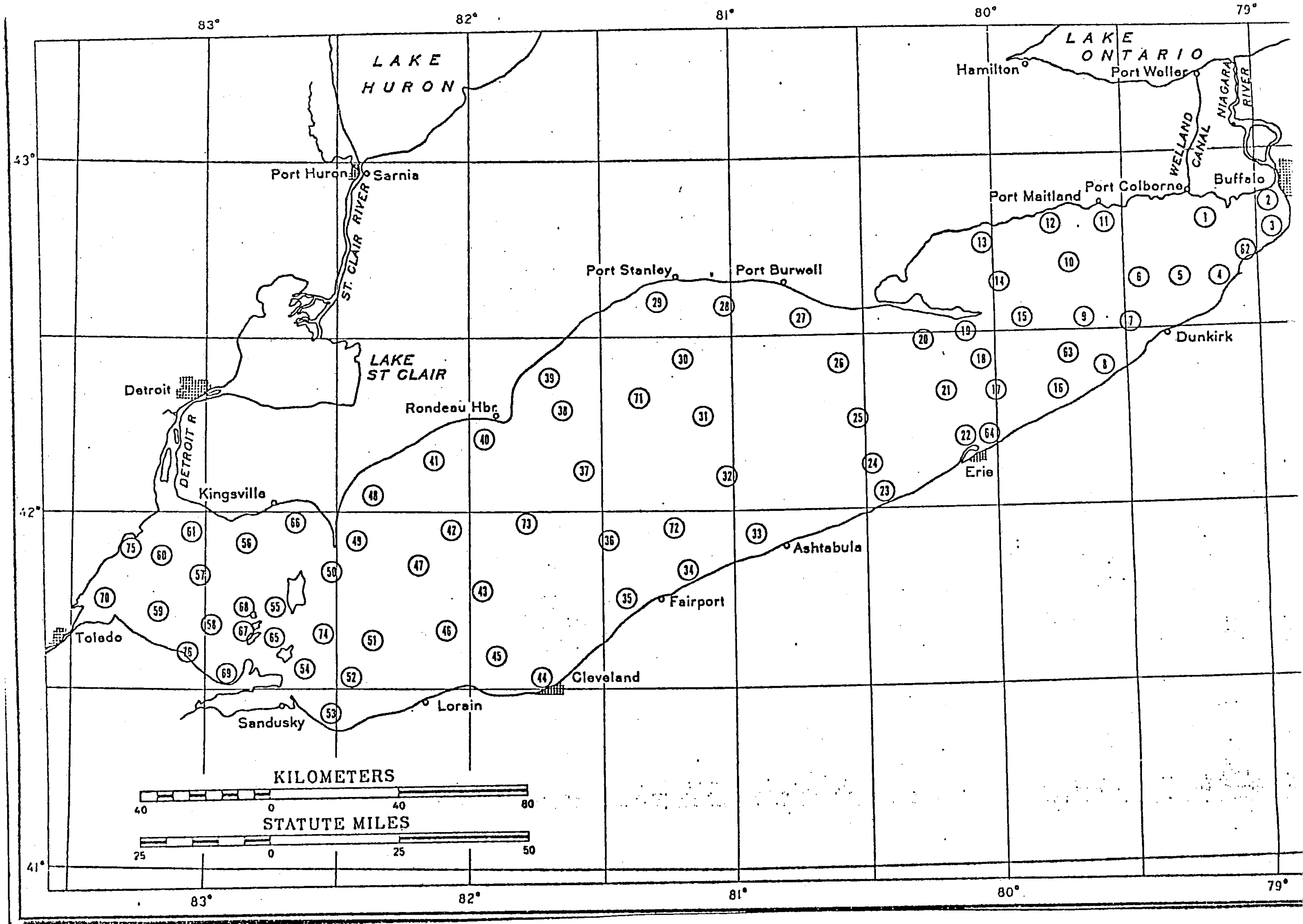


FIGURE 8. Center for Lake Erie Area Research and Great Lakes Laboratory Monitoring Stations in the Nearshore and Open Lake Portions of Lake Erie.

