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Evaluation of Alternatives and Costs for Nonpoint Source Controls in the United States Great Lakes Basin

Great Lakes Basin Commission

International Reference Group on Great Lakes Pollution from Land Use Activities

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INTERNATIONAL JOINT COMMISSION

AN EVALUATION OF ALTERNATIVES AND COSTS FOR NONPOINT SOURCE CONTROLS IN THE UNITED STATES GREAT LAKES BASIN

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NONPOINT SOURCE CONTROLS

IN THE UNITED STATES

GREAT LAKES BASIN

by

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DISCLAIMER

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S U M M A R Y

This report presents an evaluation of nonpoint source problems affecting the Great Lakes and estimated costs for a range of remedial control programs. The consideration of potential critical problem areas was limited to the following:

- Urban areas

  Stormwater runoff and combined sewer overflows

  Construction site runoff

  Runoff controls for new developments

- Agricultural areas

  Erosion and sedimentation

  Animal waste disposal

- On-site waste disposal

PROBLEM AREAS

An important concept developed in this evaluation is the potential contributing area (PCA). The PCA is defined as that portion of the Great Lakes drainage basin or portion thereof from which contaminants associated with land use activities could reasonably be expected to enter the Great Lakes. The extent of the PCA for each of 72 hydrologic areas which comprise the U.S. Great Lakes Basin was estimated on the basis of available information; U.S. Geological Survey 1:250,000 topographic maps and soils association data collected as a part of PLUARG Task B.

Data were collected for urban areas of 2,500 persons or more within the potential contributing area. Problems and control measures were evaluated using information and methods developed for the U.S. Environmental Protection Agency 1976 Needs Survey for combined sewer overflows and stormwater discharges. The most cost-effective (in terms of dollars/ton removed) combinations of combined sewer and stormwater controls for three levels of solids removal efficiencies were selected for each urban area. Projected annual growth rates were used to estimate costs for construction sediment controls and detention ponds in new developments.

Estimated cropland acreage and erosion control needs for moderate- and fine-textured soils in the PCA were provided by state and local Soil Conservation Service offices. In addition, descriptions of recommended best management practices for erosion control, with estimated one-time and recurring costs per acre, were provided.

Information was also provided on the number of animal feedlot operations in the PCA requiring waste control systems and the approximate cost per system.

The evaluation of on-site waste disposal problems was severely hampered by a lack of information on estimated system failure rates. "Best guess estimates" of failure rates were compiled for each lake basin based on contacts with selected local health offices, 208 planning agencies, and others. Three remedial alternatives were considered in estimating costs: connection to a centralized treatment facility via a pressurized sewer, installation of a mound filter bed, and regeneration using hydrogen peroxide. Because of problems with estimating remedial program needs, cost estimates for on-site waste disposal should be considered with care.

ESTIMATED COSTS

Lake Superior

Fourteen urban areas in the potential contributing area of the Lake Superior basin were included in the evaluation. Average annual costs for urban stormwater and combined sewer controls ranged from $2.3 million to $8.4 million per year. Construction sediment controls would cost approximately $50 thousand per year. The application of best management practices would cost up to $2.9 million per year in average annual terms. Animal waste controls would cost an estimated $20 thousand per year. Correction of on-site waste disposal problems would entail average annual costs of $900 thousand per year.

Lake Michigan

There were 47 urban areas identified in the Lake Michigan basin potential contributing area. Average annual costs for urban stormwater and combined sewer controls ranged from $33.4 million to $107.0 millipn per year. Construction sediment controls and detention ponds in new developments would add an estimated $3.7 million and $32.0 million per year, respectively. The application of best management practices to all moderate- and fine-textured soils in the PCA (estimated area of 478 thousand hectares) would have an average annual cost of $9.7 million. Limiting their use to fine-textured soils only would reduce the cost to $6.0 million per year. Animal waste controls for the 1,044 feedlot operations in the PCA requiring waste control systems would cost $1.8 million per year. Finally, correcting the approximately 18,000 failing on-site waste disposal systems would require an estimated investment of $4.5 million per year.

Lake Huron

Average annual costs for combined sewer and stormwater controls in the 16 urban areas in the Lake Huron basin PCA range from $6.0 million to $18.3 million per year. The application of construction sediment controls would cost $700 thousand per year, while detention ponds would cost $4.0 million per year. The application of best management practices to the 280 thousand hectares (691 thousand acres) of cropland on medium- and fine-textured soil in the PCA would have an average annual cost of $4.4 million per year. Limiting these practices to fine-textured soils would reduce the cost to $2.7 million per year. Feedlot controls would cost an estimated $500 thousand per year. On-site waste disposal improvements for approximately 8,600 systems would have an average annual cost of $2.2 million per year.

Lake Erie

Average annual cost estimates ranging from $101.0 million to $295.7 million per year were found for the 77 urban areas in the Lake Erie potential contributing area. Construction sediment controls and detention ponds in newly developed areas were estimated to cost $4.7 million and $35.7 million per year, respectively. The cost of applying best management practices to 1,774 thousand hectares (4,382 thousand acres) of cropland in the Lake Erie PCA as $18.1 million per year in average annual terms. Animal waste controls for the 1,350 operations in the PCA would cost $1.8 million per year. On-site waste disposal improvements for the more than 97,000 systems estimated to be malfunctioning would have an average annual cost of $26.2 million per year.

Lake Ontario

Stormwater and combined sewer control costs for the 23 urban areas in the Lake Ontario basin PCA were estimated to range from $14.0 million to $37.1 million per year. Construction sediment controls and detention ponds in new developments would add $900 thousand and $5.8 million per year, respectively. Best management practices applied to the 341 thousand hectares (842 thousand acres) requiring erosion controls in the PCA would have an average annual cost of $2.5 million per year. Limiting the use of these practices to fine-textured soils would reduce the cost to less than $100 thousand per year. Provision of waste controls for the 265 feedlot operations in the PCA would cost $800 thousand per year. Finally, correction of on-site waste disposal problems for more than 53,000 systems would have an annual cost of $10.2 million.

Costs for each lake basin are summarized in Table 1.

ALTERNATIVE STRATEGIES

Total remedial program strategy costs for the Great Lakes were estimated by selecting various combinations of controls for each of the 15 river basin groups. Four alternative remedial strategies were defined:

- Basinwide remedial measures,
- Remedial measures applied throughout the potential contributing area,
- Treatment priorities based on diffuse source tributary loads, and
- Treatment priorities based on local nearshore water quality.

Remedial strategy costs for the U.S. Great Lakes basin ranged from $110.8 million per year to a high $972.4 million per year, which assumed basinwide controls with high efficiency urban stormwater and combined sewer treatment. The strategy felt to best represent the probable cost of a nonpoint source control program for the U.S. Great Lakes basin was that based on nearshore water quality, with an estimated average annual cost of $141.7 million per year. On a per capita basis, the cost of this strategy would be less than five dollars per person per year, based on an estimated U.S. basin population of 29.7 million persons in 1975.

TABLE 1

REMEDIAL MEASURE AVERAGE ANNUAL COST SUMMARY

PRACTICE	LAKE BASIN ($ millions)				
	Superior	Michigan	Huron	Erie	Ontario
Urban Areas					
Low Level Treatment	2.3	33.4	6.0	101.0	14.0
Medium Level Treatment	5.5	93.3	18.1	240.1	18.6
High Level Treatment	8.4	107.0	18.3	295.7	37.1
Chlorination -					
Combined only	< 0.1	0.5	0.2	1.7	0.3
Both	0.3	6.6	0.8	15.4	1.4
Sediment Controls	< 0.1	3.7	0.7	4.7	0.9
Detention Ponds	-	32.0	4.0	36.4	5.9
Agricultural Areas					
Best Management Practices:					
All Soils	2.9	9.7	4.4	18.1	2.5
Fine Soils	2.9	6.0	2.7	10.2	< 0.1
Animal Waste Controls	< 0.1	1.8	0.5	1.8	0.8
On-Site Waste Disposal	0.9	4.5	2.2	26.2	10.2

Remedial strategy costs for the U.S. Great Lakes basin ranged from $110.0 million per year to a high $912.4 million per year, which assumed basinwide controls with high efficiency urban stormwater and combined sewer treatment. The strategy felt to best represent the probable cost of a nonpoint source control program for the U.S. Great Lakes basin was designed on nearshore water quality, with an estimated average annual cost of $141.7 million per year. On a per capita basis, the cost of this strategy would be less than five dollars per person per year, based on an estimated U.S. basin population of 29.7 million persons in 1975.

1 INTRODUCTION

This report was prepared as Subactivity 2.1.2, Technical Remedial Measures, of Task A of the International Reference Group on the Pollution From Land Use Activities (PLUARG) of the International Joint Commission through an Interagency Agreement between the U.S. EPA, Region V, and the Great Lakes Basin Commission. A Detailed Study Plan Supplement prepared in August of 1976 by PLUARG defined the purpose of this subactivity to be the following:

1. Determine from the ongoing studies in Tasks C and D what apparent problem areas have been identified.

2. With the assistance of Task C and D technical staff and other acknowledged experts working in similar fields, identify a range of remedial measures which might be undertaken to solve the apparent problems.

3. Through a search of the existing literature, determine what other options are available for reducing problems associated with pollution from land drainage in the Great Lakes Basin.

4. Identify the kinds of remedial actions adopted in different countries as a result of varying cultural responses to the solutions of similar problems. Emphasize those areas with similar climatic and physiographic conditions as those found in the Great Lakes Basin.

5. Through an analysis of existing research findings in conjunction with the technical staff of Tasks C and D, evaluate the effectiveness of measures detailed in 2, 3, and 4, both in terms of the level of pollutant reductions achieved and anticipated, and the level of investment required to implement and operate, either by government or by the private sector, a particular control.

6. Assess both the direct and indirect costs associated with the implementation of these remedial measures.

7. Assess the costs of controlling nonpoint source pollution generated from specific land use activities relative to the cost estimates available for controlling pollution generated from point sources and from atmospheric inputs.

In the time since the Study Plan Supplement was prepared, a great deal of work has been accomplished in this subactivity. PLUARG has published an Evaluation of Remedial Measures to Control Nonpoint Sources of Water Pollution (IJC, 1977c) which fulfills the requirements specified in numbers 2, 3, and 4 above. It also meets number 5 to some extent, where the effectiveness of an individual measure is considered and associated direct unit costs estimated. In addition, work has been carried out by investigators to define problem areas (1 above) and to assess the relative contributions of point, nonpoint, and atmospheric loadings (related to 7 above).

Because of the intensive activity underway or completed in identifying problems and cataloging remedial measures to deal with them, this report focuses on the remaining objective for this activity, the assessment of costs associated with the implementation of remedial measures. This does not mean, however, that the other objectives have not been addressed. Although the focus is on implementation and costs of remedial control programs, information on Basinwide and specific problem areas and remedial measure alternatives has been developed as needed for the analysis. Thus, criteria are presented for the identification of problem areas across the Great Lakes Basin. Also, additional information on remedial measures is presented as appropriate.

Based on the above discussion the following objectives were defined for this project:

1. To develop and apply a uniform set of criteria across the (U.S.) Great Lakes Basin for the identification of problem areas in terms of their input of pollutants to the Great Lakes.

2. To develop and apply a methodology for estimating costs, both capital and operational, for the implementation of remedial measure alternatives to these problem areas.

3. To show the interrelationships and implications of the technical remedial measures examined and the management framework within which they are applied.

4. To estimate the probable cost of a (U.S.) Great Lakes Basin nonpoint source control program based on the criteria and methods developed.

In terms of the first objective, it must be noted that the purpose of identifying problem areas was to facilitate the estimation of implementation costs of remedial measure alternatives. It was not designed to provide a detailed picture of nonpoint source problems in the Great Lakes Basin; such information is being developed by other PLUARG studies. It is hoped, however, that the criteria and methodology defined herein may provide some useful insight and guidance to these other investigators, and that the results will complement their work. The reader is therefore cautioned against placing undue emphasis or importance on that aspect of this study and to keep in mind the purpose for which it was developed.

An accurate assessment of the cost of controlling nonpoint source pollution requires that a detailed study be made of the magnitude and source of the problems, the physical characteristics of the problem area, the hydrologic and climatic factors acting upon the problem area, and the full range of specific remedial measures available for application in that problem area. For the purposes of PLUARG there also must be consideration of how that area, as a part of the total Great Lakes drainage basin, affects the water quality of the Great Lakes receiving waters.

In actuality, such a detailed analysis cannot be performed for the Great Lakes Basin as a whole, or even a major portion of it. Instead, a methodology must be developed based on a set of simplifying and generalizing assumptions that allow the investigator to examine broad areas without concern for local variability. For the purposes of this analysis, such an approach is sufficient for defining the range of costs that might be expected in implementing a remedial action program at the Great Lakes or lake basin scale. Actual implementation of remedial measures would, of course, have to be predicated on an in-depth study of local conditions.

The following procedure has been used in performing this analysis. First, problem areas have been identified throughout the (U.S.) Great Lakes Basin by application of a set of problem assessment criteria and procedures. Important concepts developed as a part of this analysis are the potential contributing area (PCA) and the potential critical problem area. As is explained further in Chapter 2, the PCA defines that area of the Great Lakes Basin where land use activities could have an impact on Great Lakes water quality. Potential critical problem areas, on the other hand, are areas within the PCA where such pollutant-generating activities are presently occurring and assumed to be contributing pollutants to the lakes. This evaluation was carried out at the hydrologic area (HA) and river basin group (RBG) level.[*] Problem summaries are also provided for each Lake Basin.

It is important to note that the identification of a land use activity, such as on-site waste disposal, as a potential critical problem in this analysis does not mean that it is presently causing significant deterioration of Great Lakes water quality. Rather, it is intended to provide information concerning the magnitude and cost of remedial programs if such problems were to be found.

The second part of the analysis is concerned with estimating costs for implementing and maintaining a range of remedial programs. These cost estimates were developed through a two-part process. First, costs for a variety of remedial program components dealing with each land use activity of concern were evaluated. Second, these components were combined to form alternative control strategies, each of which defines an approach that could be taken in controlling land-derived inputs. Total costs for each strategy, based on the components that define it, were developed for the entire Great Lakes Basin. The cost estimation procedures are explained in more detail in Chapter 2.

This approach was not designed to develop a "single best" remedial strategy; as was discussed above there are too many local variables that must be considered in tailoring specific recommendations to a specific problem area. General conclusions

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*A river basin group (combination of several watersheds) is a subdivision of a lake basin based on hydrologic boundaries. The U.S. Great Lakes drainage basin has been divided into 15 RBGs. Hydrologic areas are subdivisions of RBGs and consist of either a single major river basin (e.g., the St. Louis and Maumee Rivers) or collections of small watersheds, which are termed complexes (e.g., The Superior Slope Complex drains the area northeast of Duluth, MN.) There are 72 hydrologic areas covering the U.S. Great Lakes Basin. A third sub-Basin unit is the planning subarea (PSA), which is an approximation of an RBG defined by political (county) boundaries.

can be drawn concerning the approach that PLUARG might take in developing its remedial action recommendations. By determining how costs vary with different mixes of components, this study provides background useful to PLUARG in formulating its recommendations. This evaluation of alternative program costs was carried out at the river basin group level with results presented by lake basin as well. As was mentioned above, alternative strategy costs were evaluated only at the Great Lakes Basin level.

In developing the remedial program alternatives to be examined it was apparent that consideration of technical (structural) measures alone would seriously distort the analysis and that nonstructural management and institutional measures must also be included. Brief discussions of important non-technical alternatives are included in Chapter 2.

The report is organized into two major sections. The first, which includes Chapter 2, presents the methodology used in identifying problems and developing cost estimates for the various control strategies. Part 2 (Chapters 3 through 8) presents the results of the problem analysis and the associated cost estimates. Chapters 3 through 7 deal with each lake basin, while Chapter 8 presents the summary of alternative strategy costs for the Basin as a whole.

2 PROBLEM AREA IDENTIFICATION AND COST ESTIMATION

A great deal of work has been done in the U.S. and Canada defining the parameters of importance in assessing the movement of pollutants from the land surface to the Great Lakes. Under the auspices of Task C, scientific and technical investigators have dissected and analyzed the dynamics of contaminant travel through the pilot watersheds. Efforts were also made to bring these results together and extrapolate them to other areas of the Basin. Task D investigators have looked at the major sources of pollutants - atmospheric deposition, shore erosion, tributary loadings, and in-lake resuspension - to provide an estimate of how much material enters the lakes annually. They have also carried out projects to assess the impact that these inputs have on the physical and biological systems of the Great Lakes. Taken together, the reports from Task C and D provide a comprehensive picture of how materials move from land to water, how much movement is taking place, and what this means in terms of the quality of the Great Lakes resource.

At the same time PLUARG conducted another major effort, Task B, to collect data and background information on factors felt to be important in creating and/or evaluating problems. Included were data on existing and projected land use, population, and economic activity, soils, geology, hydrology, material applications to the land surface, and potential pollutant-generating activities. This material has been collected in tabular and graphical form to provide a basis for assessing current and future pollution problems.

Task A, specifically this part of Task A, Technical Remedial Measures, draws on all of the various activities described above. This chapter describes the procedures used in identifying potential critical problem areas and developing a range of remedial program cost estimates for them. The first part of the chapter presents the general approach and defines important concepts used in the analysis. Following this, the problem identification criteria and cost evaluation techniques are presented for those land use activities affecting Great Lakes water quality. Finally, there is a brief discussion of those activities not considered to have a significant impact on Great Lakes water quality and for which costs have not been developed.

GENERAL APPROACH

The focus of this effort was the development of a set of problem identification and cost evaluation techniques which could be used across the Great Lakes

Basin. This section describes the general approach taken in carrying out this activity and defines a number of important concepts developed in doing so.

PROBLEM AREA IDENTIFICATION

The procedure used in identifying problem areas was based on an examination of the physical and cultural features related to water quality problems in each basin: land use, soils, and the presence or absence of pollutant-generating activities. Much of this information had been collected as part of PLUARG Task B activities. Some, however, was not available from PLUARG and was obtained elsewhere or was estimated. The criteria and assumptions used are described later in this chapter.

The result of this analysis is a description of potential critical problem areas; that is, areas which have certain characteristics (e.g., land uses, soil types) which indicate that they may cause water quality problems. The problem descriptions have both quantitative and qualitative information; every effort was made to provide an estimate of the magnitude of a problem.

Although an analysis based on land characteristics will identify those areas which may cause water quality problems it does not provide any indication as to whether or not those problems will affect the Great Lakes. Clearly, if the area is on the lakeshore or at the mouth of a tributary, then it is likely that it would have an impact on the lake. Would it have an impact however if it were 10 km upstream? Or 50 km? Or 100 km? Would it have an impact if it were 10 km from a tributary or the shore?

For the purposes of this study, the concept of a potential contributing area (PCA) was developed. As it is used in this report, the PCA is that part of the Great Lakes basin or portion thereof from which contaminants associated with land use activities could reasonably be expected to enter the Great Lakes. It is important to note that <u>potential contributing area is not synonomous with potential critical problem area</u>. The latter defines an area where an activity or activities are taking place which may result in a significant impact on receiving water quality. The PCA, on the other hand, is the area within which such land use activities could contribute pollutants to the Great Lakes. Designation of a PCA does not imply that there are activities causing Great Lakes water quality problems within it; in some regions in the Basin there are PCAs without any significant problems. Rather, it means that if pollution-causing activities were to take place within it, then a significant portion of the contaminants would enter the lakes.

The PCA is closely related to the concept of a "hydrologically active area" (HAA), which has been described elsewhere (see, for example, IJC, PLUARG Annual Report, 1977a). Briefly, the HAA is an area which contributes directly to surface runoff even during minor storm and snow melt events. It is characterized by steep slopes, soils with low infiltration rates and infiltration capacity, or high ground water table.

The pilot watershed study investigators have endorsed this concept in their Summary Report (IJC, 1978a):

"...major portions of the sediment (80 to 90%) are generally contributed by 5 to 20% of the land area i.e. the hydrologically active area concept. It is clear that 'wall to wall' remedial measures are neither feasible, nor desirable and measures need only be applied to those areas comprising hydrologically active zones (which normally occupy the land bordering drainage ways and natural stream courses)...As a gross approximation, the treatment of the active areas of the 30% of the agricultural part of the basin which is presently contributing 60% of the sediment load from agricultural land may have the potential to reduce this input by 50%. Thus an overall reduction of 30% of the agricultural sediment load may be achieved by treating 4.5 to 6% of the land surface."

It is difficult to identify the extent of this HAA throughout the Great Lakes basin. The PCA is a first-cut at identifying that portion of the total basin which may contribute sediment and related pollutants. The HAA is a further refinement of this area and represents that part of the Basin which is contributing the most heavily and where remedial measures should be concentrated. Because the PCA was defined on the basis of relatively general criteria, the HAA may be of much more limited extent. There may also be cases in which the HAA extends beyond the potential contributing area along the stream channels.

The potential contributing area was delineated using the following criteria. Information sources used were USGS 1:250,000 topographic maps and soils association data collected as a part of PLUARG Task B.

1. Portions of the Great Lakes drainage basin above large inland lakes were assumed to make no significant pollutant contributions to the Great Lakes.

2. Areas characterized by hummocky topography with immature drainage patterns and kettle lakes were assumed to make no significant pollutant contributions to the Great Lakes.

3. Areas characterized by poorly defined drainage patterns and extensive inland wetland areas were assumed to not make significant pollutant contributions to the Great Lakes.

4. Portions of the Great Lakes drainage basin above reservoirs of high trap efficiency (estimated as 90 percent or more), or systems of reservoirs of high combined trap efficiency were assumed to not make a significant pollutant contribution to the Great Lakes. It was further assumed that a high trap efficiency would be maintained throughout the time period of concern to PLUARG.

5. Areas characterized by sandy textured soils were assumed to make no significant contribution of pollutants to the Great Lakes except when an urban area was located on such a soil that otherwise would be within the potential contributing area.

Although these criteria are useful in narrowing the scope of the problem area assessment, they do have several limitations. First, they are very general, designed to be used with information readily available from accessible sources. As a result, the PCAs based on them are only a rough approximation of what the "true" areas should be. Detailed information on topography, soils (including texture, permeability, and drainage characteristics), and soil moisture conditions would be needed to refine the boundaries. Carrying out such an analysis for the entire Great Lakes drainage basin is not feasible.

Another problem is that the criteria do not make reference to a particular storm event size or range of storm events for which they are applicable. The areal extent of the potential contributing area will vary depending on the intensity and duration of the storm it is measured against. It is not difficult to see that the potential contributing area of a given basin will vary from near zero percent for small storms to one hundred percent for very large, infrequent events. There could be significant seasonal variations as well. The criteria were developed to represent the potential contributing area of a storm of undefined, although moderate, magnitude. Also, it was assumed that the ground is not frozen. This is reflected by the fact that impoundments and lakes are assumed to retain significant amounts of sediment and that sandy textured soils do not make significant contributions.

Refining the potential contributing area delineation process to account for a specific storm event, range of storm events, or seasons (e.g., the spring runoff area versus the summer-fall area versus the winter area) would be difficult for the reasons described above. In addition, it could add to the errors in the analysis by greatly increasing the level of complexity without an accompanying improvement in the detail of the data on which it is based.

Another problem with the criteria is that they do not account for groundwater movement. There may be areas in the Basin where groundwater flow is a meaningful proportion of the total water movement occurring in that area and may be an important carrier of contaminants to surface waters. Also, some of the land use activities of concern to PLUARG, in particular waste disposal operations, may contribute directly to groundwater contamination through leaching. Because of this, the effects of land use activities on groundwater quality and the relationship between ground water and surface water are an important consideration.

Although it is important that PLUARG consider groundwater effects in its investigation, data on ground water in the Great Lakes basin are scarce. Information available throughout the Basin is limited to well yields, with some water quality data. In addition, little is known about the mechanisms and magnitude of land use impacts on groundwater quality. Although the Menomonee River pilot watershed study did consider groundwater effects, such studies were not a major PLUARG effort. As a result, consideration of groundwater effects in delineating the PCA (and identification of potential critical problem areas) was limited.

The final limitation in the criteria is that they are applicable only to the movement of sediment and sediment-associated contaminants from the land to the

Great Lakes. The movement of soluble phosphorus, for example, is not adequately reflected by the criteria. The presence of reservoirs or inland lakes could, under some circumstances, stimulate the release of additional soluble phosphorus. Conversely, the soluble fraction could be reduced by sediment adsorption and algal uptake. Similarly, the very fine sediment fraction is not reflected; much of the fine material, with its associated contaminants, may pass through a reservoir or lake.

The above discussion has covered the weaknesses in the PCA concept. It should be emphasized however that it does provide a mechanism for focusing the problem area analysis from the Great Lakes perspective. Identification of this area is the key to meeting the PLUARG objective of dealing with pollution from land use activities as it affects the Great Lakes. The alternative is to assume that contaminants from all parts of the Basin, regardless of their location, will reach the lakes and thus are of concern to PLUARG. Although such an approach would ensure that no problems are overlooked, the cost of a remedial program dealing with them would be enormous (one of the control strategy alternatives estimates this cost).

In addition to the identification of potential critical problem areas based on land use activities, diffuse tributary loading estimates were used to identify those hydrologic areas which contribute the greatest share of the (U.S.) total diffuse load to the lakes.* For example, if one hydrologic area, comprising one percent of the total (U.S.) Great Lakes Basin was found to contribute five percent of the total (U.S.) diffuse load to the lakes, then it could be assumed that pollution-causing activities are taking place within that area. Furthermore, it would indicate that more intensive efforts to define those problems and develop remedial programs for them should be concentrated in that area rather than in other areas not contributing as much. This procedure was used as a screening process to determine which parts of a lake drainage basin were the most significant in terms of their contributions of land-derived pollutants. It was also used in the development of one of the alternative control strategies, described later in this chapter.

Estimated diffuse tributary loads of sediment and phosphorus (total and ortho) were examined to determine which hydrologic areas contribute the greatest share of the total load entering the Great Lakes basin from the U.S. side. A Contribution Index (CI) was developed to indicate the relative diffuse load contributions from a given hydrologic area. A CI value was calculated for each of the above three parameters for each hydrologic area as follows:

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*The term "diffuse tributary load" is used to describe the residual tributary load not accounted for when municipal discharges (greater than 1 mgd) and known industrial loadings are subtracted from total tributary load. As such it includes not only the nonpoint source load but also base flow, small municipal plants, unknown or unauthorized industrial loadings, atmospheric loads, etc.

$$CI = \frac{\text{Percent of total Great Lakes Basin diffuse tributary load from hydrologic area i}}{\text{Percent of the total Great Lakes PCA in the potential contributing area of hydrologic area i}}, \text{ or}$$

$$CI = \frac{\dfrac{L_{ji}}{\sum\sum_{ji} L_{ji}}}{\dfrac{PCA_{ji}}{\sum\sum_{ji} PCA_{ji}}} \text{, where}$$

L_{ji} = load from the hydrologic area i in lake j, and

PCA_{ji} = potential contributing area of hydrologic area i in lake j.

As can be seen, the purpose of the index is to remove the effect of areal extent in comparing the diffuse load contributions from each hydrologic area. If a hydrologic area contributed in proportion to its PCA, a ratio of 1.0 would be expected if all factors were equal. Higher values indicate areas in which problems may be occurring. Those areas for which the index value was less than 1.0 for each of the parameters were considered to be less significant in terms of their impact on the lakes.

The Contribution Index is aimed at evaluating the relative importance of the diffuse load entering the Great Lakes from a given hydrologic area. It does not reflect the amount of nonpoint source load carried to surface streams in the hydrologic area and the possible need for a nonpoint source control program to protect local water quality.

The diffuse load estimates used in this analysis were taken from Sonzogni, et al, United States Great Lakes Tributary Loadings (IJC, 1978), prepared as a part of PLUARG Task D activities. An important assumption used in calculating these estimates was that one hundred percent of the point source inputs throughout the hydrologic area were transported to the lake. Although this does not agree with the assumptions made regarding the potential contributing area, it does give the most conservative estimate of diffuse loads. Thus, it will reduce the possibility of overstating the diffuse load contributions from a given area.

It should be noted that CIs were not calculated for all hydrologic areas; in some cases, the estimated extent of the PCA was so small that an unrealistically high CI value resulted. Although this may be related to problems in the criteria used to delineate the PCA, it was decided that those areas would not be included in evaluation based on CIs. Most of these areas were relatively undeveloped and had low diffuse loads when compared to other areas on a unit area load basis.

EVALUATION OF REMEDIAL PROGRAM COSTS

Remedial program costs were estimated in two stages. First, a set of alternative remedial program components were defined for each land use activity of concern. Each of these program components is a control measure or program for reducing pollutant loadings from a given land use activity category. Examples include the implementation of construction sediment controls, the application of best management practices on all agricultural lands in the potential contributing area, or the use of high efficiency stormwater treatment measures.

These program components were then used to define alternative control strategies. An alternative control strategy is a set of program components selected on the basis of their geographic extent, estimated effectiveness, and/or relation to observed Great Lakes water quality problems. In other words, a particular control strategy represents a policy decision regarding control priorities. How these priorities are established will affect the estimated total (U.S. Great Lakes Basin) cost of that strategy. Thus, the range of strategies available will generate a corresponding range of costs incurred for dealing with nonpoint source problems affecting the lakes.

Because this study could not select any one strategy as being the preferred policy, a range of strategies was defined based on different approaches to setting control priorities. While these strategies do not represent the full range of options available, from no program whatsoever (with zero cost) to Basinwide controls, they do present a range of reasonable choices. More importantly, they illustrate an approach that could be taken in analyzing and comparing a wide range of policy options on the basis of a common factor (in this case, cost).

The alternative control strategies are defined following the discussion of the land use activities.

Cost estimating procedures were developed for each set of program components associated with a given land use activity. These procedures were then applied to the potential critical problem areas identified in each river basin group. The cost estimation procedures are described below.

While the focus of this report remains on technical solutions for nonpoint source problems, there is also a discussion of management considerations for several of the land use activities. A control program cannot rely solely on technical solutions; in most cases there is an optimum mix of structural and non-structural program components which achieve the desired level of control in the most cost-effective manner. Often, the framework in which technical measures are implemented determines the long-term success of the project. Although this analysis does not determine what this mix is for any given problem, it does discuss several aspects of the management question.

MAJOR LAND USE ACTIVITIES

At the outset of the PLUARG study, nine land use categories were identified as possibly causing Great Lakes water quality problems: urban; agriculture; forestry; transportation and utility corridors; recreation areas; solid, liquid, and deepwell disposal sites; shoreline and riverbank erosion; extractive sites; and shoreline landfilling. Each was evaluated in terms of its potential contribution to lake water quality problems (IJC, 1974). Further study during the course of PLUARG has focused on two major activities as the most significant non-point source contributors of sediment and phosphorus to the Great Lakes - urban stormwater and construction site runoff, and row crop agriculture. In addition, on-site sewage disposal systems (i.e., septic tanks) and intensive animal feeding and waste disposal operations may contribute significant amounts of phosphorus to the lakes in some areas. The remaining activities were found to contribute very little to water quality problems in the lakes.

Recognizing the above findings, remedial program cost estimates were prepared only for those land use activities identified as having a significant impact on the lakes. This section presents the criteria and methodology used in identifying the extent of potential critical problem areas and the alternative remedial program components and cost estimation procedures developed for each. There is also a discussion of management considerations and non-technical alternatives related to them. Following this, there is a brief discussion of those activities not thought to represent significant sources of contaminants to the lakes but which may cause some local water quality problems.

Estimated remedial capital and annual operation, maintenance, and recurring practice costs for the land use activities of concern are shown throughout the report. Costs are also presented in average annual terms; capital amortized over 25 years at 10 percent per year plus annual operation, maintenance and recurring practice costs. The period and interest rate were selected to facilitate comparison between the results of this activity and other related efforts underway as a part of PLUARG.

URBAN AREAS

POTENTIAL CRITICAL PROBLEM AREAS

The following criteria were used in assessing the impact of urban areas on the Great Lakes:

1. All population concentrations of 2,500 persons or more within the PCA were assumed to be a significant source of sediment and associated contaminants to the Great Lakes.*

2. It was assumed that major urban areas (population greater than 10,000 persons) in the PCA within 150 km of the lakes were sources of bacteriological contamination.

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*The selection of 2,500 persons as the minimum urban area was based on data availability; there were no indications that this limit was significant in terms of potential water quality impacts.

3. All construction activities taking place within the PCA were assumed to be a significant source of sediment and associated contaminants to the Great Lakes.

4. Urban areas throughout the Great Lakes Basin were assumed to contribute soluble conservative contaminants (i.e., chloride) to the lakes. The significance of these contributions however is generally not known.

The selection of the 150 km limit for bacteria contributions to the lakes was based on information related to bacteria die-off rates (discussed in Velz, 1970). The death rate of bacteria in an unfavorable environment (i.e. a river) was assumed to be constant; that is, a given percentage of the remaining population dies over each successive time unit. Stream survival rates are determined by a wide variety of factors including temperature, pH, nutrient availability, sedimentation and adsorption, and competitive life. Studies under a wide range of conditions indicate that under summer conditions less than 10 percent survive after two days, even on large streams. Survival rates are even less on moderate sized streams, three percent after two days.

The selection of 150 km was made to approximate a one to two day residence in the stream prior to discharge to the receiving lake. This figure was adjusted to take into account differences in urban area size as distance from the lake increased (i.e., as distance increased the minimum urban population considered significant also increased).

As the fourth criterion states, urban areas throughout the Basin were assumed to be sources of chloride, primarily from street salting operations. Because there were generally not any defined problems associated with chloride levels in the lakes or nearshore waters (with the exception of Irondequoit Bay on Lake Ontario), no cost estimates were developed for alternative snow removal methods.

The methodology used to evaluate the extent of urban area problems and the subsequent costs of alternative remedial measures was based on procedures developed for the USEPA 1976 Needs Survey for Combined Sewer Overflows and Stormwater Discharges (USEPA, 1977a). A simplified flow diagram of the evaluation process is shown in Figure 1. A listing of the program used is included in Appendix 1.

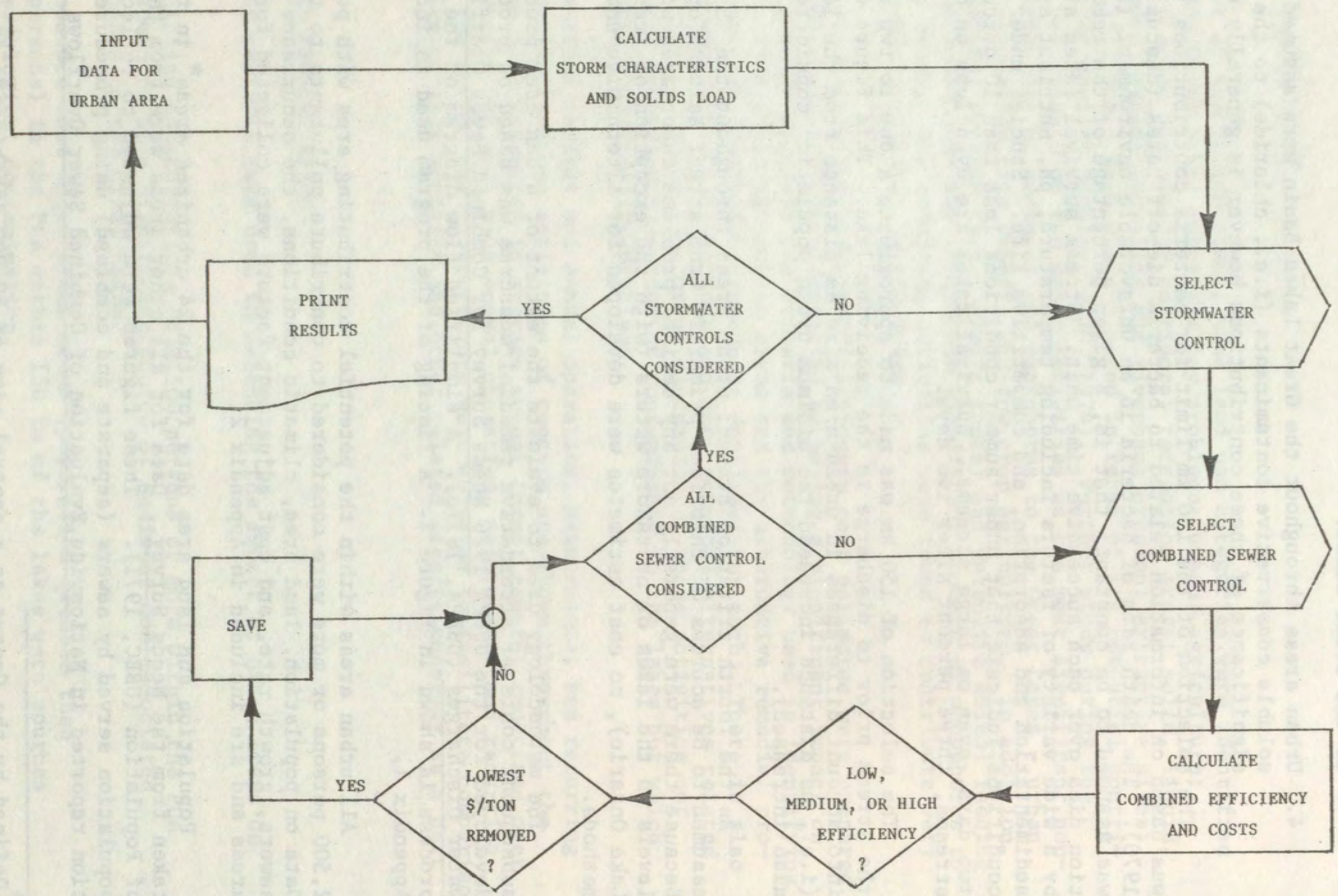
All urban areas within the potential contributing area with populations of 2,500 persons or more were considered to contribute pollutants to the Great Lakes. Data on population, land area, climatic conditions, the occurrence of combined sewers, growth rate, and cost adjustment factors were collected for each of those areas and are included in Appendix 2.

Population and land area data for the 24 urbanized areas* in the PCA were taken from the Needs Survey. Data for all other areas were from the 1970 Census of Population (USBC, 1971). These figures were adjusted to reflect the area and population served by sewers (separate and combined) using procedures and information reported in Nationwide Evaluation of Combined Sewer Overflows and Urban

*Defined by the Census as a central city of 50,000 inhabitants or more, and the surrounding closely settled territory (i.e. suburbs).

FIGURE 1

SUMMARY FLOWCHART OF
URBAN AREA ANALYSIS PROCEDURE



Stormwater Discharges, Volume II: Cost Assessment and Impacts (USEPA, 1977b). Factors used for this adjustment are shown in Table 2. The data in Appendix 2 have been adjusted by these factors. Estimates of the total urban area (both in and outside of the PCA) for each state and river basin group were taken from 1970 Census information and adjusted by the factors in Table 2.

TABLE 2

AREA AND POPULATION ADJUSTMENT FACTORS*

STATE	SEWERED AREA ADJUSTMENT FACTOR	SEWERED POPULATION ADJUSTMENT FACTOR
Indiana	0.28	0.76
Michigan	0.35	0.79
Minnesota	0.21	0.71
New York	0.59	0.96
Ohio	0.28	0.76
Pennsylvania	0.39	0.85
Wisconsin	0.26	0.67

*Illinois was not included due to its limited Great Lakes drainage.

The fraction of each urbanized area served by combined sewers was taken from estimates in the Needs Survey. Estimates for other areas are statewide averages based on data in the Nationwide Evaluation related to non-urbanized areas. Estimates of the average combined sewer drainage area were also based on statewide averages presented in the EPA Needs Survey.* Regional population growth rates were taken from the 1975 National Assessment (GLBC, 1975). Climatic data related to average annual rainfall and annual days with measurable precipitation were taken from the EPA Needs Survey.

It must be pointed out that the method used in this report was designed to produce aggregate cost estimates based on the data for a number of areas; it was not designed to be used for individual areas. Because of this, results for individual areas would be misleading and thus have not been presented.

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*An exception to this were the values used for Wisconsin cities. In this case, the Needs Survey value of 84 acres per overflow was felt to be too low. Figures for Milwaukee confirmed this (SEWRPC, 1973) and the following procedure was used to determine values for Wisconsin urban areas:

$ASCO = CS * AC + (1-CS) * AS$, where

ASCO is the average combined sewer overflow drainage area in acres,
CS is the fraction of the area served by combined sewers,
AC is the average combined sewer drainage area, assumed to be 154 acres, and
AS is the average storm sewer outfall drainage area, assumed to be 230 acres.

ALTERNATIVE REMEDIAL PROGRAM COMPONENTS

Three program components were defined for the reduction of stormwater and combined sewer overflow problems based on the degree of suspended solids removal:

- Low Level Treatment: Stormwater and combined sewer overflow treatment with less than 30 percent solids removal;

- Medium Level Treatment: Stormwater and combined sewer overflow treatment with more than 30 but less than 60 percent solids removal;

- High Level Treatment: Stormwater and combined sewer overflow treatment with greater than 60 percent solids removal.

Suspended solids were selected as the design pollutant because of the availability of cost estimating procedures and removal efficiency data. Because sediment acts as a transport mechanism for a variety of other pollutants, most notably phosphorus, it is possible to relate sediment load reductions to reductions in other pollutants. In doing this, the most important factor to consider is the variability of dry weight concentration of the pollutants (generally expressed as μg of contaminant per gram of solids) as a function of particle size; in general, the greatest amount of the pollutant is associated with the fine-grain sediments. As a result, removal efficiencies of these associated pollutants will generally be less than the solids reduction.

The five treatment methods considered for stormwater and combined sewer overflows and their estimated solids removal efficiencies are listed in Table 3.

TABLE 3

STORMWATER AND COMBINED SEWER CONTROL METHODS

	ALTERNATIVE	APPLICATION	ESTIMATED SOLIDS REMOVAL
1	Best Management Practices	Stormwater	10-25%*
	Screening-Swirl Concentration	Combined Sewers	20%
2	Sedimentation	Both	35%
3	Air Floatation with Chemicals	Both	60%
4	Flocculation-Sedimentation	Both	80%
5	Filtration	Both	93%

* Calculated for each area

The computer program used evaluated each combination of stormwater and combined sewer controls for each urban area, estimating capital, operating, and total discounted cost and combines removal efficiencies. A 90th percentile* storm was used for the estimation of facility size and costs.* Total cost (present value) estimates were based on a 20-year plant life,with operation and maintenance discounted at 6.625 percent, the current (February 1978) federal discount rate. An estimated cost effectiveness figure in dollars per ton of solids removed based on the total cost was calculated for each control combination and the most cost effective combination for each treatment level - low, medium, and high - selected. Summaries of costs and aggregate treatment efficiencies were then produced for each river basin group; These are presented in the second part of this report.

Two remedial program components were developed to deal with bacteriological problems related to urban runoff and combined sewer overflows:

- Chlorination of combined sewer overflows in conjunction with medium or high level treatment, and

- Chlorination of both stormwater and combined sewer overflows in conjunction with medium or high level treatment.

Chlorination costs were included only for those areas identified as potential sources of bacteriological problems. The selection of chlorination as the method of treatment was based solely on the availability of cost estimation procedures.

Finally, two program components were included which relate to the prevention of nonpoint source problems in developing areas:

- The application of construction sediment controls to all new urban area construction in the potential contributing area, and

- The provision of stormwater detention ponds in all newly developed urban areas.

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*The 90th percentile storm is that storm which produces more rainfall than 90 percent of all storms; conversely, it is exceeded by one storm out of ten. Its choice in this case was arbitrary and was not related to the potential contributing area.

Estimates of the extent of new development in each urban area were obtained by multiplying the average annual population growth rate by the present unadjusted urban acreage (i.e. including the unsewered areas). Although this does not account for changes in settlement densities or development outside of urban areas it provides a uniform basis for cost estimating. In those areas with a predicted population decline (e.g. the Lake Superior basin) a value of 0.1 percent per year was assumed to account for maintenance of the present urban base through road construction, regrading, etc. In these cases the cost of detention ponds was not calculated.

The cost estimation procedures used in evaluating each of the seven remedial program components described above are included in the program listing in Appendix 1. Further information on them, including background assumptions, can be found in the EPA <u>Needs Survey Report</u>. It must be noted however that while the equations used for calculating costs are essentially the same, this study has used a somewhat different approach in their application so that strict comparisons of results are not possible.

<u>MANAGEMENT CONSIDERATIONS</u>

The preceding discussion of urban runoff control was primarily limited to activities associated with collection of runoff and its subsequent treatment and transport through storm sewers or open ditches to a convenient outfall - i.e. technical or structural controls. There are other alternatives which are nonstructural in that they involve regulatory and administrative programs such as passage of an ordinance to reduce street litter and debris or to require cleaning of private parking lots. Generally, both the structural and nonstructural approaches require action by local units of government for their implementation. In the case of structural measures, the focus of action would be on the local public works agencies while in the case of the nonstructural measures, the major local involvement would be through the planning commission or zoning board and the building safety department.

Several of the nonstructural management alternatives available include the following:

- Promotion of private runoff management using on-site controls such as roof-top storage and multi-purpose storage areas;
- Regulation of the location, timing and density of new development so as to minimize adverse effects of resultant runoff;
- Designation of environmentally sensitive areas (such as the hydrologically active zone) within which development would be limited or carefully controlled; and
- Restriction or control of the deposition of potential pollutants on the land surface.

The effectiveness of measures such as these is unknown due to the lack of experience in their application. Some, such as the restriction of development in certain areas, may be subject to legal challenge if implemented. Others, such as limiting the deposition or use of potentially polluting materials, may be difficult to enforce.

Local units of government do, however, have significant powers, particularly through zoning, planning, and plat review to effectuate some of these controls. One of the keys to successful implementation is likely to be the adjustment of local public policy so that significant incentives exist for developers to provide on-site stormwater management that will be compatible with public investments in drainage systems. Two approaches are available:

1. On-site stormwater control devices may be required as a condition of development. Municipal engineering and planning departments could specify requirements in accordance with standards and criteria identified in an ordinance. This requirement may be based on the concept that new development should pay for itself and not place undue burdens on the community. Similar arrangements already exist where developers are required to pay for or directly provide traffic control improvements such as additional turning lanes or signals for new shopping centers.