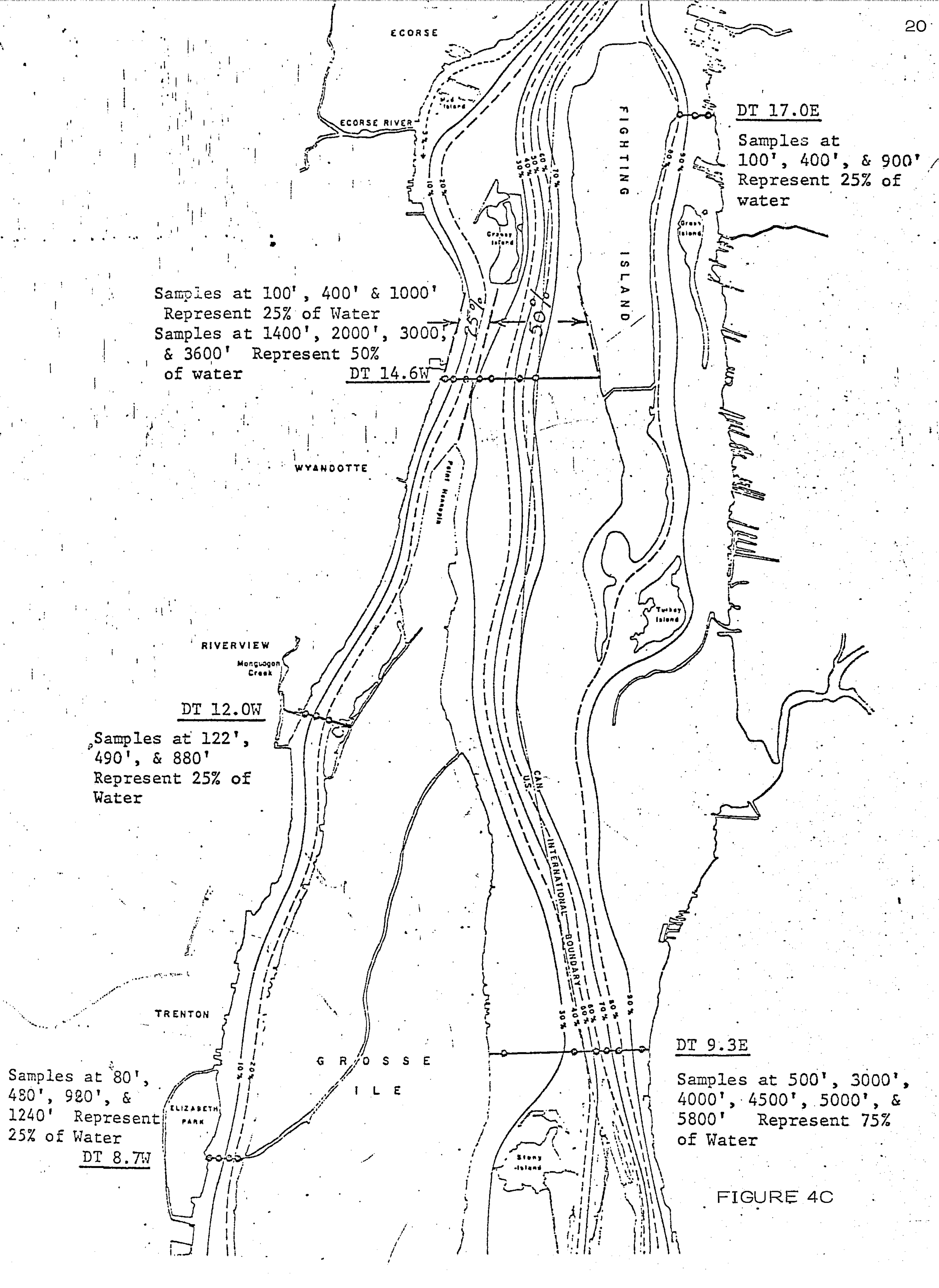

ECORSE
ECORSE RIVER
Mud Island
Grassy Island
FIGHTING ISLAND
Grass Island
DT 17.0E
Samples at 100', 400', & 900' Represent 25% of water
Samples at 100', 400' & 1000' Represent 25% of Water
Samples at 1400', 2000', 3000', & 3600' Represent 50% of water
25%
50%
DT 14.6W
WYANDOTTE
Point Hennepin
Turkey Island
RIVERVIEW
Monguagon Creek
DT 12.0W
Samples at 122', 490', & 880' Represent 25% of Water
CAN
US
INTERNATIONAL BOUNDARY
10%
20%
30%
40%
50%
60%
70%
80%
90%
TRENTON
GROSSE ILE
ELIZABETH PARK
Stony Island
Samples at 80', 480', 980', & 1240' Represent 25% of Water
DT 8.7W
DT 9.3E
Samples at 500', 3000', 4000', 4500', 5000', & 5800' Represent 75% of Water