2. On-site stormwater control devices may be negotiated in return for density bonuses. This arrangement is utilized by New York City as a means of encouraging developers to provide urban amenities in new private developments. A similar incentive mechanism could be used to encourage on-site runoff management.

As was stated earlier, the particular approach selected by a given area is likely to be a combination of both structural and non-structural techniques. The lack of federal funds for the development of extensive stormwater control systems as specified in Section 36 of the Federal Clean Water Act of 1977 (P.L. 95-217) means that increased emphasis will be placed on the use of management and planning alternatives. The effectiveness of this approach in relation to solving Great Lakes problems remains to be seen.

AGRICULTURAL AREAS

POTENTIAL CRITICAL PROBLEM AREAS

The following criteria were used to assess the extent of agricultural nonpoint source problems throughout the U.S. Great Lakes Basin:

1. Row crops grown within the PCA, especially those on fine-textured soils, were assumed to be a significant source of sediment and nutrients entering the Great Lakes.

2. Areas having rotations limited to close grown crops, hay, and pasture were assumed to have sediment and nutrient losses far less than those having row crops in the rotation.

3. Orchard areas within the PCA were assumed to present a high potential for loadings of toxic materials, specifically lead, copper, and arsenic from past pesticide application.

4. The use of pesticides was assumed to not represent a significant source of contaminants to the Great Lakes.

5. Fertilizer applications made in accordance with proper soil test results were assumed to not result in excessive contributions of nutrients except as associated with erosion from agricultural operations. Furthermore, it was assumed that the incidence of excessive fertilizer applications will decrease in the future. Therefore, it was assumed that water quality problems associated with agricultural fertilizer use were not significant.

6. Problems associated with contributions of nutrients and organic matter from animal feedlot operations of 100 or more animal units were considered to be significant in terms of their impact on Great Lakes water quality when they are within the potential contributing area.

7. Application of manure to agricultural lands was assumed not to make a significant contribution to Great Lakes water quality problems provided it is incorporated into the soil before it freezes. Manure applied to frozen ground or not incorporated into the soil before the ground freezes was assumed to be significant in terms of its impact on Great Lakes water quality if done within the potential contributing area.

The assumption regarding high yields of toxic contaminants from old orchard areas was based on findings reported in the draft "Preliminary Summary Report of Pilot Watershed Studies" (IJC, 1977b). Because these contaminants are associated with sediment, measures to reduce construction site erosion were assumed to provide adequate control.

The assumption that pesticide use does not present a significant problem was based on two factors. First, the change from persistent organo-chlorine (e.g., DDT, dieldrin, chlordane, and heptachlor) to organophosphates, such as atrazine, which decompose in the environment, has reduced the threat of bioaccumulation in the food chain. Second, State and Federal regulations will, when fully implemented, provide users, including individual farm operators, with training in the proper application and potential hazards of pesticides. Increased use of erosion control practices should reduce the movement of pesticides from the land even further.

Detailed studies have indicated that high natural nutrient levels of most soils accounted for most of the nutrient losses from agricultural land. Application of fertilizers and manure does cause some increase in the nutrient loads, but only to a limited degree. Practices which fail to incorporate them into the soil, such as broadcasting of fertilizer without immediate plowdown, magnify their impact. Also, continuous application at levels above those needed for plant growth was found to increase nutrient losses somewhat. Nevertheless, fertilizer and manure applications were found not to be the major cause of nonpoint source nutrient inputs to the lakes (results reported in the draft PLUARG Final Report, dated April 1978). Thus, it was assumed that they were generally not a significant concern requiring specific remedial action. As was the case with pesticides, improved erosion control practices should be sufficient.

ALTERNATIVE REMEDIAL PROGRAM COMPONENTS

Three alternative remedial program components were defined related to control of agricultural erosion:

- Application of Best Management Practices (BMPs) for sediment control to all lands needing treatment throughout the (U.S.) Great Lakes Basin;
- Application of BMPs to all lands needing treatment within the PCA; and
- Application of BMPs only to fine-textured soils within the PCA.

Data used to evaluate Basinwide problems were based on Cropland Needs Inventory figures. Data on the extent of problem areas within the potential contributing area were supplied by the Soil Conservation Service offices in each of the Great Lakes states except Illinois, which did not have a significant amount of cropland in its PCA. These data were organized by county, with further resolution by soil association.* Only medium- and fine-textured soils were included in the analysis.

Best Management Practices are conservation practices recognized as being effective in reducing the delivery of sediment, nutrients and pesticides to waterways, thereby leading to improved water quality. SCS offices in each Basin state (except Illinois) were asked to provide information, including application costs, on recommended BMPs needed to reduce soil losses to the tolerable limit for each soil association of concern. The specific BMPs used varied with each soil association, and have not been included in this report. An example BMP, based on a 100-acre unit, is shown in Table 4. Maintenance costs have not been included in the estimates made in the second part of this report.

* Descriptions and maps of the major soil associations throughout the U.S. Great Lakes Basin have been published by the IJC as a part of the PLUARG Technical Report Series. (IJC, 1976 a-e)

TABLE 4

SAMPLE BEST MANAGEMENT

PRACTICES FOR A 100-ACRE UNIT

PRACTICE	UNIT COST	UNITS NEEDED	ONE-TIME COST ($)	RECURRING COST ($/YEAR)
Diversion	$0.70/Ft	2,000	1,400	
Grassed Waterway	$1.50/Ft	100	150	
Tile Drain	$0.80/Ft	200	160	
Stripcrop	$6.00/Ac	50		300
Contour Farming	$4.00/Ac	50		200
Minimum Till	$4.00/Ac	30		120
Cover Crop	$18.00/Ac	10		180
Terrace	$1.00/Ft	200	200	
Conservation Cropping System	$ 0/Ac	25		0
Total Cost per 100 acres			1,910	800

The practices included in the recommended BMPs were developed primarily to reduce soil erosion to enhance and preserve soil productivity; their effectiveness in reducing water quality problems has not been extensively tested. Several studies have indicated that the delivery ratio, the ratio of gross erosion to sediment actually delivered to drainage ways, can be significantly increased by the application of some management practices. This is primarily because some practices are most efficient in reducing the movement of relatively large size soil particles. The resultant runoff, enriched with fine particles, can move much further than the larger particles. It is also well known that the fine particle size fraction contains most of the particulate bio-available phosphorus. As a result, an erosion control practice which is efficient in reducing gross erosion may be quite inefficient in reducing delivery of phosphorus to the Great Lakes. Considerably more research will be necessary before it can be determined how efficient a management practice is in reducing phosphorus loadings relative to gross erosion.

Another consideration is the cost-effectiveness of a given BMP in terms of the cost per unit area of application per unit of pollutant reduction. The cost must be assessed against the particular pollutant most important to the Great Lakes, i.e. phosphorus. The above discussion of practice efficiency again becomes important. Consider, for example, the installation of grassed waterways. This is a practice designed primarily to abate gully and rill erosion in areas of concentrated runoff. In gully erosion the principal erodant is deep horizon material which is generally low in bio-available phosphorus. Thus, this practice does little to reduce phosphorus pollution to the Great Lakes. At the same time, it is extremely important to the farmer, because it prevents the ruination of his fields by gully formation.

Another example is the installation of parallel terraces with tile outlets (PTOs). The PTO serves the same function as the grassed waterway in eliminating gully erosion, but it serves a function which the grassed waterway cannot; because flow is restricted at the vertical tile outlet, water is ponded behind the berm and phosphorus-bearing sediment settled out. The grassed water does not perform this function. The initial cost of the PTO is higher than that of the waterway, although the long-term cost may be less. More importantly, very little land is taken out of production--only about 50 square feet around the vertical tile, while the entire length of the waterway is out of production. Also, especially important to contour plowing, there is no obstacle to continuous operation of machinery across the slope.

Another management practice which may be of great importance to diffuse source pollution control, but which has previously been considered only as a production enhancement practice, is the installation of underground tile drainage. The pilot watershed studies undertaken in the Maumee and Portage river basins have shown evidence that in areas of flat, poorly drained soil, sediment and nutrient yields may be reduced significantly by the installation of tile drainage. Further, tile drainage reduces moisture levels in imperfectly drained soils and improves the moisture retention capacity of the soil. This factor will cause attenuation of runoff during storms. Peak velocities that cause streambank erosion should also be reduced. Another reason for using tile is that the no-tillage crop management system may be employed on a great many more soil types when tile drainage is employed. Also, the increased production obtained through the use of tile will offset many of the costs of other conservation practices which must be employed. While it is too early to assess how much of an impact tile drainage may have on diffuse source pollution reduction, it is becoming evident that it will be an important BMP for poorly drained high clay watersheds. A low level of cost sharing should be sufficient to increase the installation of tile.

The above discussion demonstrates that more research and demonstration projects will be required to evaluate the use of agricultural erosion control techniques for water quality improvements.

It is important to note that although this analysis does produce cost estimates for each of the three alternative remedial program elements it does not provide estimates of their effectiveness in reducing pollutant inputs to the lakes. The value of using the tolerable loss, which is defined for each soil type based on productivity objectives, as a guide in developing a water quality management program has not been determined. For the purposes of this analysis, however, it has been adopted as the best available measure of success in reducing problems related to crop production.

In addition to the three program components developed for problems related to crop production, two have been included for animal waste management:

- Provision of waste management controls for all feedlot operations of greater than 100 animal units throughout the Basin; and
- Provision of waste management controls only for those feedlot operations of greater than 100 animal units in the potential contributing area.

Information on the number of beef, hog, and poultry operations throughout the basin was obtained from the Inventory of Land Use and Land Use Practices reports prepared as a part of Task B (IJC, 1976a-e). Data on operations within the potential contributing area were supplied by the SCS offices in each state. Cost estimates for waste control systems were also supplied by each SCS office. It was assumed that the ratio of operations with adequate waste controls to the total number of operations in the PCA for a given planning subarea was representative of the ratio for the planning subarea as a whole.

MANAGEMENT CONSIDERATIONS

Technical remedial measures for control of agricultural sources of pollution have been discussed in terms of best management practices. These practices include a variety of specific measures which are directed at reducing the loss of soil from farmland as well as controlling the adverse water quality impacts of feedlots, and fertilizer, animal waste, and pesticide application. To clearly determine the specific practices to be employed at a given location, site-by-site analysis would be required. The question most appropriately discussed in this section is how to organize the management system so that it encourages and assures the adoption of the best suited practices for any given situation by individual farmers. The preferred management approach will likely be one that can maximize the technical expertise available locally to assure effective site-by-site determination of those practices needed, given the unique characteristics of each farm operation.

The following management arrangements could be utilized to assure adequate implementation of appropriate best management practices:

1. Amend state enabling legislation for Soil Conservation Districts (SCDs) to provide for mandatory participation in the conservation plan program for designated high priority areas.

2. Pass state legislation to establish mandatory performance standards respecting soil loss, animal management, fertilizer, and pesticide use.

3. Revise federal fiscal assistance programs to provide for greater cost share to farmers for water quality related practices.

4. Develop an intensified technical assistance and education program utilizing existing capabilities of SCS, Cooperative Extension Service (CES), Agricultural Stabilization and Conservation Service (ASCS), and SCDs.

Mandatory Conservation Plan Participation

The present system whereby technical assistance is offered to cooperators through the soil conservation districts in each county with support of SCS could be augmented to move beyond its present purely voluntary nature. This approach would require passage of legislation to strengthen the present capability of the SCDs in management of pollution from agricultural runoff. This might be done through new state laws mandating that farmers develop land conservation plans for their farms and that the plans be certified by the local SCD. Legislation enacted in 1975 in New York, for example, requires every owner or occupier of agricultural land exceeding 25 acres to apply to their soil and water conservation district for a conservation plan. The same objective might also be accomplished by an amendment to the existing soil conservation district laws to provide the SCDs with land use control authority (presently SCDs have such authority in only two of the basin states--Wisconsin and Illinois). Under either approach, the legislation should make it clear that the plans are to address practices to control or reduce water pollution from agricultural activities.

The conservation plans need not be mandatory for all farms. The heavy technical and administrative workload imposed by requiring all farmers to have certified conservation plans may create an unrealistic management burden on the SCDs and the SCS. Further, it is not clear that water quality problems are so extensive in all portions of the region that a blanket requirement is even necessary.

Therefore, an important component of this approach may be a mechanism for selective application of conservation plan requirements. This could be achieved through designation of "areas of special concern," such as hydrologically active areas, by the SCD. Conservation plans would be mandatory only within such areas. The areas should include only the lands where agricultural losses could obviously designate one or two particular practices as the key to solving problems throughout the district. Either arrangement would allow the SCD to realistically address the priority problems in its jurisdiction. Designations could be made in conjunction with the preparation of SCD annual work programs. There may be serious problems administering such a program, however.

Mandatory State Performance Standards

A state soil erosion control program based on mandatory performance standards might specify maximum allowable soil loss (for example, as derived through the Universal Soil Loss Equation) and other standards associated with feedlot, fertilizer, pesticide, or animal waste management. This approach goes beyond voluntarism but stops short of a program requiring permits for agricultural operations. Farmers might be considered to be in compliance with the standards if they were following an approved conservation plan, but such a plan would not necessarily be a prerequisite for compliance with the standards. Where compliance problems arise, a series of specified enforcement actions would be available to local and state agencies.

Fiscal Incentives Program

A variety of incentives could be implemented to encourage adoption of appropriate practices on a voluntary basis. The present arrangements whereby the county ASCS committees define local priorities for cost sharing of various management practices under the Agricultural Conservation Program (ACP) could be specifically coordinated with approved 208 plans and ongoing 208 planning and water quality monitoring systems. This would provide a feedback mechanism that could change local ACP policy on a county-by-county basis in response to water quality needs. Such a coordination arrangement would assure that the ACP expenditures are directed toward those practices and those geographic areas where the greatest water quality benefits can be realized. Coordination with cost share funding as provided for in Section 35 of the 1977 Clean Water Act should also be effected.

In addition to providing for coordination to assure that ACP funds are channeled most effectively toward solution of water quality problems, the level of financial support for the program should be increased. Current cost share funds available are too limited to provide a sufficient incentive for adoption of BMPs which will limit productivity or impose additional costs on the individual farmer. The present maximum amount that can be paid to any one farmer ($2,500) in a single year is too low to provide a meaningful incentive for individual action with today's high costs and market uncertainties. Provision should be made for ACP increases in the following areas:

1. Total annual dollar amount available to each county committee.

2. Allowable percentage rate of cost share so that rates can be set selectively high for key areas with special water quality problems.

3. Total annual dollar amount that can be made available to an individual farmer in a given year for large capital expenditure practices.

A more active approach to providing fiscal assistance may produce better results. Additional incentives that could be implemented through changes in federal agency policy might involve crop credits, soil bank payments, criteria for eligibility for price support payments or conditions for qualification for Farmers Home Administration loans or loan guarantees. All of these revisions in policies, standards, or criteria should focus on making the receipt of federal benefits contingent upon practice of sound land conservation techniques that will minimize water quality problems. As an alternative, bonus amounts of funds could be provided where such techniques are adopted.

Consideration should also be given to establishing contractual obligations for maintaining best management practices once they are installed. Under such an approach individual farm operators would agree to maintain structural improvements as a condition for further participation in cost sharing programs. The operator would also be liable for reimbursement of capital costs for such improvements if they were not adequately maintained. An example of such an approach is the Great Plains Conservation Program, administered by the Soil Conservation Service. Similar provisions will be included in the Rural Clean Water Program authorized by Section 35 of the 1977 Clean Water Act.

Intensified Voluntary Program

Since many elements of a nonpoint source management program are already in place, this alternative can be implemented with no change in existing institutional arrangements. It requires that county ASCS committees, SCS, SCDs and other involved agencies take advantage of the recent interest in water quality issues and adjust their programs to control agriculturally related pollution. This would involve an intensified program of assistance to farm owners and operators within the Basin and the coordination of SCD high priority conservation goals and interim five-year conservation needs with Great Lakes water quality needs. Additionally, it would require the coordination of those areas designated by each SCD for priority effort with those areas found in the technical analysis to be most in need of improved land management.

ON-SITE WASTE DISPOSAL

POTENTIAL CRITICAL PROBLEM AREAS

Properly installed and maintained septic tank and drainfield systems were considered to be an effective waste disposal system without significant water quality impacts. In some areas, however, malfunctioning septic tank systems have been identified as a source of phosphorus, and to a lesser extent, nitrogen.

Date have previously been reported on the extent of nonsewered housing throughout the basin (IJC, 1976 a-e). Estimated failure rates defined as an abnormally high amount of phosphorus entering the drainage system) for the total number of systems were not inlcuded however and were generally found to lacking throughout the Basin. An assumed rate of 30 percent for the Great Lakes as a whole was included in one report (IJC, 1978), without information on how it was developed.

The only state for which information could be found was Wisconsin. A report prepared by the Wisconsin Department of Natural Resources (WIDNR, 1977) estimated failure rates by county. The average rate for counties in the Lake Superior portion of the state was 40 percent while the Lake Michigan portion averaged 18 percent.

Failure rate estimates used in this analysis are shown in Table 5. They were developed through contact with selected county health offices, Section 208 programs, and others. In general, those contacted had little knowledge of actual numbers of failures due to the many diverse problems in collecting the information. As a result, these estimates represent nothing more than a 'best guess' in most areas and should be interpreted as such.

Estimates of the total number of failing systems in each Basin county were obtained by multiplying the estimated failure rate by the total number of nonsewered households. The number of systems within the potential contributing area was estimated by assuming an even distribution of systems across each county and multiplying the total number by the fraction of the county within the PCA. There was no account taken concerning proximity of the systems to drainage channels or lakes. Planning subarea figures were used to determine the number of urban versus rural systems.

ALTERNATIVE REMEDIAL PROGRAM COMPONENTS

There are a number of alternatives available for use in areas where the standard septic tank-drainfield system is unsuitable. Several are discussed in the remedial measures catalogue prepared as a part of PLUARG (IJC, 1977c). Additional information is available from a number of sources (see for example, NSF, 1977).

While many alternatives are available to the individual, such as aerobic treatment units, biological and incinerating toilets, electro-osmosis, and alternating drain fields, their inclusion in a regionwide analysis such as this would not be appropriate. First, the selection of a particular system is based on a variety of local factors impossible to evaluate at this level. Also, their limited use to date makes cost estimation difficult. Finally, there is some doubt as to whether all alternatives would be acceptable for use throughout the Basin; local and state ordinances may prohibit or discourage the use of some.

TABLE 5

ASSUMED ON-SITE SYSTEM FAILURE RATES

LAKE BASIN	PERCENT	WISCONSIN
Superior	30	(40%)
Michigan	12	(18%)
Huron	10	
Erie	25	
Ontario	60	

TABLE 6

ALTERNATIVES FOR ON-SITE WASTEWATER DISPOSAL PROBLEMS

	C O S T*	
METHOD	CAPITAL	OPERATING
Connection to Central Treatment via Pressurized Sewer	$2,250**	$115/year†
Mound Adsorption Bed	2,600††	35°
Hydrogen Peroxide Regeneration	350°	-

*Costs are dollars per household

**Average of values reported by Kreissl and Bowne in NSF, 1977, and Bounds in EPA, 1977c.

†Reported by both Bowne and Bounds

††Average of values reported by Kreissl and Maurer in NSF, 1977

°Reported by Kreissl in NSF, 1977

For this reason, the consideration of alternatives for on-site waste disposal has been limited to the three shown in Table 6. The first, the use of a presurized sewage collection system, can be applied where centralized treatment is desired. Studies (see NSF, 1977; EPA, 1977c) have shown that such a system can be a cost-effective alternative to gravity-feed sewers where dwelling densities are low or there are severe site limitations (e.g. shallow depth to bedrock, high water table, etc.).

The second alternative, mound systems, involves the construction of a suitable filter bed. It can be applied in almost all situations, including soils with either too low or too high percolation rates, shallow soils, and high water table. Furthermore, its estimated costs are close to the average cost of a wide range of alternatives, including those listed above.

Finally, the third alternative, hydrogen peroxide treatment, is for regeneration of systems which have failed primarily from poor maintenance.

The following equation was used for estimating the cost of correcting on-site waste disposal problems:

$$C = (0.75X + 0.25Y) * PS + (0.25X + 0.75Y) * (0.5M + 0.5R),$$ where

C is the cost of correcting existing problems,

X is the number of failing urban systems

Y is the number of failing rural systems,

PS is the cost of a pressurized collection system, per household,

M is the cost of a mound system, per household, and

R is the cost of regenerating a system.

As the above equation shows, the following assumptions were made:

1. Seventy-five percent of urban area households and 25 percent of rural households with failing systems would be connected to treatment facilities using pressurized systems. The estimated cost does not include the cost of sewer extensions to those households whose systems are not failing.

2. Of the failing systems that remain, half would install mound systems and half would only require hydrogen peroxide regeneration.

These assumptions were made for cost estimation purposes only and were not based on actual data. Given the quality of the data regarding failure rates however, they were sufficient.

Two sets of cost figures were calculated using the estimating function defined above:

- Correction of problems throughout the Great Lakes Basin, and
- Correction of problems only within the potential contributing area.

MANAGEMENT CONSIDERATIONS

Technical measures to correct or prevent pollution from private sewage disposal involve methods that range from assuring or improving the performance of a conventional septic tank-soil absorption system to those that utilize an entirely different technology for waste treatment. The following management approaches are aimed at achieving the same objective (i.e. correction or prevention of problems from private sewage disposal). They do not focus on technology, but rather on legislative/institutional alternatives that would allow the most appropriate technical solution to a given problem.

The approaches discussed in this section include the following:

1. Assure density of private sewage disposal systems does not exceed land capability by:

    1. Use of quota systems;

    2. Use of zoning controls.

2. Require operator permits to assure continuing maintenance of private sewage disposal systems.

3. Establish maintenance districts to carry out required pump-outs, replacements and other maintenance operations for system owners.

4. Establish sewer districts to own and maintain individual systems.

5. Adjust sanitary codes to require more extensive investigation of site conditions prior to permit issuance.

Regulation of Private Sewage Disposal Density Through Permit Quotas

Under this approach health departments would establish quotas for the maximum number of septic tank system permits available in a specifically defined area as a means of assuring that the density of septic tank systems does not exceed a predetermined environmentally safe level. The jurisdiction of the managing agency could be divided into several districts based upon environmental factors relevant to suitability of site location for septic tank systems utilizing soil absorption fields (ST/SAS's). Existing density of septic tank systems and plans for future extension of sewer service would also be taken into account in establishing districts and setting quotas. Districts with soils well suited for ST/SAS's might have permit quotas fixed at high levels to reflect the relatively large number of systems that could be accommodated on those soils without threat of system malfunction or failure. Districts where soils are unsuited for ST/SAS's would be assigned a low quota. When that number of ST/SAS's are installed, the density of septic tank systems would not be great enough to generate significant pollution problems when systems fail or malfunction. Applicants wishing to develop in areas where public sewer services are planned would not be subject to a quota. Applicants proposing to utilize alternative on-site systems without soil absorption fields or surface discharge for which permits would be required would also be exempt from the quota system.

The local health departments would be the lead agencies in managing the permit quota program. Additionally, local units of general purpose government would have a support role through land-use planning, public works planning (through Section 201 facility plans), and zoning policy and actions. Other institutional arrangements would remain essentially unaffected. Under this alternative, health departments would continue to administer their permit issuance programs as before; however, the maximum number of permits available for issuance in a given area would be set by the county or district board of health as appropriate. Owners of existing systems would be issued permits retroactively. Once all permits were issued, proposed new developments would have to do one of the following:

1. Utilize an on-site waste disposal system that does not employ a tank and drain field (provided an alternative system which adequately protects the environment can be identified and approved for use).

2. Utilize a surface discharge system (if allowed by the state) and obtain a proper permit.

3. Obtain a permit from an individual within the district who has abandoned his septic tank system or is converting to other means of disposal.

Local planning, zoning, and public works agencies would be expected to help determine and periodically review the quotas for each district and provide assistance in the initial definition of districts. Since these districts are to be largely based upon intrinsic land suitability for ST/SAS's, additional technical assistance might be available through local soil conservation districts and the regional planning agency.

Regulation of Private Sewage Disposal Density Through Zoning

Density of ST/SAS's can also be controlled through local government zoning authority. This would be implemented through specification of minimum lot sizes for residences where on-site disposal systems are required. As above, the jurisdiction of the local unit of government with zoning authority would be divided into districts based upon environmental factors relevant to suitability of site location for septic tank systems utilizing soil absorption fields. For areas where soils are well suited for the ST/SAS, specified minimum lot sizes need only be large enough to assure provision of adequate distances from lot lines, buildings, streams, and wells, and that space for a second absorption field is available (e.g. 20,000 to 40,000 square feet). For areas where soils are progressively less well-suited for the ST/SAS, the minimum lot sizes would be progressively higher.

The mechanism for implementing these lot size requirements would best be through a set of supplementary district regulations where pre-existing zoning requirements are augmented by special density requirements for on-site systesm.

Require Operator Permits to Assure Continuing Maintenance of Private Systems

Health departments could require owners of private disposal systems to maintain current operational permits for their sewage disposal systems. The permits might incorporate features of the National Pollutant Discharge Elimination System (NPDES) in that required maintenance and system performance standards could be written into the permit. The permits would expire after a fixed period of time (e.g. one or two years) with renewal contingent upon the fulfillment of assigned maintenance tasks. For example, in the case of septic tank systems, renewal might be based upon documentation that the septic tank has been pumped out or that the level of settled solids is sufficiently low to assure proper operation until the next permit renewal. In the case of alternative waste disposal systems with more elaborate management requirements (e.g. recirculating toilets, incinerating toilets), the permit could specify conditions of operation which would assure proper functioning of the system.

Require System Owners Subscribe to a Public Maintenance Program

Under this approach, a public service agency would be established to perform necessary operation and maintenance functions for all on-site systems within its jurisdiction. Specifics of the arrangement could vary considerably. The district would make periodic inspections of existing septic tank systems, remove accumulated settled solids, and carry out other maintenance requirements as necessary. These maintenance functions could include installation of new absorption fields, curtain drains, or complete replacement of existing systems with suitable alternatives. In the case of system failures where no alternative on-site treatment systems are found to be feasible, the district might install recirculating systems with holding tanks and provide regular pumping of wastes as a public service. Provision of pump and haul services would have to be conditional upon availability of adequate disposal facilities at nearby sewage treatment plants.

Establish Sewer Districts to Own and Maintain Individual Systems

This approach is a variation of that discussed above. The major difference is that under this alternative, the on-site systems would be owned by the maintenance district. The discussion above is fully applicable to this alternative. Management arrangements differ for this alternative in that the maintenance district would be completely involved in all management functions. Under the above alternative, the district would be limited to operation and maintenance activities. As the owner of on-site systems, the district would be in a position to be a full partner in planning, policy setting, and coordination for providing waste treatment services in rural areas. The district would be capable of providing the most suitable waste treatment system for any area within its jurisdiction whether it be individual septic tanks, decentralized package plants, ST/SAS's serving small clusters of residences, or traditional centralized sewage collection and treatment systems. That is, for areas that become sufficiently urbanized to justify provision of services, the district may become the wastewater treatment agency by direct provision of services or through contract with other agencies.

The major, additional advantage of public ownership of on-site systems is greater flexibility. First, the district has the complete discretion to install the alternative system which will perform most effectively in the event of a total failure of an ST/SAS. Also under this arrangement, waste treatment systems can be installed in homes which currently have no treatment at all.

More importantly, this arrangement provides for an even distribution of cost burdens where failures do occur. In the case of the previous alternative, homeowners may resist some district recommendations to avoid high user charges. With public ownership of the systems, the user would pay a standard fee regardless of the specific solution needed to correct water pollution problems. Costs of providing adequate sewage treatment would be distributed over the entire community.

Another significant advantage of the alternative is that federal financial assistance through the facility construction grant program (under Section 201 of PL 92-500) could be obtained to further reduce an individual's costs for system replacement. 1977 Amendments to the Clean Water Act now make on-site systems eligible for a 75 percent grant assistance if the systems are publicly owned.

Adjust Sanitary Codes to Require More Extensive Site Analysis Prior to Permit Issuance

More extensive soil investigation requirements can be most directly implemented by adjustments in policy and administrative procedures of local or state health departments. Existing codes and health department rules and regulations generally only address soil percolation rates in the context of absorption field square footage requirements.

OTHER LAND USE ACTIVITIES

The preceding section highlighted the procedures used to identify problems and evaluate alternative remedial program costs for the activities considered to have a significant impact on the Great Lakes. This section presents a brief discussion of management considerations related to land use activities which do not make a substantial contribution to Great Lakes problems, although they may cause significant local problems now and in the future.

SOLID, LIQUID, AND DEEPWELL DISPOSAL

Solid and liquid waste disposal is a ubiquitous land use activity representing a significant potential for local ground and surface water contamination. The extent to which these local problems impact on the Great Lakes is unclear however. It was the conclusion of Task C investigators that "waste disposal...operations may constitute local problems but are not a significant threat to the total Great Lakes System" (IJC, 1977b).

This is not to say that such activities can be ignored however. Although there are regulatory programs controlling waste disposal operations of all types, there is a continuing need to ensure that proper design criteria and maintenance practices are followed. Furthermore, the existence of many closed disposal sites represents a significant potential for future problems.

In developing a program to control pollution from solid waste disposal sites there are a number of alternative remedial approaches available (see for example, IJC, 1977c). Most of these measures rely on restricting the movement of ground and surface water around the disposal site to reduce the movement of contaminants in solution. This can be done by rerouting the flow of water around the site or by providing a flow barrier so that contaminated water cannot enter or leave the site.

Full implementation of the Federal Resource Conservation and Recovery Act (RCRA) will bring about changes in the solid waste management programs of several states. Therefore, present variability from one state to another regarding effectiveness and extent of different program elements is not of major long-term significance. Major elements that RCRA will require states to address are elimination of open dumping, operation of landfills and control of hazardous waste disposal.

All states in the Basin operate regulatory programs which require the licensing of disposal sites, the operators of such sites and public and private solid waste haulers. Monitoring of ground and surface water quality for leachate contamination is not a component of regulatory programs in all states but in many instances it can be required. Programs in several states require submission of local solid waste management plans. All states are working toward the closing of active open dumps so that all local disposal operations utilize sanitary landfills or other approved methods.

FORESTED AREAS

Because forestry operations were not considered to have a significant impact on Great Lakes water quality, technical measures and associated costs were not developed for them. There are however several measures which form the basis for good forest management and timber harvesting practices. These are briefly discussed below (from IJC, 1974).

Most water quality problems associated with forestry are related to harvesting operations, specifically from skidding and road construction. Careful planning can reduce logging and skid trail area by up to 40 percent. Planning can also reduce excessive gradients and cuts for trails and roads. The provision of adequate drainage along roads is important to prevent erosion. Also, roads should not cross streambeds unless bridges or closed culverts are provided. Finally, the provision of undisturbed buffer strips along watercourses helps to prevent excessive sedimentation.

Timber stand management practices can also have an impact on local water quality. Careful timing and control of drift in the application of pesticides and fertilizers will prevent problems with their use. Use of prescribed burning for brush control or slash removal should include a consideration of possible water quality impacts. Also, stand thinning operations should be carried out in such a manner as to reduce the potential for erosion and sedimentation from heavy equipment use. Finally, grazing intensity and location should be carefully controlled to retain an adequate plant cover and protect the soil near streambanks and the lakeshore.

Erosion control is taken into consideration when designing a timber sale on national forest land. Transportation systems are planned in advance of proposed timber sales. Both permanent and temporary road systems needed to log the sale are reviewed by an engineer, hydrologist, soil scientist, and/or forester. Once the sale is made, there are various timber sale contract clauses that are designed to protect the resource and prevent any resource damage. The U.S. Forest Service identifies areas where harvesting may be unacceptable such as steep topography. These lands are classified as marginal.

Great Lakes states have mechanisms similar to that of the Forest Service with respect to state agency management of state forest land. Legislative arrangements for control of private forest practices on private land are quite limited. These statutes do not provide for mandatory control of private actions. Rather where they do exist they focus on incentives to promote forestry or regulations to prevent adverse impacts of harvesting on neighboring lands (e.g. slash disposal regulations).

EXTRACTIVE AREAS

In general, extractive operations related to the production of sand and gravel, dimension stone, crushed stone, and metallic ores do not have a direct significant continuing impact on Great Lakes water quality. Exceptions include areas, especially those along the shoreline, where mine tailings and processing wastes have been disposed of and associated water quality problems demonstrated. There may also be problems related to the atmospheric transport and subsequent deposition of particulate material on the potential contributing area.

The only extractive activity potentially creating diffuse source problems in the Great Lakes is oil and gas drilling. The disposal of waste brines, either on the surface using diked disposal ponds, or by subsurface injection may create local problems if they occur near any of the Great Lakes. Also, the migration of brines into fresh water aquifers via improperly plugged old wells could create problems.

As is the case with any waste disposal problem, the most effective solution is to prevent problems from occurring by careful preplanning of disposal operations, proper equipment maintenance and personnel training, and monitoring of the disposal site. Clear guidelines concerning the suitability of sites to accept waste brines, the rate at which they can be applied, and other factors would also prevent future problems.

Amelioration of problems caused by past drilling operations is complicated by the fact that the extent of the problem is unknown and, action is only taken after a problem develops. Once a problem does become apparent there should be quick action taken to plug the offending well.

Because there are no apparent Great Lakes water quality problems arising from oil and gas drilling, no program components have been developed. Cost estimates for programs to prevent future problems through better drilling and disposal practices and improved regulation are not known. Cost estimates for plugging abandoned wells range from $1,500 to $14,000 per well (EPA, 1973).

TRANSPORTATION AND UTILITY CORRIDORS

Problems related to transportation and utility corridors are limited to erosion and sedimentation during construction phases, the application of pesticides, and in the case of major transportation facilities, the application of deicing compounds. Those problems related to construction are best controlled by the same mechanism as urban construction in general. Numerous techniques are available to reduce construction site erosion (many are described in IJC, 1977c). There should also be attention given to stabilizing steep slopes, cuts, and shoulders after construction has been completed.

The application of pesticides, especially herbicides to control unwanted vegetation, is not expected to be a significant water quality concern as existing laws and regulations should reduce the incidence of misuse of these chemicals.

Road salt applications are the major source of chloride inputs to the Great Lakes (IJC, 1978a). However, except in a few local areas, there are no problems related to elevated chloride levels in the Lakes at present and projected levels are well below drinking water standards (IJC, 1978b). While it may be true that there are not any Great Lakes problems related to salt use on roads, however, local jurisdictions may want to consider possible impacts on local water quality.

RECREATION AREAS

Problems related to recreation activities are slight, generally limited to inadequate on-site wastewater disposal facilities and erosion caused by intensive use. The correction of these problems is related to a much larger problem than water quality, that of providing adequate recreation facilities to an expanding population. Solutions are tied to the acquisition and development of new sites and improved management in existing areas. Correction of situations causing water quality problems can be carried out through existing programs and would represent a very small fraction of the recreation program budget throughout the Basin. Thus, costs for them were not included in this analysis.

Another problem related to recreation is the intensive development of seasonal homes which may have improperly functioning disposal systems. Costs for correcting these problems have been included with on-site disposal in general.

LAKESHORE AND RIVERBANK EROSION

Because lakeshore erosion is not considered to cause significant open lake water quality problems, costs for controls have not been included. It can be expected however that other programs for erosion control will continue to reduce whatever impact lakeshore erosion does have.

Costs for possible streambank erosion control in the Great Lakes Basin have been estimated elsewhere and will not be repeated here (IJC, 1977d).

SHORELINE LANDFILLING ACTIVITIES

The two principal activities of concern are the disposal of polluted dredge spoil and the disposal of solid industrial waste along the shoreline. Problems in the latter class are very limited in extent and the magnitude of the problem related to them unknown. Also, because there are control programs carried out at the state and federal levels requiring disposal permits and an assessment of potential environmental impacts (see program description in IJC, 1978c Joint Summary Report), it is not anticipated that severe problems will develop in the future. Costs for alternative waste disposal practices have not been developed.

The disposal of polluted dredge spoil may have a significant impact on water quality if carried out improperly (IJC, 1974). Because there are projects underway to provide confined disposal facilities for polluted dredge spoil, cost estimates for this activity have not been included.

ALTERNATIVE CONTROL STRATEGIES

Out of the nine land use activity categories defined by PLUARG, remedial control program components have been defined only for the following:

- Urban Areas
  - Stormwater runoff and combined sewer overflows
  - Construction site runoff
- Agricultural Areas
  - Tillage operations
  - Animal waste control
- On-site waste disposal

The remaining activities were not considered to present a significant water quality threat to the Great Lakes. Because of the inherent coarseness or "grain" in regionwide cost estimation for what are essentially very local or site-specific problems it was felt that costs for many of these other activities would not have a significant effect on the estimates in any case. Thus, the ranges calculated based on the above activities probably would not change significantly if the other activities could be factored in.

This section outlines a series of alternative control strategies, defined earlier as a set of program components representing decisions on the allocation of remedial program resources based on their geographic extent, estimated effectiveness, and/or relation to observed Great Lakes water quality problems. Four strategies were defined and are summarized in Table 7. This display format has been used in Chapter 8 to show the costs of each strategy for the Great Lakes Basin.

TABLE 7

ALTERNATIVE REMEDIAL STRATEGIES

		URBAN							AGRICULTURE					ONSITE		TOTAL
									CROPLAND			FEEDLOTS				
		LOW	MED	HIGH	CLR 1	CLR 2	SED	POND	BASIN	PCA	FINE	BASIN	PCA	BASIN	PCA	
I. Basin Treatment	A	X[a]					X	X	X			X		X		
	B		X[a]		X		X	X	X			X		X		
	C			X[a]		X	X	X	X			X		X		
II. Treatment Only in the PCA	A	X					X	X		X			X		X	
	B		X		X		X	X		X			X		X	
	C			X		X	X	X		X			X		X	
III. Treatment Priorities Based on Contribution Index	High	X					X	X		X			X		X	
	Medium						X	X		X						
	Low						X				X					
IV. Treatment Priorities Based on Local Nearshore Water Quality	Eutrophic	X					X	X		X			X		X	
	Mesotrophic						X	X		X						
	Oligotrophic						X				X					

[a]Basinwide Estimates

Alternative 1: Basinwide Controls

Basinwide controls represent the maximum cost strategy, based on the assumption that all areas contribute some significant amount of pollution to the lakes and that controls are needed everywhere. It does not recognize differences in water quality between the lakes or the potential contributing area concept. This strategy is not considered to be a realistic alternative but is only included to provide a ceiling cost figure.

As Table 7 shows, there are three subalternatives for this strategy based on the level of urban stormwater control selected. Chlorination of combined sewer overflows is assumed for the medium level alternative, while chlorination of both combined sewer and stormwater runoff is assumed for the high level treatment alternative.

Alternative 2: Controls Within the Potential Contributing Area

The application of remedial measures for all potential critical problem areas within the PCA is a refinement from simply applying controls throughout the Basin. This strategy, based on the assumptions presented earlier, should be as effective as the Basinwide strategy but at a much lower cost. It still shares the problem that it does not recognize the differences between lake basins in terms of problem severity. Thus, while it is an improvement, it still may provide more stringent controls than are necessary to ameliorate lake water quality problems. Nonetheless, it does serve as a useful benchmark against which other strategies can be compared.

Once again, there are three subalternatives based on the level of urban runoff control.

As was mentioned above, the major problems with the first two control strategies is that they do not take into account differences in the control needs between lakes; Lake Erie needs may be more severe than those of Lake Superior, for example. Neither do they consider the differences in cost-effectiveness between controls for different land use activities; controls to reduce agricultural problems may cost less per ton of sediment or phosphorus removed than controls on urban runoff. Thus, only certain control programs may be needed to reduce a problem sufficiently. The two strategies described below take these factors into account in selecting the program components included in each.

Alternative 3: Controls based on Tributary Inputs

This alternative is based on the diffuse pollutant loads delivered by each tributary. In this way, those tributaries with the greatest input, and presumably the greatest impact on the lakes, receive the highest level of controls. Those which do not contribute heavily would be subject to less intensive controls.

The approach used in this analysis was based on the contribution index described earlier. This index is an expression of the unit area load based on the PCA of a given tributary normalized against all other tributaries across the (U.S.) Great Lakes Basin. Tributaries can then be grouped on the basis of their index values. For this analysis the following procedure was used:

1. Contribution indices for suspended sediment, total, and orthophosphorus were calculated for each hydrologic area.

2. Based on these indices, each hydrologic area was put into one of three groups:

   a. high load, if the suspended solids and one of the two phosphorus indices were greater than 2.0;
   b. moderate load, if one or more of the indices was greater than 1.0; and
   c. low load if none of the indices was greater than 1.0.

3. Each river basin group was classified as a high, moderate, or low load area based on the characteristics of its component hydrologic areas.

Although these divisions are somewhat arbitrary they do illustrate the concept. As is shown in Table 7, high level treatment of urban runoff, construction-site sediment controls, PCA-wide agricultural controls and on-site waste improvements were all included in the high load areas. Moderate load area programs were limited to agricultural and construction sediment controls. Finally, the low load areas had improved agricultural practices only on fine-textured soils and construction site controls.

Alternative 4: Nearshore Water Quality

One of the most important factors to consider when developing a pollution control program is the condition of the receiving water; have the waters already been impacted by pollutant inputs or is the program primarily concerned with preventing problems in the future? In the first case, the program must be aimed at reducing existing sources of pollutants and controlling the growth of new sources. The second instance may only require minimal controls on present sources with more stringent controls on new sources.

Although this strategy does provide the strongest controls in the areas with the greatest need, the problem remains as to how those areas are identified. This is especially true when evaluating nonpoint sources of pollution. Two factors make this evaluation difficult. First, it is not possible to easily determine if an observed water quality problem is being caused primarily by point or nonpoint source inputs.* Second, except in certain cases, it is not possible to relate water quality conditions in the lakes to specific activities on the land. Those cases in which such a linkage may be established are in embayments or other areas of restricted circulation. Problems in the open lakes are much more difficult to evaluate because of the complex mixing forces acting on inputs once they enter the water body.

Despite these problems, a strategy was defined in which the level of control was based on the quality of nearshore waters as reflected by their trophic status. Information supplied by the IJC staff on nearshore water quality used in classifying the river basin groups is presented in Chapter 8.

In developing the combination of program components to be applied in each area an objective of water quality improvement was adopted for the eutrophic and mesotrophic areas, while nondegradation was adopted for the oligotrophic waters. The program components included in each group were the same as those used in the alternative based on the contribution indices.

There were areas in the Basin, such as the Apostle Islands complex (hydrologic area 1.1.3), where the principal problems were known to be related to other causes--lakeshore erosion in this case. There were others, such as southern Green Bay, where significant point source inputs were known to occur. They were included in this analysis, however, to provide an estimate of the cost of a nonpoint source approach.

This chapter has outlined a set of procedures for identifying and evaluating nonpoint source problems and remedial programs. The remainder of this report, Chapters 3 through 8, presents the results of their application throughout the Great Lakes Basin.

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*Two points of clarification are needed here. First, there are contaminants which arise primarily from point sources, such as certain industrial wastes, and may be identified as such. Second, if there are both point and nonpoint source inputs of a particular pollutant, in this example phosphorus, entering a eutrophic water body, they cannot be viewed as separate sources, one of which is causing the problem. Rather, the total input must be evaluated and controls instituted at the source for which the most cost-effective reduction can be had. The problem then becomes one of determining which source to control first. This does not take into account regulatory requirements in which even minor point sources will be controlled before major nonpoint sources.

3 LAKE SUPERIOR BASIN

LAKE BASIN SUMMARY

BASIN DESCRIPTION

The United States portion of the Lake Superior basin covers almost 44,000 square kilometers (16,985 square miles). Approximately 46 percent of the area is located in Michigan, 36 percent in Minnesota, and the remaining 18 percent in Wisconsin. The Lake Superior basin is divided into two river basin groups: River Basin Group 1.1, which lies almost entirely in Minnesota and Wisconsin; and River Basin Group 1.2, which includes the Lake Superior drainage of Michigan. Figure 2 is a map of the Lake Superior drainage basin.

The Lake Superior basin is typified by either low rounded hills with deep cut valleys, or level to gently undulating plains. Exceptions occur in Michigan's Huron and Porcupine mountains, the ridges of the Keweenaw Peninsula, and the steep slopes northeast of Duluth.

The soils in the western portion of the basin are poorly drained while those in Michigan and northeastern Wisconsin, composed of sandy loams, sandy clays, and sandy clay loam are better drained. Forests cover 90 percent of the land, while agricultural areas account for three percent. Hardwood stands of beech, birch, maple, and aspen typify the Michigan-Wisconsin areas while hardwood and softwood mixes characterize the Minnesota portion. The most important agricultural products are potatoes, clover seed, and dairy products.

Mineral production, economically significant in this region, includes clay, iron ore, peat, sand and gravel, silver, copper, and crushed stone.

The population density is a low 12 people per square kilometer (31 per square mile). The estimated 1975 population of the basin counties was 541,000 people, an increase of about two percent from the 1970 level of 529,500 people. Three counties - St. Louis County, Minnesota; Douglas County, Wisconsin; and Marquette County, Michigan - account for approximately 61 percent of the total population.

Water quality is generally excellent throughout the basin, although some localized areas such as the lower St. Louis River and St. Louis Bay experience water quality problems from both municipal and industrial wastewater sources. Shoreline and streambank erosion in the Wisconsin and parts of the Michigan portion of the drainage basin also create problems.