FIGURE 4C

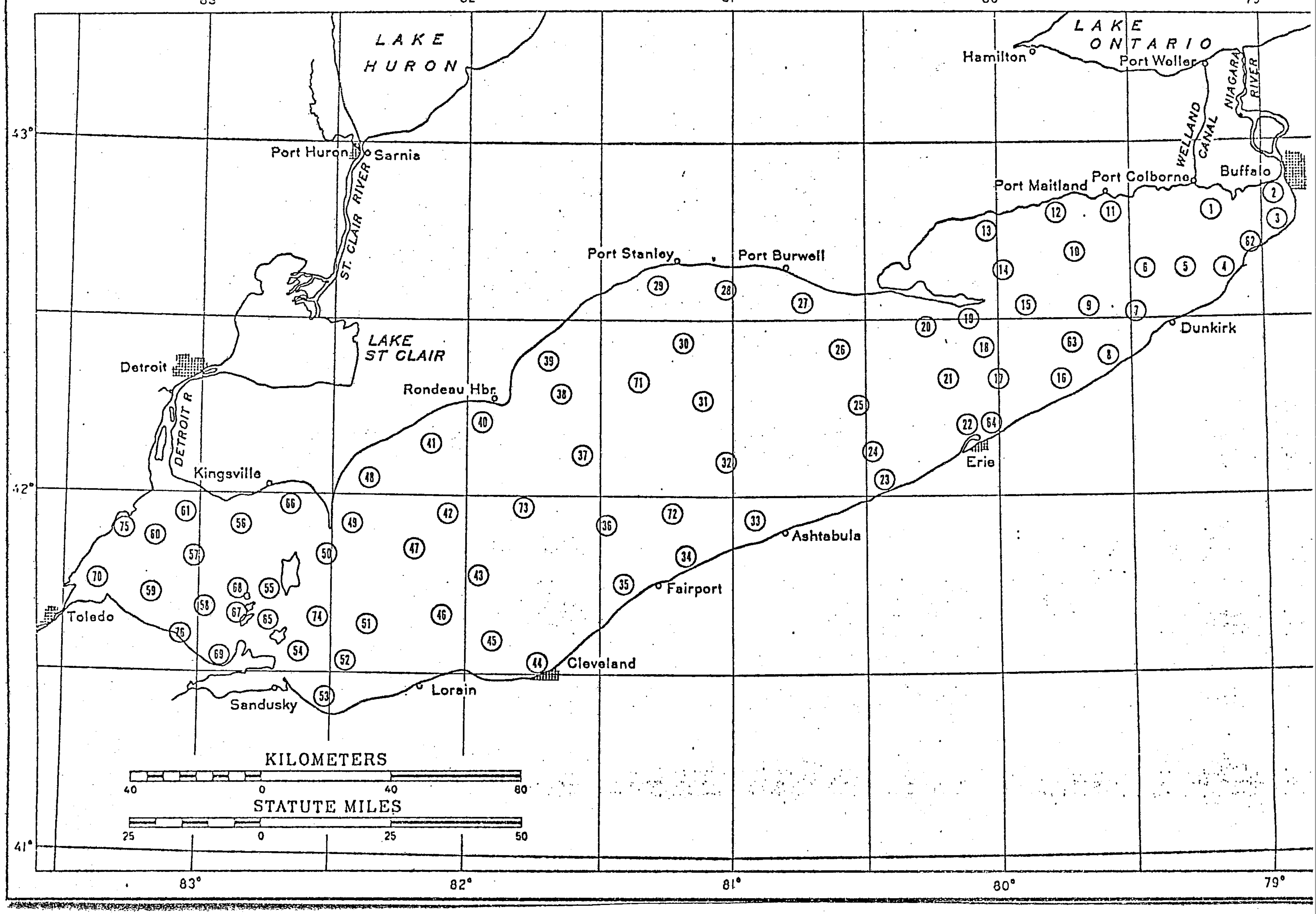


FIGURE 8. Center for Lake Erie Area Research and Great Lakes Laboratory Monitoring Stations in the Nearshore and Open Lake Portions of Lake Erie.