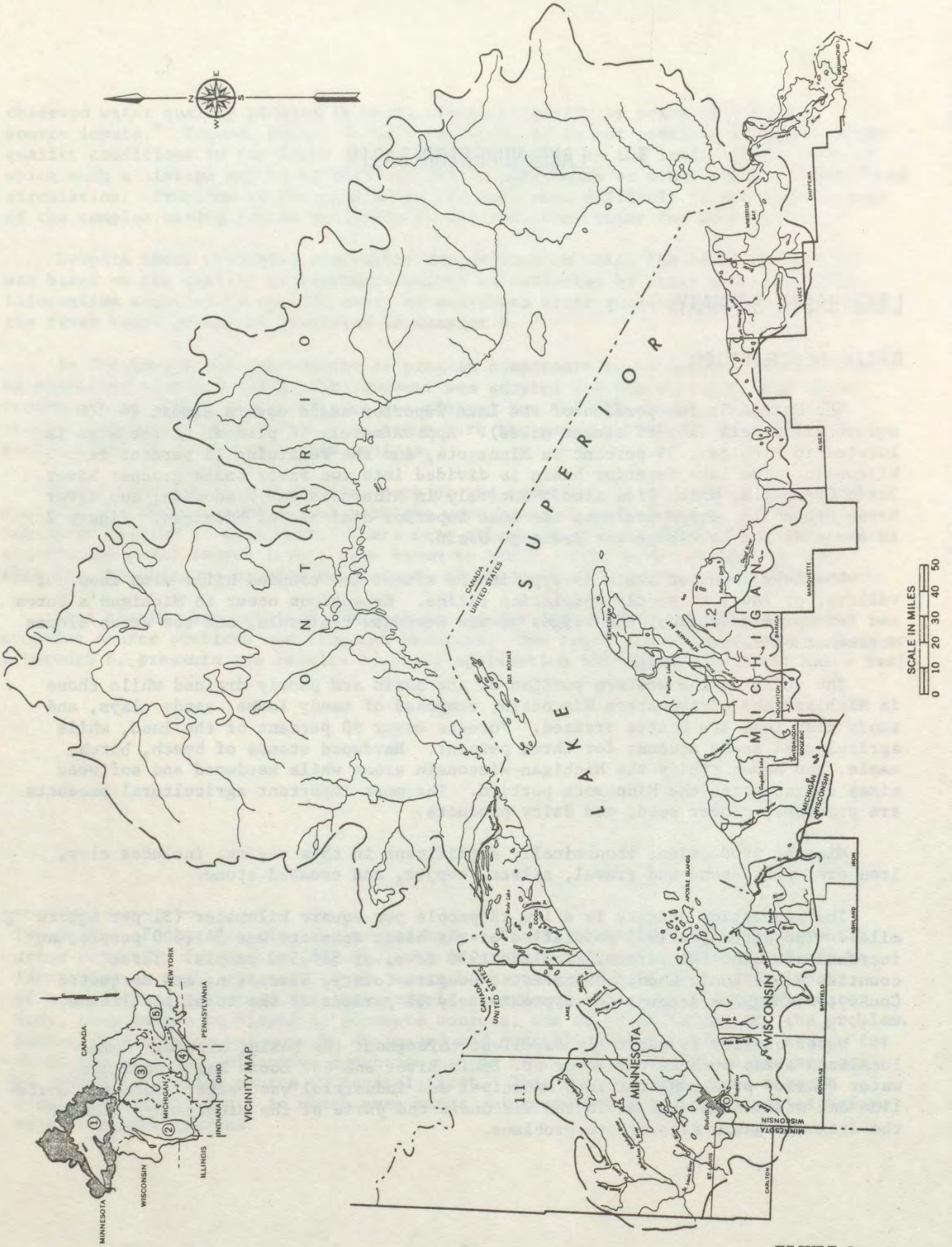


FIGURE 2

LAKE SUPERIOR BASIN

PROBLEM AREA SUMMARY

The estimated potential contributing area of Lake Superior totals 14,350 square kilometers (5,510 square miles), or slightly less than one-third of the total lake basin area. Most of this potential contributing area is located in the western half of the basin.

An assessment of diffuse tributary sediment and phosphorus loadings to the lake has identified the following areas as having a significant input of one or both of those contaminants: the St. Louis, Bad, and Ontonagon River basins, and the Apostle Islands and Huron Mountains complexes.

The following potential critical problem areas and associated remedial costs were identified on the basis of land use activities.

URBAN AREAS

There are 14 urban areas with a total population of 366,025 covering 130,506 acres in the potential contributing area of Lake Superior. An annual growth rate of 0.1 percent was assumed for cost estimation purposes.

Average annual costs for combined sewer and stormwater treatment for those cities in the potential contributing area range from $2.3 million to $8.9 million per year. Chlorination would add up to $300 thousand per year. Control costs for all basin urban areas with more than 2,500 persons range from $6.6 million to $25.8 million per year.

Construction sediment controls for those cities in the potential contributing area were estimated at $48 thousand annually. The annual cost for all the basin's urban areas would be $95 thousand.

AGRICULTURAL AREAS

Although agriculture is not a significant land use here, about 33 thousand hectares (80 thousand acres) out of a total 72 thousand hectares (177 thousand acres) of cropland in the potential contributing area need erosion control measures. Best management practices would require a one-time investment of $3.7 million and recurring expenses of $2.5 million for an average annual cost of $2.9 million. Limiting these practices to only the fine-textured soils would cost $3.5 million one-time and $2.5 million recurring. There would not be a significant change in terms of the average annual cost. The application of BMPs to all basin cropland needing these measures would cost $13.5 million one-time and $9.1 million recurring, for an average annual cost of $10.6 million.

Sixteen cattle feedlot operations in the potential contributing area are without adequate waste control. Installation of waste management systems in the potential contributing area would cost $200 thousand, while the cost for installation throughout the lake basin would be $900 thousand.

ON-SITE WASTE DISPOSAL

Improperly installed and/or maintained septic systems, particularly in the Duluth, Minnesota area and in the eastern portion of Michigan's upper peninsula have resulted in localized water quality problems. It was estimated that 3,960 septic tanks are failing in the potential contributing area and, thus, may have an impact on Lake Superior. The average annual cost to remedy these failures would total $0.9 million, with capital costs of $6.7 million and annual operating expenses of $180 thousand. For all failures in the lake basin, remedial measures were estimated to be $30.5 million capital and $823 thousand operating for an average annual cost of $4.2 million.

The costs for urban, agricultural, and on-site waste disposal remedial measures are summarized in Table 8.

OTHER PROBLEMS

Other problems in the basin include lakeshore and riverbank erosion in the red clay areas of western Lake Superior and mine tailings disposal areas throughout the region.

TABLE 8

COST SUMMARY

FOR LAKE SUPERIOR

PRACTICE	CAPITAL COST ($ millions)	OPERATION, MAINTENANCE AND RECURRING COST ($ millions)	AVERAGE ANNUAL COST* ($ millions)
Urban Areas			
Low Level Treatment	15.3	0.6	2.3
Medium Level Treatment	40.8	1.0	5.5
High Level Treatment	58.8	1.9	8.4
Chlorination -			
Combined only	0.3	<0.05	<0.1
Both	2.4	<0.05	0.3
Sediment Controls	-	0.05	<0.1
Detention Ponds	-	-	-
Agricultural Areas			
Best Management Practices:			
All Soils	3.7	2.5	2.9
Fine Soils	3.5	2.5	2.9
Animal Waste Controls	0.2	-	<0.1
On-Site Waste Disposal	6.7	0.2	0.9

* Average annual costs are the sum of capital costs amortized over 25 years at 10 percent interest per year, plus annual operation, maintenance and recurring costs.

RIVER BASIN GROUP 1.1

DESCRIPTION

River Basin Group 1.1, located in the northwest portion of the Great Lakes Basin, drains over 23,900 square kilometers (9,200 square miles) of Minnesota, Wisconsin, and Michigan land bordering the western shores of Lake Superior. As is shown in Figure 3, the corresponding planning subarea includes four counties in northeastern Minnesota, and four counties in northwestern Wisconsin. The RBG is divided into five hydrologic areas: Superior Slope, St. Louis River, Apostle Islands, Bad River, and Montreal River.

The bedrock geology of the region includes rocks of Precambrian age which are now buried under Cretaceous sediments and/or glacial debris.

As Figure 4 shows, the northern part of the region is rocky and stoney with soils deep to shallow over bedrock. A relatively shallow strip along Lake Superior is nearly level to sloping lake plain. Soils are predominantly loams, sandy loams, and silt loams, developed from glacial deposits. A band of clay extends along the lakeshore in Minnesota. East of Duluth and extending to the Wisconsin-Michigan border is a region of highly erodible red-brown clays and silty clays; erosion rates in this area are among the highest in the Lake Superior basin. Erodibility is generally moderate to high throughout the region, although the forest cover prevents serious erosion problems in most areas.

RBG 1.1, with more than 16,000 kilometers (10,000 miles) of streams, has a mean stream density of approximately 0.7 kilometer of stream per square kilometer (1.1 mile per square mile). The major rivers are the St. Louis River in Minnesota, and the Bad River in Wisconsin. Low flow characteristics vary throughout the region depending on soil characteristics. Rivers that drain sand and loam areas are sustained during droughts by substantial contributions of ground water. Rivers draining the clay areas, however, flood quickly during rainy periods but have minimal flows during droughts. Large amounts of suspended sediments and chemical constituents are contributed to Lake Superior from the clay areas.

Most of RBG 1.1 is undeveloped. Forests cover almost nine-tenths of the area while four percent is used for crop and pastureland. Less than one percent is urbanized. Table 9 shows the major land cover in each of the five hydrologic areas in RBG 1.1.

The area has experienced a relatively stable population in recent years increasing only from about 336,000 persons in 1940 to 345,000 in 1970. Approximately 63 percent of the population lived in urban areas in 1970. Important urban areas include (1975 population estimates): Duluth, Minnesota (pop.: 103,739); Superior, (pop.: 30,038), Ashland (pop.: 9,398), and Hurley, Wisconsin (pop.: 2,418); and Ironwood, Michigan (pop.: 8,561). Total employment in 1970 was 122,000, which is slightly more than the 1960 level. Employment in agriculture, fisheries, and forestry has declined drastically, with the 1970 level less than one-fifth of the

FIGURE 3

PLANNING SUBAREA 1.1

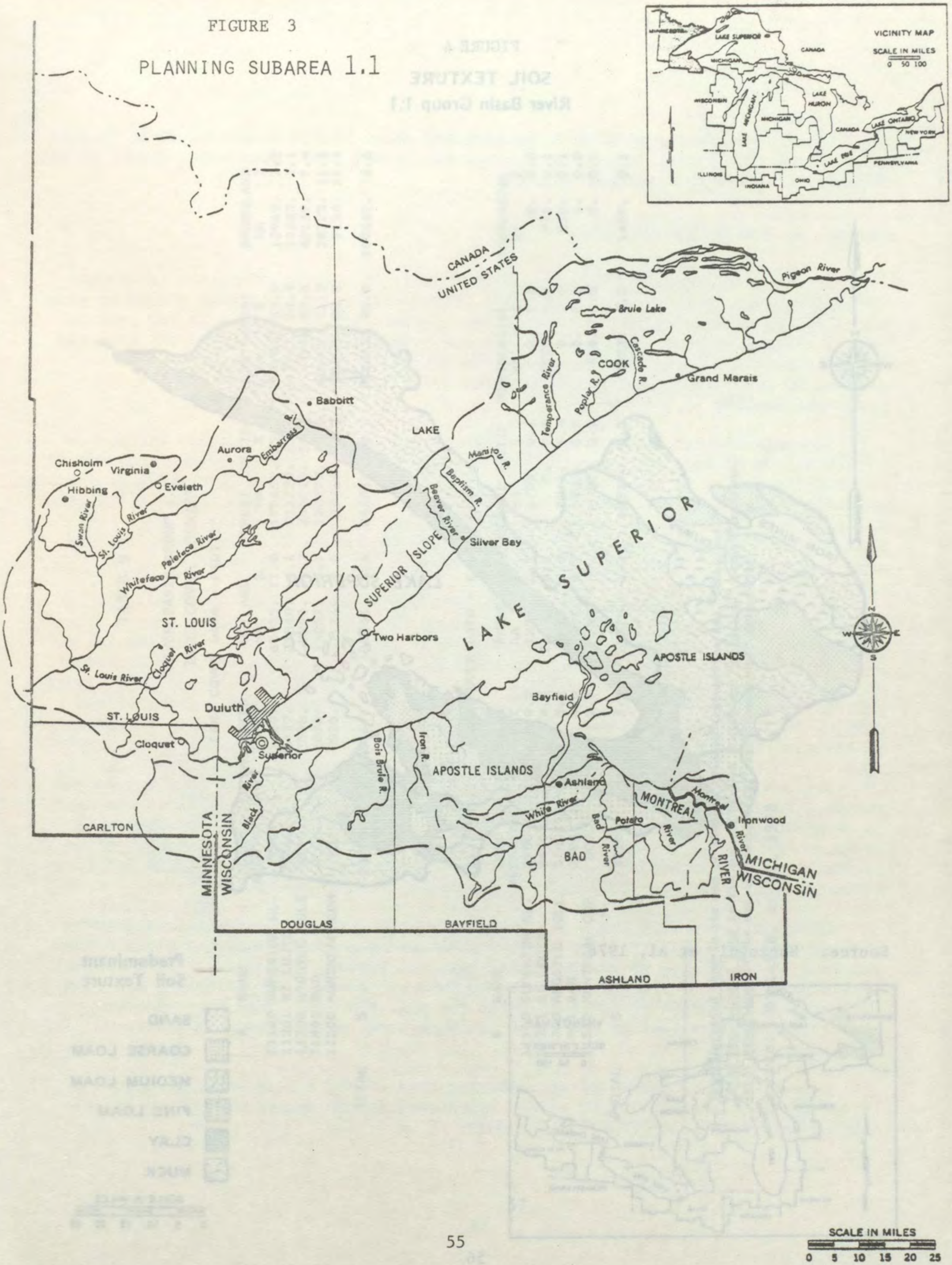
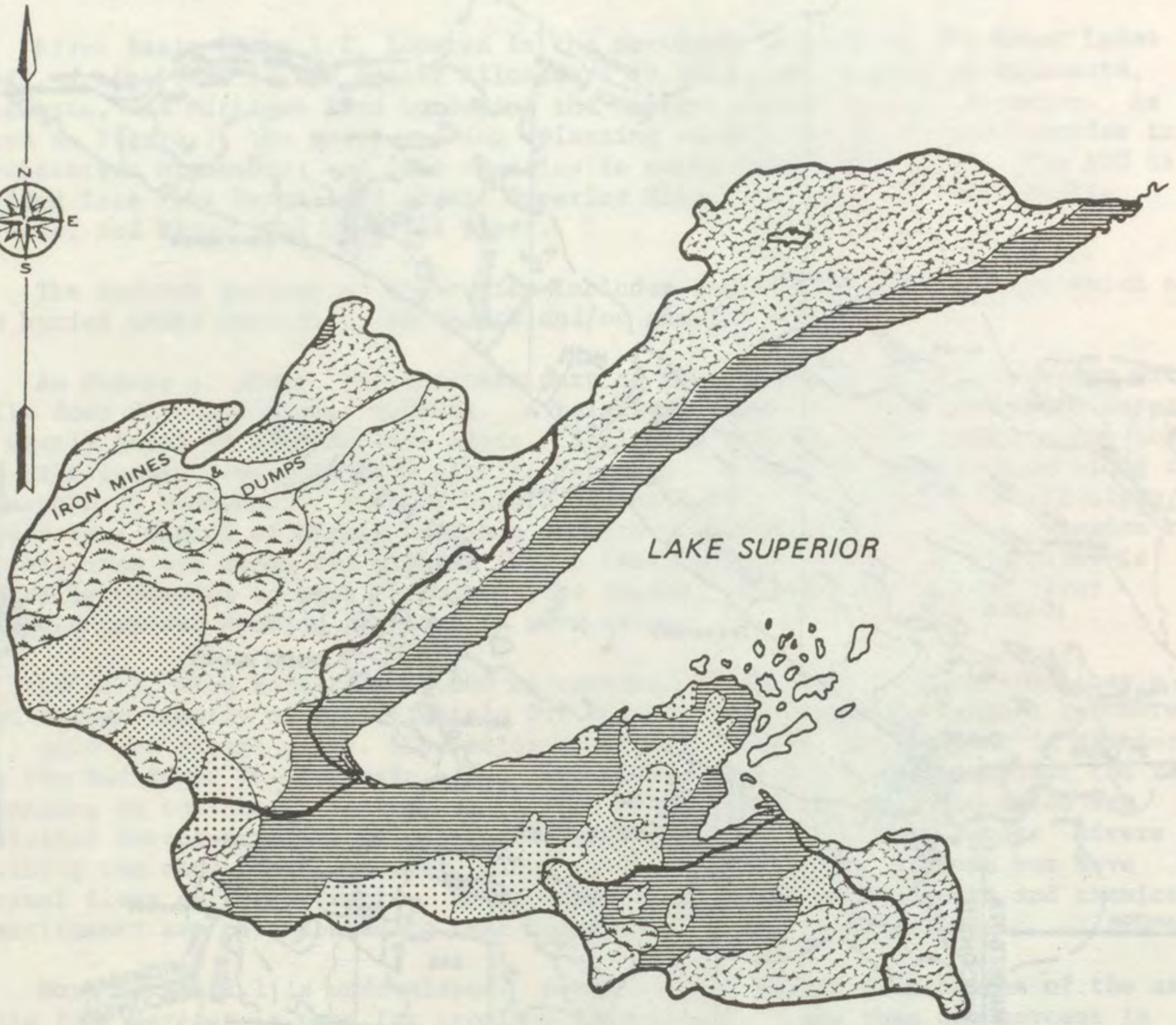


FIGURE 4

SOIL TEXTURE

River Basin Group 1.1



Source: Sonzogni, et al, 1978

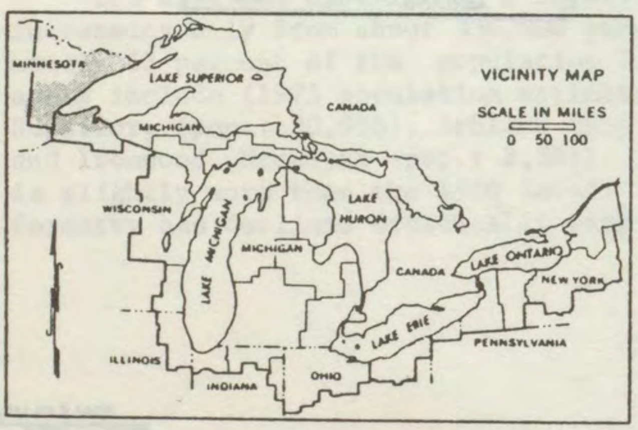


TABLE 9

RIVER BASIN GROUP 1.1

LAND COVER SUMMARY

LAND COVER DATA - PART 1

#	NAME	LAND AREA:KM2	INLAND WATER HA	WETLAND HA	%	FOREST (DECID) HA	%	FOREST (CON) HA	%	BRUSHLAND HA	%
11100	SUPERIOR SL.	5950.	21420.	65425.	11.0	195659.	32.9	314782.	52.9	12962.	2.2
11201	ST LOUIS	9440.	26432.	38848.	4.1	211720.	22.4	607967.	64.4	10683.	1.1
11300	APOSTLE ISLE	5140.	3598.	8800.	1.7	305915.	59.5	114395.	22.3	48139.	9.4
11401	BAD	2580.	3096.	13057.	5.1	123777.	48.0	80429.	31.2	28725.	11.1
11500	MONTREAL COM	800.	1520.	7176.	9.0	29766.	37.2	31070.	38.8	9134.	11.4
TOTAL	5	23910.	56066.	133306.	5.6	866837.	36.3	1148642.	48.0	109642.	4.6

LAND COVER DATA - PART 2

#	NAME	LAND AREA:KM2	GRASSLAND HA	%	BARREN HA	%	PLOWED FIELD HA	%	RESIDENTIAL HA	%	COMMERCIAL HA	%
11100	SUPERIOR SL.	5950.	1234.	0.2	1234.	0.2	3703.	0.6	0.	0.0	0.	0.0
11201	ST LOUIS	9440.	43704.	4.6	26222.	2.8	0.	0.0	3885.	0.4	971.	0.1
11300	APOSTLE ISLE	5140.	26916.	5.2	2070.	0.4	7247.	1.4	0.	0.0	518.	0.1
11401	BAD	2580.	10445.	4.0	261.	0.1	1306.	0.5	0.	0.0	0.	0.0
11500	MONTREAL COM	800.	2283.	2.9	82.	0.1	82.	0.1	408.	0.5	0.	0.0
TOTAL	5	23910.	84583.	3.5	29870.	1.2	12337.	0.5	4293.	0.2	1489.	0.1

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*Total forested land is the sum of the two "forest" categories and "brushland."
Total agricultural land is the sum of "plowed field" and "grassland" classifications.
Total urban land is the sum of "residential" and "commercial" categories.

Source: Monteith, et al, 1978

1940 level. Manufacturing activities employed about 21,000 people or about 71 percent of the work force. Mining operations employed 11,000, over nine percent of all workers, 11 times the national average.

POTENTIAL CONTRIBUTING AREA

The Superior Slope hydrologic area northeast of Duluth, Minnesota is characterized by relatively rugged topography. Streams draining this area are short with steep gradients and few impoundments. The northern inland portion of the area is poorly drained, however, with many lakes and some wetlands; that area was excluded from the potential contributing area. The potential contributing area of this complex is approximately two-thirds of the total drainage area, or about 4,000 square kilometers (1,550 square miles).

Although the St. Louis River basin covers an area of 9,450 square kilometers (3,630 square miles), the potential contributing area is limited by the presence of several reservoirs in the lower portion of the river. Assuming that these reservoirs maintain a high trap efficiency, land upstream of the Scanlon Dam at river kilometer 40 (rivermile 25) will not contribute contaminants to Lake Superior. Thus, the potential contributing area is about 700 square kilometers (270 square miles) and consists primarily of the Duluth-Superior-Cloquet metropolitan area.

The Apostle Islands complex is much like the Superior Slope in that it is drained by a great many small streams although the gradient is not as steep. The inland portion of this area is characterized by extensive wetlands and many lakes, with an immature drainage system. In addition, the presence of major impoundments or lakes on several of the streams, in particular on the Bois Brule and Iron Rivers, further limits the potential contributing area. Approximately 75 percent of the complex or 3,850 square kilometers (1,500 square miles), was assumed to be potentially contributing.

The drainage pattern of the Bad River is poorly defined with many swamps and marshes, especially near the mouth. However, because much of the soil in the area is erodible clay there is still a significant contribution of sediment from this basin to the lake. It was assumed that the contributing area is limited to those portions covered with erodible clays, approximately one-half of the total Bad River drainage area, or about 1,300 square kilometers (500 square miles).

Although there is a small impoundment located near the mouth, it was assumed that the potential contributing area of the main stem of the Montreal River extends upstream to the cities of Ironwood, Michigan and Hurley, Wisconsin. The potential contributing area of the West Fork of the Montreal was assumed to extend upstream to Montreal, Wisconsin at the outflow of the Gile Flowage. This encompasses approximately 50 percent of the total drainage area, or 400 square kilometers (125 square miles).

In summary, the potential contributing area of RBG 1.1 is shown in Figure 5. It covers approximately 10,000 square kilometers (3,800 square miles), or 40 percent of the RBG.

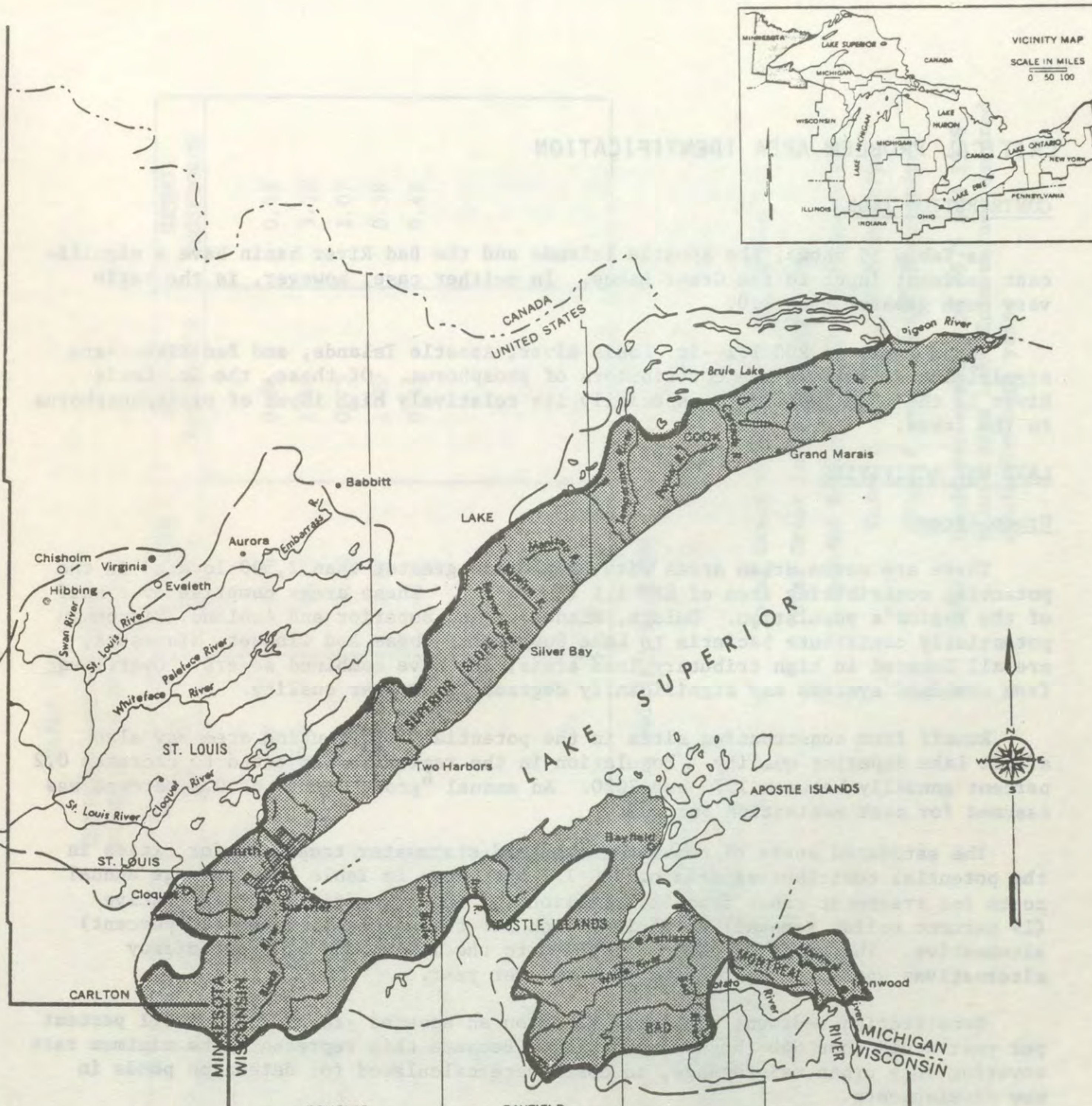
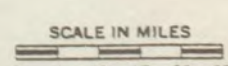


FIGURE 5

POTENTIAL CONTRIBUTING AREA OF RBG 1.1



CRITICAL PROBLEM AREA IDENTIFICATION

CONTRIBUTION INDEX

As Table 10 shows, the Apostle Islands and the Bad River basin have a significant sediment input to the Great Lakes. In neither case, however, is the ratio very much greater than 1.0.

Three areas in RBG 1.1--St. Louis River, Apostle Islands, and Bad River--are significant diffuse source contributors of phosphorus. Of these, the St. Louis River is the most important, especially its relatively high input of orthophosphorus to the lakes.

LAND USE ACTIVITIES

Urban Areas

There are seven urban areas with population greater than 2,500 located in the potential contributing area of RBG 1.1 (Table 11). These areas comprise over half of the region's population. Duluth, Minnesota and Superior and Ashland, Wisconsin potentially contribute bacteria to Lake Superior. These and Cloquet, Minnesota, are all located in high tributary load areas, and have combined sewers. Overflows from combined systems may significantly degrade lake water quality.

Runoff from construction sites in the potential contributing area may also affect Lake Superior quality. Population in the region is projected to decrease 0.2 percent annually between 1970 and 2020. An annual "growth rate" of 0.1 percent was assumed for cost estimation purposes.

The estimated costs of combined sewer and stormwater treatment for cities in the potential contributing area of RBG 1.1 are shown in Table 12. Average annual costs for treatment range from $1.2 million for the low efficiency alternative (19 percent solids removal) to $5.1 million for the high efficiency (83 percent) alternative. The addition of chlorination to the medium and high efficiency alternatives would add up to $300 thousand per year.

Construction sediment controls, based on an assumed growth rate of 0.1 percent per year would cost $40 thousand annually. Because this represents the minimum rate covering only urban maintenance, no costs were calculated for detention ponds in new developments.

Estimated combined sewer and stormwater treatment average annual costs for all urban areas with more than 2,500 persons in RBG 1.1, range from $6.2 to $20.0 million and are shown in Table 13. Chlorination cost estimates were not included. The composite urban area adjustment factor is a weighted average based on the non-urbanized areas of Minnesota, Wisconsin, and Michigan. Construction sediment controls throughout the RBG would cost $70 thousand annually.

TABLE 10

CONTRIBUTION INDICES
RIVER BASIN GROUP 1.1

HYDROLOGIC AREA	LAND AREA (km^2)*	PCA AREA (km^2)*	SUSPENDED SOLIDS	TOTAL PHOSPHORUS	ORTHO PHOSPHORUS
Superior Slope	5,950	4,000	0.15	0.36	0.53
St. Louis River	9,452	700	0.36	1.40	3.55
Apostle Islands	5,140	3,850	1.00	0.73	1.07
Bad River	2,580	1,300	1.07	1.00	0.58
Montreal River	800	400	0.11	0.85	0.48

*To convert square kilometers to square miles, multiply by 0.386

$$CI = \frac{\text{(\% of Great Lakes Diffuse Load) (from hydrologic area)}}{\text{(\% of Great Lakes PCA in) (hydrologic area)}}$$

Total Great Lakes PCA = 105,950 km^2

Total Great Lakes Diffuse Loads

Suspended Solids = 9,492,407 Mtonnes/yr.

Total P = 13,155 Mtonnes/yr.

Ortho P = 3,007 Mtonnes/yr.

NOTE: Loads are average of 1975 and 1976 values with Lake Erie values assured equal for both years

TABLE 11

URBAN AREAS IN THE POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 1.1

URBAN AREA	HYDROLOGIC AREA		POPULATION (1970)	AREA (ACRES*) (1970)
Duluth, MN	St. Louis River	1.1.2	110,438	45,485
Superior, WI	St. Louis River	1.1.2	32,237	25,461
Cloquet, MN	St. Louis River	1.1.2	8,699	2,112
Silver Bay, MN	Superior Slope	1.1.1	3,504	4,159
Two Harbors, MN	Superior Slope	1.1.1	4,437	1,919
Ashland, WI	Apostle Islands	1.1.3	9,615	8,445
Ironwood, MI	Montreal River	1.1.5	8,711	3,710
TOTAL			177,641	91,291
Planning Subarea 1.1			345,155	9,473,500

*To convert acres to hectares, multiply by 0.4047

TABLE 12

URBAN CONTROL SUMMARY FOR RBG 1.1

NUMBER OF URBAN AREAS: 7

LOW LEVEL OF TREATMENT (<30% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.19

CAPITAL COST	: $	7962226.
ANNUAL OPERATING COST	: $	308994.
AVERAGE ANNUAL COST*	: $	1186178.

MEDIUM LEVEL OF TREATMENT (30% TO 60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.53

CAPITAL COST	: $	20766528.
ANNUAL OPERATING COST	: $	564484.
AVERAGE ANNUAL COST*	: $	2852294.

HIGH LEVEL OF TREATMENT (>60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.83

CAPITAL COST	: $	35865920.
ANNUAL OPERATING COST	: $	1199257.
AVERAGE ANNUAL COST*	: $	5150540.

CHLORINATION (MEDIUM AND HIGH LEVEL TREATMENT ONLY)

	COMBINED SEWER ONLY	COMBINED AND STORM SEWERS
CAPITAL:	279295.	2370981.
O&M :	12689.	56444.
ANNUAL*:	43458.	317651.

*Average annual cost equals capital amortized over 25 years at 10 percent interest per year plus annual operation and maintenance cost.

TABLE 13

ESTIMATED COST OF CONTROLS FOR ALL URBAN AREAS, RBG 1.1

TREATMENT LEVEL		COST IN PCA ($ millions)	ADJUSTED AREA IN PCA (ACRES*)	COST PER ACRE ($)	TOTAL URBAN ACREAGE	ADJUSTED** URBAN ACREAGE	TOTAL RBG COST ($ millions)
LOW	Capital	7.96	12,310	650	185,344	48,190	31.3
	O&M	0.31	12,310	25	185,344	48,190	1.2
MEDIUM	Capital	20.77	12,310	1,690	185,344	48,190	81.4
	O&M	0.56	12,310	45	185,344	48,190	2.2
HIGH	Capital	35.87	12,310	2,910	185,344	48,190	140.2
	O&M	1.20	12,310	95	185,344	48,190	4.6

*To convert acres to hectares, multiply by 0.4047

**Composite urban area adjustment factor = 0.26

Average Annual Cost:

Low:	$ 6.2 million
Medium:	11.2 million
High:	20.0 million

Agricultural Areas

There are 56 thousand hectares (139 thousand acres) of cropland within the potential contributing area of RBG 1.1 (Table 14). Forty-eight percent of this cropland, or 27 thousand hectares (66 thousand acres) require treatment. Information from the SCS office in Minnesota indicated that all 3,100 hectares (7,700 acres) of the cropland in that state is presently within allowable soil loss limits; subsequent cost analysis did not include the Minnesota portion of the basin. According to Conservation Needs Inventory data, 96 thousand hectares (237 thousand acres) of cropland in the planning subarea required erosion control in 1968.

The potential contributing area accounts for eight cattle feedlot operations, one swine and one poultry operation (see Table 15). Only two of the cattle feedlots have waste controls, although both of the others do. Based on information in Inventory of Land Use [IJC, 1976a], it was estimated that some 39 cattle feedlots in the planning subarea may not have waste control systems.

Agricultural runoff from this region may have an impact, although minor, on Lake Superior water quality.

Application of best management practices to all moderate and fine-textured soils in the potential contributing area (Wisconsin only) would have a one-time cost of $3.6 million and recurring costs of $2.5 million. The average annual cost is $2.9 million. Costs for BMPs applied only to fine-textured soils (227 thousand hectares) are $3.4 million and $2.5 million one-time and recurring, respectively, and $2.9 million annual. Application of best management practices to all soils in the planning subarea would have a one-time cost of $12.9 million and recurring costs of $9.0 million. The average annual cost is $10.4 million.

The capital cost of installing waste management systems in the potential contributing area was estimated to be $108 thousand; for the planning subarea, it would be approximately $708 thousand. Average annual costs are less than $100 thousand.

On-Site Waste Disposal

Nonsewered nonfarm residences account for 32,180 units or 27 percent of the total housing units in the planning subarea. Of this, 90 percent are in rural areas.

Approximately 8,030 units, or one-quarter of the nonsewered nonfarm residences are located in the potential contributing area (Table 16). Of these, about 35 percent are in the Superior Slope complex and 38 percent in the Apostle Islands area.

Throughout much of this region, soil and groundwater conditions pose severe limitations on the use of on-site disposal systems. The red clay areas of Wisconsin and the north shore area between Duluth and Two Harbors have especially difficult problems. Individual on-site disposal systems in RBG 1.1 are potentially significant contributors to pollution of Lake Superior.

The estimated capital investment required to alleviate problems with failing septic systems within the potential contributing area is $4.8 million, with an

TABLE 14

COSTS FOR INSTALLING AGRICULTURAL BEST MANAGEMENT PRACTICES
IN THE POTENTIAL CONTRIBUTING AREA (PCA) OF RIVER BASIN GROUP 1.1

COUNTY	TOTAL ACRES* IN POTENTIAL CONTRIBUTING AREA	ACRES IN PCA NEEDING TREATMENT	COSTS FOR ALL SOILS ($ millions)		COSTS FOR FINE-TEXTURED SOILS ($ millions)	
			One-Time	Recurring	One-Time	Recurring
MINNESOTA**						
Carlton	15,000	3,000	0	0	0	0
Cook	540	100	0	0	0	0
Lake	7,400	3,400	0	0	0	0
St. Louis	6,000	1,200	0	0	0	0
WISCONSIN						
Ashland	25,525	11,900	1.1	0.2	1.1	0.2
Bayfield	37,500	17,250	0.9	0.9	0.9	0.9
Douglas	41,120	27,047	1.4	1.4	1.4	1.4
Iron	5,700	2,100	0.2	0.03	0.0	0.0
TOTAL	138,785	65,997	3.6	2.5	3.4	2.5

*To convert acres to hectares, multiply by 0.4047

**Soil loss throughout this acreage was within allowable limits as of January 1978.

TABLE 15

COST FOR INSTALLING AGRICULTURAL WASTE MANAGEMENT SYSTEMS
IN POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 1.1

COUNTY	TOTAL NUMBER OF FEEDLOT OPERATIONS >100 ANIMAL UNITS IN PCA			NUMBER OF FEEDLOT OPERATIONS IN PCA NEEDING TREATMENT			TOTAL COST ($ thousands)		
	CATTLE	SWINE	POULTRY	CATTLE	SWINE	POULTRY	CATTLE (at $ * per system)	SWINE (at $ * per system)	POULTRY (at $ * per system)
MINNESOTA									
Carlton	0	0	0	0	0	0	0	0	0
Cook	0	0	0	0	0	0	0	0	0
Lake	1	0	0	1	0	0	8	0	0
St. Louis	1	1	1	0	0	0	0	0	0
WISCONSIN									
Ashland	0	0	0	0	0	0	0	0	0
Bayfield	0	0	0	0	0	0	0	0	0
Douglas	6	0	0	5	0	0	100	0	0
Iron	0	0	0	0	0	0	0	0	0
TOTAL	8	1	1	6	0	0	108	0	0

*MINNESOTA
Cattle $8,000 per system
Swine 5,000 " "
Poultry 5,000 " "

*WISCONSIN
Cattle $20,000 per system
Swine 12,000 per system
Poultry 7,000 per system

TABLE 16

ON-SITE WASTE DISPOSAL, RBG 1.1

COUNTY	TOTAL NUMBER OF SYSTEMS	PERCENT OF COUNTY IN PCA	ESTIMATED NUMBER OF SYSTEMS IN PCA	NUMBER FAILING	CAPITAL COST ($\$X10^6$)	OPERATING COST ($\$X10^3$)	AVERAGE ANNUAL COST ($\$X10^6$)
MINNESOTA							
Carlton	3,278	22	720	220	0.37	10.3	0.05
Cook	724	50	360	110	0.19	5.1	0.02
Lake	1,768	30	530	160	0.27	7.5	0.04
St. Louis	16,256	15	2,440	730	1.25	34.1	0.17
WISCONSIN							
Ashland	1,896	33	630	250	0.43	11.7	0.06
Bayfield	2,922	50	1,460	580	0.99	27.1	0.14
Douglas	4,087	40	1,640	650	1.11	30.4	0.15
Iron	1,249	20	250	100	0.17	4.7	0.02
TOTAL	--	--	8,030	2,800	4.78	130.9	0.65

additional $130 thousand per year in operating and maintenance costs (Table 16). The average annual cost is $650 thousand.

Extrapolating these figures to the entire planning subarea yields an estimated capital cost of $19.2 million and operating costs of $525 thousand per year. The average annual cost is estimated to be $2.6 million.

Other Problems

Of the 533 kilometers (331 miles) of shoreline in RBG 1.1, 190 kilometers (118 miles) are subject to erosion. Especially significant are the red clay bluffs extending from Duluth, Minnesota to Ashland, Wisconsin; 15 percent of the 170 kilometers (105 miles) of this shoreline was classified as being subject to critical erosion by the Upper Great Lakes Regional Commission (described in Seibel, et al, 1976). The eroded red clay is the major source of turbidity problems in southwestern Lake Superior.

Of the 16,448 kilometers (10,220 miles) of riverbanks in the RBG, only five percent is subject to erosion. Of this, 528 kilometers (328 miles) are under moderate erosion stress, and 248 kilometers (154 miles) are experiencing severe erosion. Most of the problems are found in Wisconsin, particularly in the areas of red clay deposits. The contribution is relatively small, amounting to approximately 10 percent of the total sediment load to the lakes from this area. However, the localized significance of this portion should not be overlooked.

Severe erosion, both along the shoreline and along streambanks, as well as resuspension has created water quality problems in the western basin of Lake Superior. Possible impacts on the lake include reduced light penetration, smothering fish spawning beds, fish species changes, reduction of drinking water quality, and a displeasing aesthetic appearance. Problems related to red clay erosion are presently being studied under Section 108 of the Water Pollution Control Act of 1972.

RIVER BASIN GROUP 1.2

DESCRIPTION

River Basin Group 1.2 is located in the northwest portion of the Great Lakes Basin, and encompasses 20,088 square kilometers (7,756 square miles) of Michigan and Wisconsin land bordering the southern shore of Lake Superior (see Figure 6). The corresponding planning subarea consists of eight counties in the northern half of Michigan's upper peninsula. RBG 1.2 is divided into eight hydrologic areas: the Porcupine Mountains complex, Ontonagon River basin, Keweenaw Peninsula complex, Sturgeon River basin, Huron Mountains complex, Grand Marais complex, Tahquamenon River basin, and the Sault complex.

The bedrock of RBG 1.2 is composed of Precambrian, Cambrian, Ordovician, and Silurian formations which yield iron ore, copper, silver, and stone. Overlying the bedrock are unconsolidated glacial and post-glacial sediments of the Quaternary system.

Rock outcrops and soils with fragipan occur within the area. Along Lake Superior from Sault Ste. Marie to the Keweenaw Peninsula is a strip of predominantly coarse-textured soils that developed on lake plains. The rest of the area is level to hilly with some mountainous areas and numerous deposits of organic soils. Soils range from deep to shallow over bedrock. Textures are coarse to fine. Figure 7 shows the predominant soil textures in this RBG.

RBG 1.2 has more than 12,200 kilometers (7,600 miles) of streams. The major rivers are the Ontonagon, Sturgeon, and Tahquemenon. Average stream density is 0.6 kilometers of stream per square kilometer (1.0 miles per square mile).

Over 90 percent of the region is covered by forests, while only about two percent is devoted to agriculture uses. Less than one percent is urban. Table 17 identifies land cover for each hydrologic area in RBG 1.2.

Population has declined slightly in the region over the past 30 years from 196,700 in 1940 to 188,400 in 1970. Of this total, approximately 52 percent lived in urban areas. Important urban areas include (1975 population estimates): Wakefield (pop.: 2,803), Bessemer (pop.: 2,797), Houghton (pop.: 6,904), Hancock (pop.: 4,977), Laurium (pop.: 2,843), Marquette (pop.: 23,078), Ishpeming (pop.: 8,559), Negaunee (pop.: 5,283), Munising (pop.: 3,466), and Newberry (pop.: 2,334). Employment in agriculture has declined recently to approximately two percent of the total labor force (61,000 workers) in 1970. Manufacturing accounts for 11 percent while mining employs approximately 12 percent of the work force (compared to less than one percent for the entire Great Lakes Basin).

POTENTIAL CONTRIBUTING AREA

The Porcupine Mountains hydrologic area has a relatively rugged topography. Streams are short and steep with many rapids and waterfalls. Soils are coarse-

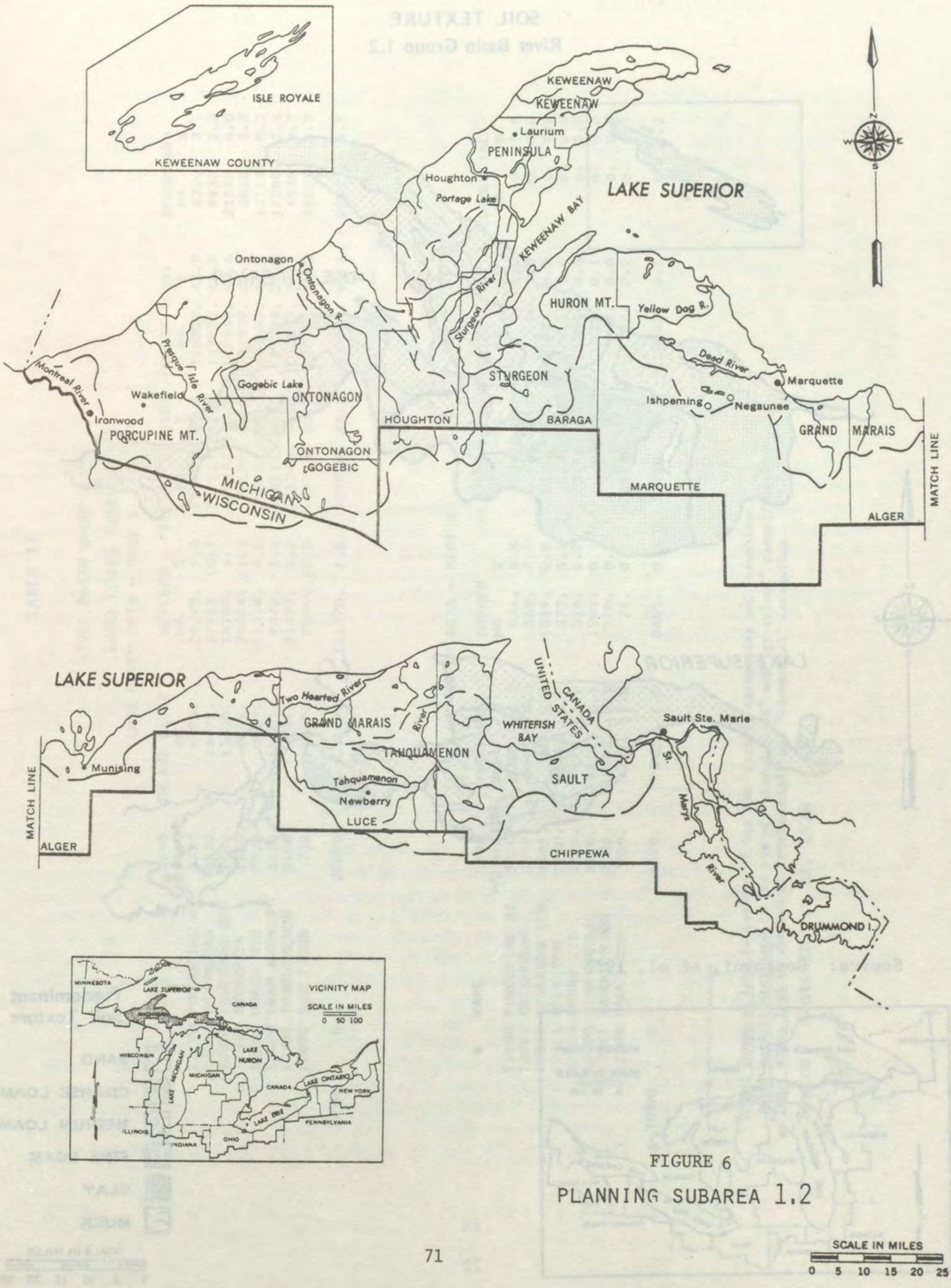


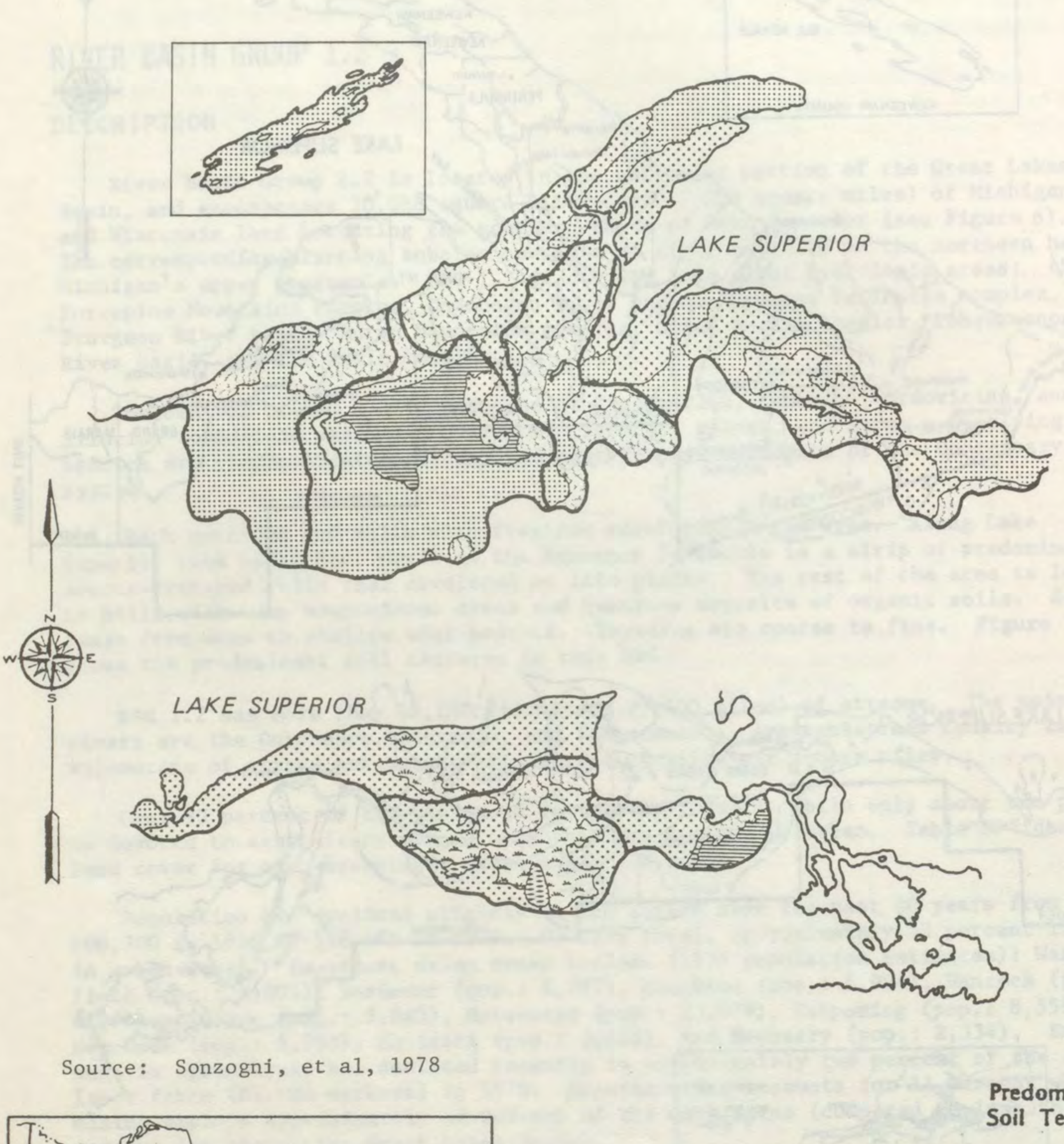
FIGURE 6

PLANNING SUBAREA 1.2

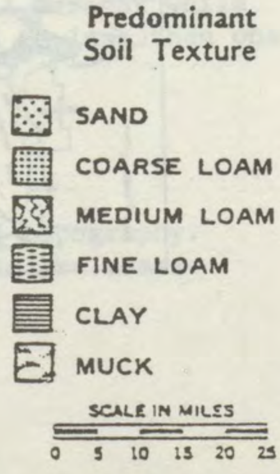
FIGURE 7

SOIL TEXTURE

River Basin Group 1.2



Source: Sonzogni, et al, 1978



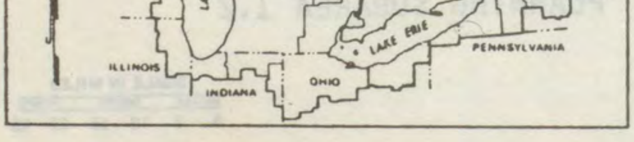


TABLE 17

RIVER BASIN GROUP 1.2

LAND COVER SUMMARY

LAND COVER DATA - PART 1

#	NAME	LAND AREA:KM2	INLAND WATER HA	WETLAND HA	%	FOREST (DECID) HA	%	FOREST (CON) HA	%	BRUSHLAND HA	%
12100	PORCUPINE MT	2720.	4896.	24375.	9.0	117719.	43.3	118827.	43.7	8310.	3.1
12201	ONTONOGAN	3530.	14473.	37913.	10.7	147237.	41.7	147973.	41.9	9938.	2.8
12300	KEWEENAW COM	3500.	13300.	14189.	4.1	160447.	45.8	149168.	42.6	21102.	6.0
12401	STURGEON	1830.	3111.	20664.	11.3	78189.	42.7	69439.	37.9	6888.	3.8
12500	HURON MTS	2520.	5040.	11314.	4.5	115971.	46.0	104657.	41.5	13114.	5.2
12600	GRAD MARAIS	3110.	10885.	9346.	3.0	188211.	60.5	93139.	29.9	11280.	3.6
12701	TAHQUAMENON	2180.	1744.	11427.	5.2	101748.	46.7	102407.	47.0	1538.	0.7
12800	SAULT COM	700.	1120.	7541.	10.8	17713.	25.3	25325.	36.2	10671.	15.2
TOTAL	8	20090.	54569.	136770.	6.8	927236.	46.2	810936.	40.4	82841.	4.1

LAND COVER DATA - PART 2

#	NAME	LAND AREA:KM2	GRASSLAND HA	%	BARREN HA	%	PLOWED FIELD HA	%	RESIDENTIAL HA	%	COMMERCIAL HA	%
12100	PORCUPINE MT	2720.	1385.	0.5	831.	0.3	554.	0.2	0.	0.0	0.	0.0
12201	ONTONOGAN	3530.	2945.	0.8	368.	0.1	6626.	1.9	0.	0.0	0.	0.0
12300	KEWEENAW COM	3500.	0.	0.0	1819.	0.5	2183.	0.6	1091.	0.3	0.	0.0
12401	STURGEON	1830.	5585.	3.1	372.	0.2	1862.	1.0	0.	0.0	0.	0.0
12500	HURON MTS	2520.	4629.	1.8	514.	0.2	514.	0.2	1286.	0.5	0.	0.0
12600	GRAD MARAIS	3110.	7412.	2.4	1289.	0.4	0.	0.0	322.	0.1	0.	0.0
12701	TAHQUAMENON	2180.	659.	0.3	220.	0.1	0.	0.0	0.	0.0	0.	0.0
12800	SAULT COM	700.	7327.	10.5	71.	0.1	1209.	1.7	142.	0.2	0.	0.0
TOTAL	8	20090.	29942.	1.5	5485.	0.3	12948.	0.6	2842.	0.1	0.	0.0

*Total forested land is the sum of the two "forest" categories and "brushland."
Total agricultural land is the sum of "plowed field" and "grassland" classifications.
Total urban land is the sum of "residential" and "commercial" categories.

Source: Monteith, et al, 1978

textured except in that area directly adjacent to Lake Superior. It was assumed that the area with coarse-textured soils does not make a significant contribution of sediment-related contaminants. The potential contributing area is thus confined to a narrow coastal belt of approximately 270 square kilometers (100 square miles) or about 10 percent of the hydrologic area.

The Ontonagon River basin is covered with a large deposit of highly erodible clay in much of its central portion. In addition, a highly erodible sandy loam underlies much of the area near the river mouth. The remainder of the basin is predominantly sandy loam and sand. Flow from the West Branch Ontonagon into the main stem is controlled at Victoria by a dam. As a result it was assumed that no significant contribution is made by that branch. Contributions from the middle and east branches of the Ontonagon were assumed to come from those areas of highly erodible clay and loam. The potential contributing area is about 1,410 square kilometers (540 square miles).

The Keweenaw Peninsula complex, covered with sands and sandy loams, is characterized by very steep rolling topography and many significant wetlands. The area is drained by a great many relatively short, straight streams, some with major impoundments at or near the mouth. The Keweenaw Peninsula is bisected by the Portage River and Portage Lake ship canal. Because the residence time of Torch Lake is approximately one year, it was assumed materials entering the lake would not have an effect on Lake Superior water quality. The only areas within the Keweenaw complex considered to be potentially contributing were the western area, which drains a loamy area, and the Houghton-Hancock urban area. These areas total about 1,050 square kilometers (400 square miles).

The Sturgeon River drains an area covered predominantly by loams of moderate to high erodibility. Topography ranges from flat to rugged with some significant wetland areas. Otter Lake, approximately 10-20 kilometers (6-12 miles) from the river mouth, intercepts all the drainage from the Otter River, a major tributary to the Sturgeon. Because of these factors, it was assumed that the potential contributing area is limited to the drainage area of the west branch and the mainstem of the Sturgeon, and is about 910 square kilometers (350 square miles).

The Huron Mountain complex is covered by sands and loamy sands in roughly equal proportions. The terrain is steep and rolling with several wetlands. Most streams are short with relatively steep gradients except near the lakeshore itself. There are many lakes and impoundments; some are very close to the mouths of the streams. Especially significant is the Dead River storage basin on the Dead River above Marquette. Because of these factors, it was assumed that the potential contributing area in this complex is limited to that area immediately around Marquette, or 130 square kilometers (50 square miles).

The Grand Marais complex is similar, in many respects, to the Huron Mountains complex. Once again, the soils are generally sand and loamy sand although there are some muck soils in the eastern portion. In addition, most of the area is drained by small streams, some with major impoundments near the mouth. As a result, the potential contributing area was assumed to be a minimal one percent of the total area, or 30 square kilometers (10 square miles), plus the Munising area.

The drainage area of Tahquamenon River, predominantly covered with mucks, sands and loamy sands, is generally flat with weakly-defined drainage patterns and many significant wetlands. Because of this, it was assumed that the potential contributing area is only one percent of the area, or 20 square kilometers (10 square miles).

The Sault complex, predominantly covered by sandy soils, is generally flat with poorly-defined drainage patterns. The potential contributing area was limited to the eastern portion of the complex, where clays and loams predominate, and totals about 280 square kilometers (110 square miles).

The potential contributing area of RBG 1.2 is shown in Figure 8. It accounts for approximately 3,000 square kilometers (1,150 square miles) or 15 percent of the RBG.

CRITICAL PROBLEM AREA IDENTIFICATION

CONTRIBUTION INDEX

The contribution index values for RBG 1.2 are shown in Table 18. As these values show, only two hydrologic areas make significant contributions of sediment or phosphorus - the Ontonagon River basin and the Huron Mountains complex. Because their potential contributing areas were assumed to be only one percent of their total areas, index values were not calculated for the Grand Marais or Tahquamenon areas.

LAND USE ACTIVITIES

Urban Areas

There are seven urban areas with population greater than 2,500 located in the potential contributing area of RBG 1.2 (Table 19). These areas comprise 28 percent of the region's population. Only Marquette, Michigan may potentially contribute bacteria to Lake Superior. In addition, several of the communities are served wholly or in part by combined sewer systems.

Severe urban erosion problems related to construction have been identified in the City of Marquette. A minimum growth rate of 0.1 percent per year was assumed for cost estimation.

Estimated costs for urban stormwater treatment for cities in the potential contributing area are summarized in Table 20. Average annual costs range from $1.1 million to $3.2 million for low and high efficiency treatment, respectively. Chlorination for bacteria control would add approximately $70 thousand per year.

Construction sediment controls for those municipalities in the potential contributing area were estimated to cost $12 thousand per year. Because an urban maintenance "growth rate" of 0.1 percent per year was assumed, costs for detention basins were not calculated.

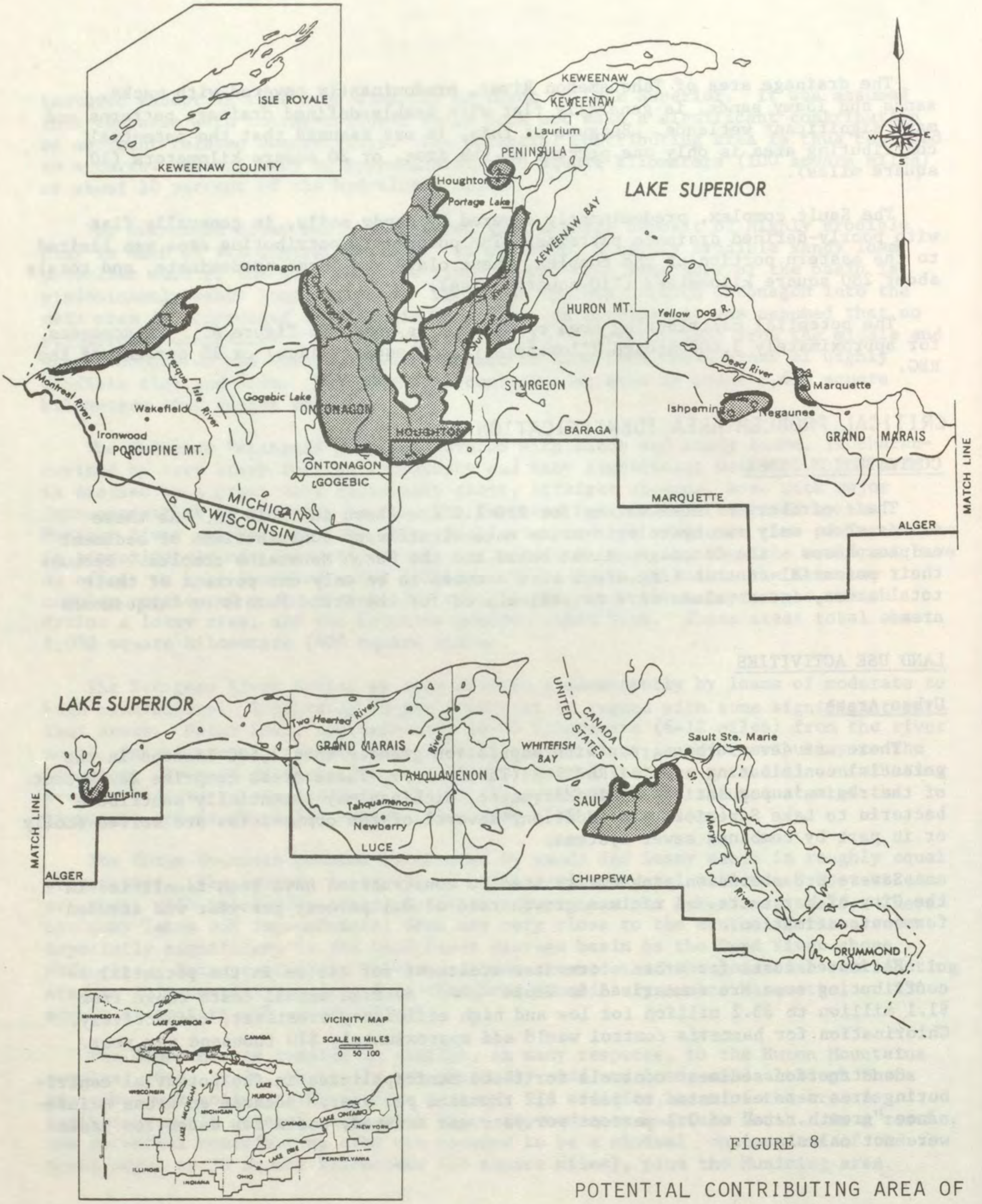


FIGURE 8

POTENTIAL CONTRIBUTING AREA OF

RBG 1.2

SCALE IN MILES
0 5 10 15 20 25

TABLE 18

CONTRIBUTION INDICES
RIVER BASIN GROUP 1.2

HYDROLOGIC AREA	LAND AREA (km^2)*	PCA AREA (km^2)*	SUSPENDED SOLIDS	TOTAL PHOSPHORUS	ORTHO PHOSPHORUS
Porcupine Mountains	2,720	270	0.74	0.64	0.66
Ontonagon River	3,530	1,410	2.89	0.74	0.72
Keweenaw Peninsula	3,500	1,050	0.15	0.16	0.24
Sturgeon River	1,830	910	0.28	0.26	0.25
Huron Mountains	2,520	130	0.89	0.79	2.36
Grand Marais	3,110	30†	–	–	–
Tahquamenon River	2,180	20†	–	–	–
Sault	700	280	0.38	0.55	0.70

*To convert square kilometers to square miles, multiply by 0.386

$$CI = \frac{(\text{\% of Great Lakes Diffuse Load})\ (\text{from hydrologic area})}{(\text{\% of Great Lakes PCA in})\ (\text{hydrologic area})}$$

†PCA was assumed to be a minimum of 1% of the area so CI values were not calculated.

Total Great Lakes PCA = 105,950 km^2

Total Great Lakes Diffuse Loads

Suspended Solids = 9,492,407 Mtonnes/yr.

Total P = 13,155 Mtonnes/yr.

Ortho P = 3,007 Mtonnes/yr.

NOTE: Loads are average of 1975 and 1976 values with Lake Erie values assured equal for both years

TABLE 19

URBAN AREAS IN THE POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 1.2

URBAN AREA	HYDROLOGIC AREA	POPULATION (1970)	AREA (ACRES*) (1970)
Hancock, MI	Keweenaw Peninsula 1.2.3	4,820	11,515
Houghton, MI	Keweenaw Peninsula 1.2.3	6,067	1,279
Ishpeming, MI	Huron Mtns. 1.2.5	8,245	5,565
Negaunee, MI	Huron Mtns. 1.2.5	5,248	8,956
Munising, MI	Grand Marais 1.2.6	3,677	3,391
L'Anse, MI	Huron Mtns. 1.2.5	2,538	1,472
Marquette, MI	Huron Mtns. 1.2.5	21,967	7,037
TOTAL - PCA		52,562	39,215
Planning Subarea 1.2		188,384	6,441,800

*To convert acres to hectares, multiply by 0.4047

TABLE 20

URBAN CONTROL SUMMARY FOR RBG 12

NUMBER OF URBAN AREAS: 7

LOW LEVEL OF TREATMENT (<30% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.19

CAPITAL COST	: $	7290533.
ANNUAL OPERATING COST	: $	285157.
AVERAGE ANNUAL COST*	: $	1088341.

MEDIUM LEVEL OF TREATMENT (30% TO 60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.54

CAPITAL COST	: $	19494208.
ANNUAL OPERATING COST	: $	472838.
AVERAGE ANNUAL COST*	: $	2620479.

HIGH LEVEL OF TREATMENT (>60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.83

CAPITAL COST	: $	22948016.
ANNUAL OPERATING COST	: $	668780.
AVERAGE ANNUAL COST*	: $	3196921.

CHLORINATION (MEDIUM AND HIGH LEVEL TREATMENT ONLY)

	COMBINED SEWER ONLY	COMBINED AND STORM SEWERS
CAPITAL :	0.	483823.
O&M :	0.	13550.
ANNUAL* :	0.	66852.

* Average annual cost equals capital amortized over 25 years at 10 percent interest per year plus annual operation and maintenance cost.

The estimated costs for combined sewer and stormwater treatment for all urban areas of 2,500 persons or more in RBG 1.2 are shown in Table 21, and range from $1.9 million to $5.7 million per year. Chlorination costs were not included. Construction sediment controls for all urban areas in RBG 1.2 were estimated to cost $21 thousand annually.

Agricultural Areas

There are 16 thousand hectares (38 thousand acres) of cropland within the potential contributing area of RBG 1.2 (see Table 22). Thirty-eight percent of this cropland, or 6 thousand hectares (14 thousand acres) requires treatment. According to Conservation Needs Inventory data, 57 thousand hectares (141 thousand acres) out of a total 106 thousand hectares (263 thousand acres) of cropland in this planning subarea required erosion control treatment in 1968.

Within the potential contributing area are 15 cattle feedlot operations (see Table 23), only five of which have waste controls. Based on information found in Inventory of Land Use [IJC, 1976a], approximately 15 cattle feedlot operations in the entire planning subarea may need to install waste management systems.

Agricultural runoff within this region may have an impact, although minor, on Lake Superior water quality.

The costs of implementing best management practices on all cropland in the potential contributing area are $60 thousand one-time, and $15 thousand recurring costs. The average annual cost is $22 thousand. All the soil associations in the potential contributing area are fine-textured. Application of best management practices to all soils in the planning subarea would have a one-time cost of $580 thousand and recurring costs of $130 thousand. The average annual cost would be $190 thousand.

The capital cost of installing waste management systems in the potential contributing area was estimated to be $100 thousand, and $160 thousand for the planning subarea.

On-Site Waste Disposal

Thirty-five percent of 22,580 residences in the planning subarea were nonsewered in 1970. Of this, 95 percent were in rural areas.

Approximately 17 percent of the nonsewered units, or 3,890 units, are located in the potential contributing area. The Ontonagon River basin, with 27 percent, and the Keweenaw Peninsula, also with 27 percent, account for most of the units located in the potential contributing area. The number of nonsewered residential units in the region is projected to increase about four percent between 1970 and 1990.

Although most areas in RBG 1.2 are considered suitable for septic tank development, there are some instances of localized problems, particularly in the potential contributing area of the Sault complex.

TABLE 21

ESTIMATED COST OF CONTROLS FOR ALL URBAN AREAS, RBG 1.2

TREATMENT LEVEL		COST IN PCA ($ millions)	ADJUSTED AREA IN PCA (ACRES*)	COST PER ACRE ($)	TOTAL URBAN ACREAGE	ADJUSTED** URBAN ACREAGE	TOTAL RBG COST ($ millions)
LOW	Capital	7.29	10,100	720	51,584	18,054	13.0
	O&M	0.28	10,100	30	51,584	18,054	0.5
MEDIUM	Capital	19.49	10,100	1,930	51,584	18,054	34.8
	O&M	0.47	10,100	50	51,584	18,054	0.9
HIGH	Capital	22.95	10,100	2,270	51,584	18,054	41.0
	O&M	0.67	10,100	65	51,584	18,054	1.2

* To convert acres to hectares, multiply by 0.4047

** Urban area adjustment factor = 0.35

Average Annual Cost:

Low:	$ 1.9 million
Medium:	4.7 million
High:	5.7 million

TABLE 22

COSTS FOR INSTALLING AGRICULTURAL BEST MANAGEMENT PRACTICES IN THE POTENTIAL CONTRIBUTING AREA (PCA) OF RIVER BASIN GROUP 1.2

COUNTY	TOTAL ACRES* IN POTENTIAL CONTRIBUTING AREA	ACRES IN PCA NEEDING TREATMENT	COSTS FOR ALL SOILS ($ millions)		COSTS FOR FINE-TEXTURED SOILS ($ millions)	
			One-Time	Recurring	One-Time	Recurring
MICHIGAN						
Baraga	8,100	4,100	0.017	0.004	0.017	0.004
Houghton	10,000	5,000	0.021	0.005	0.021	0.005
Ontonagon	20,300	5,300	0.022	0.005	0.022	0.005
TOTAL	38,400	14,400	0.060	0.014	0.060	0.014

*To convert acres to hectares, multiply by 0.4047

TABLE 23

COST FOR INSTALLING AGRICULTURAL WASTE MANAGEMENT SYSTEMS
IN POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 1.2

COUNTY	TOTAL NUMBER OF FEEDLOT OPERATIONS >100 ANIMAL UNITS IN PCA			NUMBER OF FEEDLOT OPERATIONS IN PCA NEEDING TREATMENT			TOTAL COST ($ thousands)		
	CATTLE	SWINE	POULTRY	CATTLE	SWINE	POULTRY	CATTLE (at $10,000 per system)	SWINE (at $6,000 per system)	POULTRY (at $ 3,000 per system)
MICHIGAN									
Baraga	11	0	0	8	0	0	80	0	0
Chippewa	1	0	0	0	0	0		0	0
Houghton	0	0	0	0	0	0	0	0	0
Ontonagon	3	0	0	2	0	0	20	0	0
TOTAL	15	0	0	10	0	0	100	0	0

The estimated capital investment required to alleviate problems with failing septic systems within the potential contributing area is $2.0 million, with an additional $50 thousand in annual operating and maintenance costs (Table 24). The average annual cost would be $260 thousand per year.

Extrapolating these figures to the planning subarea yields an estimated capital cost of $11.3 million and annual operating costs of $300 thousand. The total discounted cost would be $15.0 million.

Other Problems

Significant problems related to the disposal of mine tailings occur at the Mineral River and the Upper Portage Entry Channel. In the former case, high chloride inputs originating from mine-drainage water of the White Pine Copper Company are degrading water quality. The problem at the Upper Portage Entry is related to contaminated bottom sediments from past copper mining activities.

In addition to mine tailing disposals there are 14 dredge disposal sites in RBG 1.2. The annual average volume of dredge spoil is 132,000 cubic meters (172,629 cubic yards), the majority of which is dumped in open lake areas. Only two confined sites are in use in the region (as of July 1974). Eight sites have some polluted material.

No additional land-related water quality problems have been identified in RBG 1.2.

TABLE 24

ON-SITE WASTE DISPOSAL, RBG 1.2

COUNTY	TOTAL NUMBER OF SYSTEMS	PERCENT OF COUNTY IN PCA	ESTIMATED NUMBER OF SYSTEMS IN PCA	NUMBER FAILING	CAPITAL COST ($\$X10^6$)	OPERATING COST ($\$X10^3$)	AVERAGE ANNUAL COST ($\$X10^6$)
MICHIGAN							
Baraga	1,407	15	210	60	0.10	2.7	0.01
Chippewa	4,202	15	630	190	0.32	8.4	0.04
Gogebic	1,255	8	100	30	0.05	1.3	0.01
Houghton	3,958	40	1,580	470	0.79	20.8	0.11
Marquette	5,969	5	300	90	0.15	4.0	0.02
Ontonagon	2,131	50	1,070	320	0.54	14.2	0.07
TOTAL	-	-	3,890	1,160	1.95	51.4	0.26

4 LAKE MICHIGAN BASIN

LAKE BASIN SUMMARY

BASIN DESCRIPTION

The Lake Michigan drainage area extends from the area just north of Chicago, through Wisconsin and the southern half of Michigan's upper peninsula to the Straits of Mackinac, the outlet of Lake Michigan, then south through Michigan and northeastern Indiana to a point just east of Chicago. The basin covers an area of 117,400 square kilometers (45,330 square miles) in four states. The Illinois drainage area excludes the Chicago and Calumet Rivers, which are now diverted out of the Lake Michigan basin into the Mississippi River basin.

Less than one percent of the area is in the State of Illinois. Five percent is in Indiana, 63 percent in Michigan, and 32 percent in Wisconsin. The Lake Michigan basin is divided into four river basin groups (RBG): RBG 2.1 covers parts of Michigan's upper peninsula and northeastern Wisconsin; RBG 2.2 includes the shoreline of Lake Michigan from central Wisconsin, through Illinois, Indiana and Michigan; RBG 2.3 includes southwestern Michigan and northeastern Indiana; and RBG 2.4 lies in the northwest portion of Michigan's lower peninsula. Figure 9 is a map of the Lake Michigan drainage basin.

The terrain is generally hilly to gently rolling. In the north, particularly in northern Michigan, bedrock outcrops create a rugged relief. Extensive sand dunes line the shore of the lake in Indiana and Michigan. Glacial deposits cover most of the basin. Fine grain glacial lake deposits with low permeability cover much of the shoreline of Lake Michigan. However, the western shore of the lake, south and east of Green Bay, and parts of the eastern shore are more permeable.

Soils vary from sandy and gravelly in parts of northern Michigan and Wisconsin to light-colored loams and clay loams in eastern Wisconsin, to variable sand and clay soils in Michigan, Indiana and Illinois. Most of the soils are quite acid and low in organic matter. Poor drainage is a problem in central Wisconsin, and parts of northern Indiana, eastern Illinois, and southern Michigan. The basin's northern extremities are forested with a spruce-fir biome on both sides of the lake, but toward the south in Wisconsin the forest cover becomes less dominant. Agricultural land is prevalent south of Green Bay. In Michigan the forest vegetation extends further south to approximately the Muskegon-Clare-Midland line. Land around the southern tip of the lake (exclusive of urban areas) is almost completely agricultural, with little tree cover remaining in Indiana and Illinois. Grapes, cherries and other fruits are important crops near the lake because of the ideal climate.

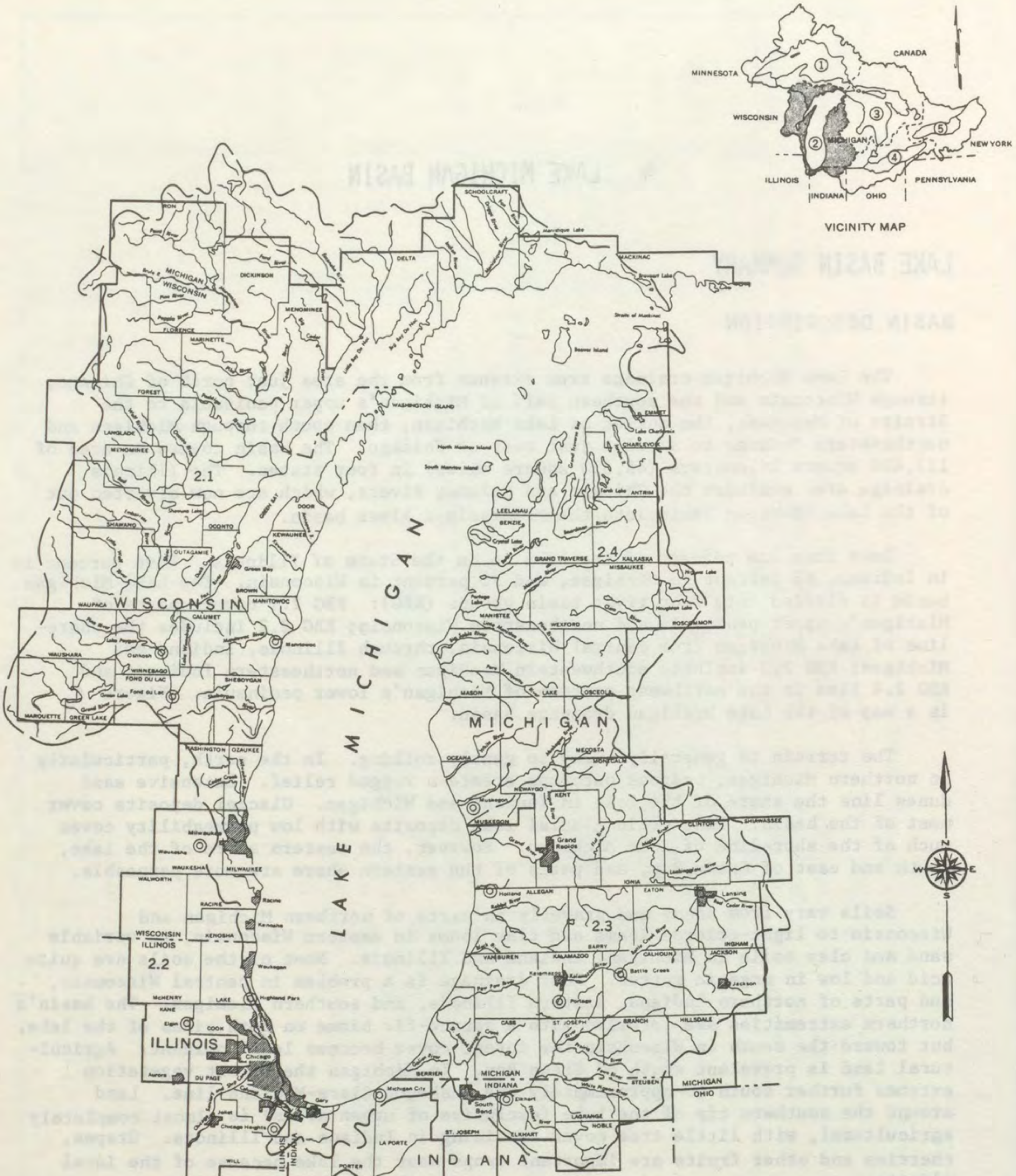


FIGURE 9

LAKE MICHIGAN BASIN

SCALE IN MILES
0 10 20 30 40 50

Important mineral products from the basin include iron, stone, sand and gravel, oil, gas, salt, gypsum, marl and peat.

In the Lake Michigan basin the population density was 55 persons per square kilometer (142 per square mile) in 1970. The estimated 1975 population of the basin counties was 6,601,695 people. The basin has two distinctly contrasting populations: the southern half is highly urbanized, while the northern half is predominately rural.

This basin has an abundant supply of surface waters which are generally of high quality. However, in the southern portion urbanization and industrialization have caused serious pollution problems in the Chicago-Gary area northward to a line from Milwaukee to Muskegon. The Green Bay and Grand Traverse Bay areas both have deteriorating water quality.

Present problems include increasing concentrations of dissolved constituents, oxygen depletion (Green Bay), chlorides (Manistee and Ludington), oil spills, overproduction of algae and fish kills. Major pollution problems are traceable to the effluents from forest products industries in the north to the lack of tertiary and, in many cases, secondary treatment in both public and private wastewater disposal systems, and to land drainage. Population growth is projected to continue and without adequate treatment, present problems will spread and restoration needs will become proportionately greater.

PROBLEM AREA SUMMARY

The estimated potential contributing area totals 10,550 square kilometers (4,050 square miles), or less than one-tenth of the total lake basin area. The southern and western portions of the basin account for the largest share of the potential contributing area.

An assessment of diffuse tributary sediment and phosphorus loadings to the lake has identified the following hydrologic areas as having a significant input of one or both of these contaminants: the Menominee complex, Oconto River, Suamico complex, Fox River, Black River (South Haven) complex and Grand River.

The following potential critical problem areas and associated remedial costs were identified on the basis of land use activities.

URBAN AREAS

There were 47 urban areas with a total population of 3,143,590 covering 1,292,138 acres identified in the potential contributing area of Lake Michigan. The annual growth rate varied from 0.4 percent in the northwestern part of the basin (RBG 2.1), to 0.8 percent in the southwest (RBG 2.2), and the southeast (RBG 2.3), and 0.5 percent in the northeast (RBG 2.4).

Average annual costs for stormwater and combined sewer controls in the potential contributing area of the basin ranged from $33.4 million to $107.0 million. Chlorination would add an estimated $0.5 to $6.6 million per year, depending upon whether or not it is limited to combined sewer overflows only. Estimated control costs for all urban areas in the basin range from $45.6 million to $141.7 million per year.

Construction sediment controls for those urban areas within the potential contributing area were estimated to cost $3.7 million per year. The construction of detention ponds in new developments would cost $31.4 million per year, with annual maintenance costs of $630 thousand. Extrapolation of these figures to all urban areas of the basin showed the following results: $4.2 million per year for construction sediment controls, $34.7 million per year for new detention ponds, and $700 thousand per year for detention pond maintenance.

AGRICULTURAL AREAS

Cropland on moderate- and fine-textured soils accounts for 977 thousand hectares (2,414 thousand acres) in the Lake Michigan potential contributing area, of which 478 thousand hectares (1,230 thousand acres) require erosion control practices. These best management practices would require an estimated one-time investment of $59 million, with annual recurring costs of $3 million. The average annual cost is thus $9.7 million. Limiting the application of best management practices only to fine-textured soils would reduce the average annual cost to $6.0 million, with one-time and recurring costs of $36.9 million and $1.9 million, respectively. These costs can be compared to the estimated cost of applying BMPs to all cropland in the Lake Michigan basin identified as requiring erosion controls in the Conservation Needs Inventory: $284.0 million one-time cost, $23.8 million recurring cost, and $55.1 million average annual cost.

One thousand and forty-four feedlot operations in the potential contributing area were identified as requiring waste management systems. The estimated capital cost of these systems was $16.3 million. Extrapolating this result to all feedlots in the lake basin yields an estimated cost of $55.8 million. Costs are $1.8 million and $6.1 million, respectively, in average annual terms.

ON-SITE WASTE DISPOSAL

It was estimated that there are approxiamtely 18 thousand malfunctioning on-site disposal systems in the potential contributing area. The estimated capital cost of correcting these problems was $32.1 million dollars, with annual operating and maintenance costs of $1.0 million. The average annual cost would thus be $4.5 million. The estimated costs of correcting all septic tank problems throughout the basin are $162.7 million capital, $5.4 million per year operating, or $23.3 million per year in average annual terms.

The costs for urban, agricultural, and on-site waste disposal remedial measures are summarized in Table 25.

OTHER PROBLEMS

Other problems identified in the Lake Michigan basin include the disposal of polluted dredge spoil and the leaching of toxic chemicals and brines from industrial waste disposal sites and abandoned oil and gas wells.

TABLE 25

COST

SUMMARY FOR LAKE

MICHIGAN

REMEDIAL MEASURES	CAPITAL COST ($ millions)	OPERATING, MAINTENANCE AND RECURRING COST ($ millions)	AVERAGE ANNUAL COST ($ millions)
Urban Areas			
Low Level Treatment	237.4	7.2	33.4
Medium Level Treatment	695.4	16.7	93.3
High Level Treatment	783.6	20.7	107.0
Chlorination -			
Combined only	5.0	0.3	0.5
Both	47.7	1.3	6.6
Sediment Controls	-	3.7	3.7
Detention Ponds	-	32.0	32.0
Agricultural Areas			
Best Management Practices:			
All Soils	59.2	3.2	9.7
Fine Soils	36.9	1.9	6.0
Animal Waste Controls	16.3	-	1.8
On-Site Waste Disposal	32.1	1.0	4.5

RIVER BASIN GROUP 2.1

DESCRIPTION

River Basin Group 2.1, located in the western portion of the Great Lakes Basin, includes 43,670 square kilometers (16,861 square miles) of Michigan and Wisconsin land draining into northwest Lake Michigan. The corresponding planning subarea includes three counties in Michigan and twenty-one in Wisconsin, as shown in Figure 10. There are seven hydrologic areas here: Menominee complex, Menominee River, Peshtigo River, Oconto River, Suamico complex, Fox River, and Green Bay complex.

The geology of RBG 2.1 consists of bedrock formations of Precambrian, Ordovician and Silurian systems which yield iron ore, basalt, granite, shale, limestone and dolomite. Unconsolidated sediments of the Quaternary system overlay the bedrock.

As Figure 11 illustrates, the northern part of the region consists primarily of sandy and loamy reddish drift soils on the upland plains. Soils range in texture from fine to coarse and in depth from exposed bedrock to glacial sediments up to 500 feet deep. Rock outcrops, shallow to bedrock soils, organic soils, and fragipans are common. The southern part has clay and loam soils on both uplands and plains. Organic soils and bedrock escarpments occur. Most of the area is rolling to hilly, with moderate to high relief.

RBG 2.1, with more than 27,353 kilometers (16,996 miles) of streams, has an average stream density of 0.6 kilometers of streams per square kilometer (1.0 miles per square mile). The major river systems are the Escanaba and Ford Rivers in Michigan, and the Pine, Menominee, Peshtigo, Oconto, Fox, Wolf, and Little Wolf Rivers in Wisconsin.

Almost three-quarters of the region is covered by forests. About 20 percent of the land is agricultural while only one percent is urban. Table 26 shows the major land cover in each hydrologic area.

Population has grown from 771,000 in 1940 to 1,005,000 in 1970, a 23 percent increase. About 57 percent of the population is urban. Important urban areas include (1975 population estimates): Menominee, Michigan (pop.: 10,374); Iron Mountain, Michigan (pop.: 8,692); Marinette, Wisconsin (pop.: 12,240); Green Bay, Wisconsin (pop.: 89,323); Appleton, Wisconsin (pop.: 59,182); Oshkosh, Wisconsin (pop.: 50,107), Fond du Lac, Wisconsin (pop.: 36,476); Manitowoc, Wisconsin (pop.: 33,057); and Sheboygan, Wisconsin (pop.: 49,431). The largest change in employment has been in the trade and services sector. Out of a total work force of 375,468 in 1970, approximately one-third was employed in manufacturing, while agriculture, forestry, and fisheries accounted for less than 10 percent (29,300) of the jobs in the region.

FIGURE 10

PLANNING SUBAREA 2.1

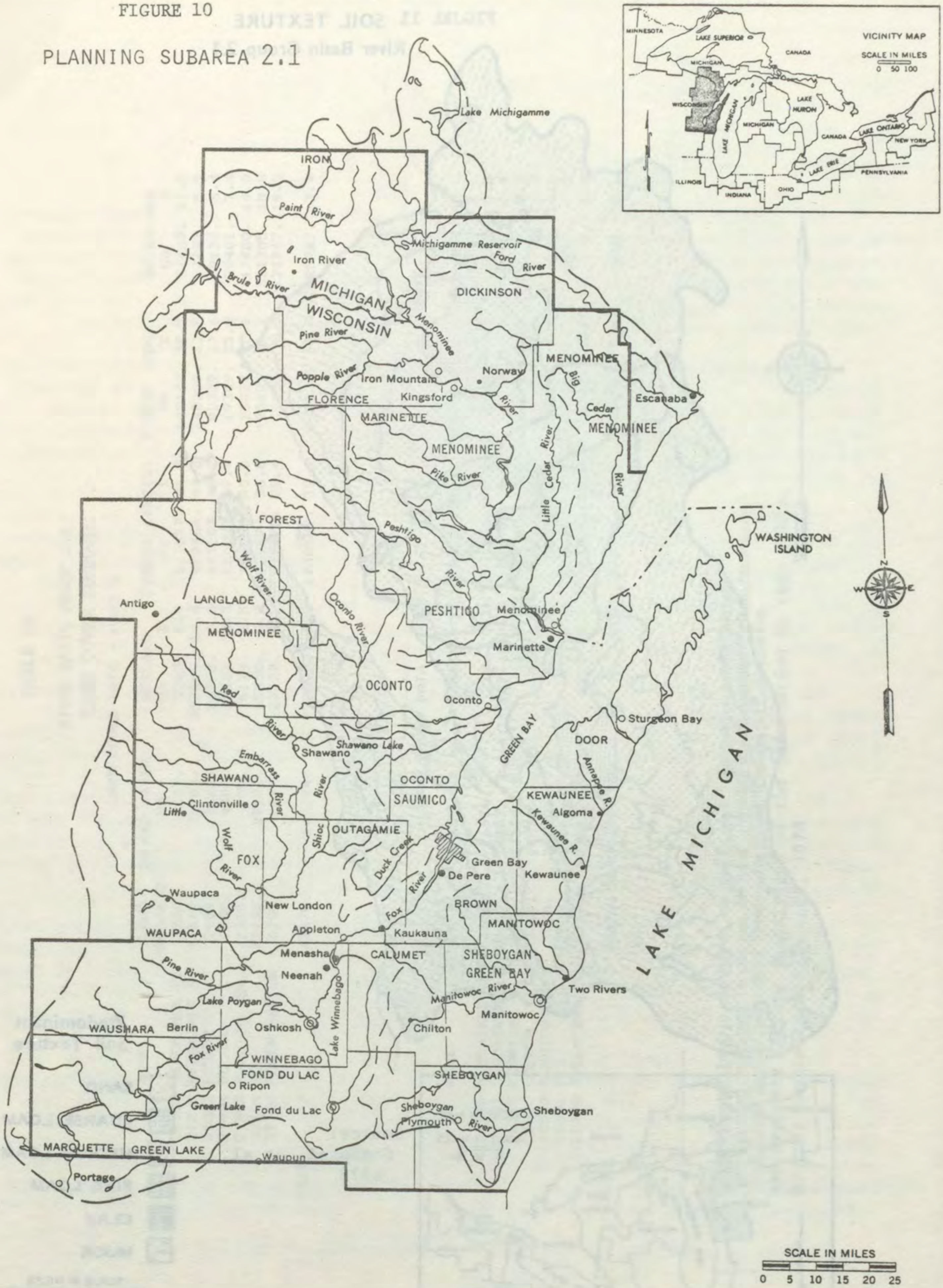
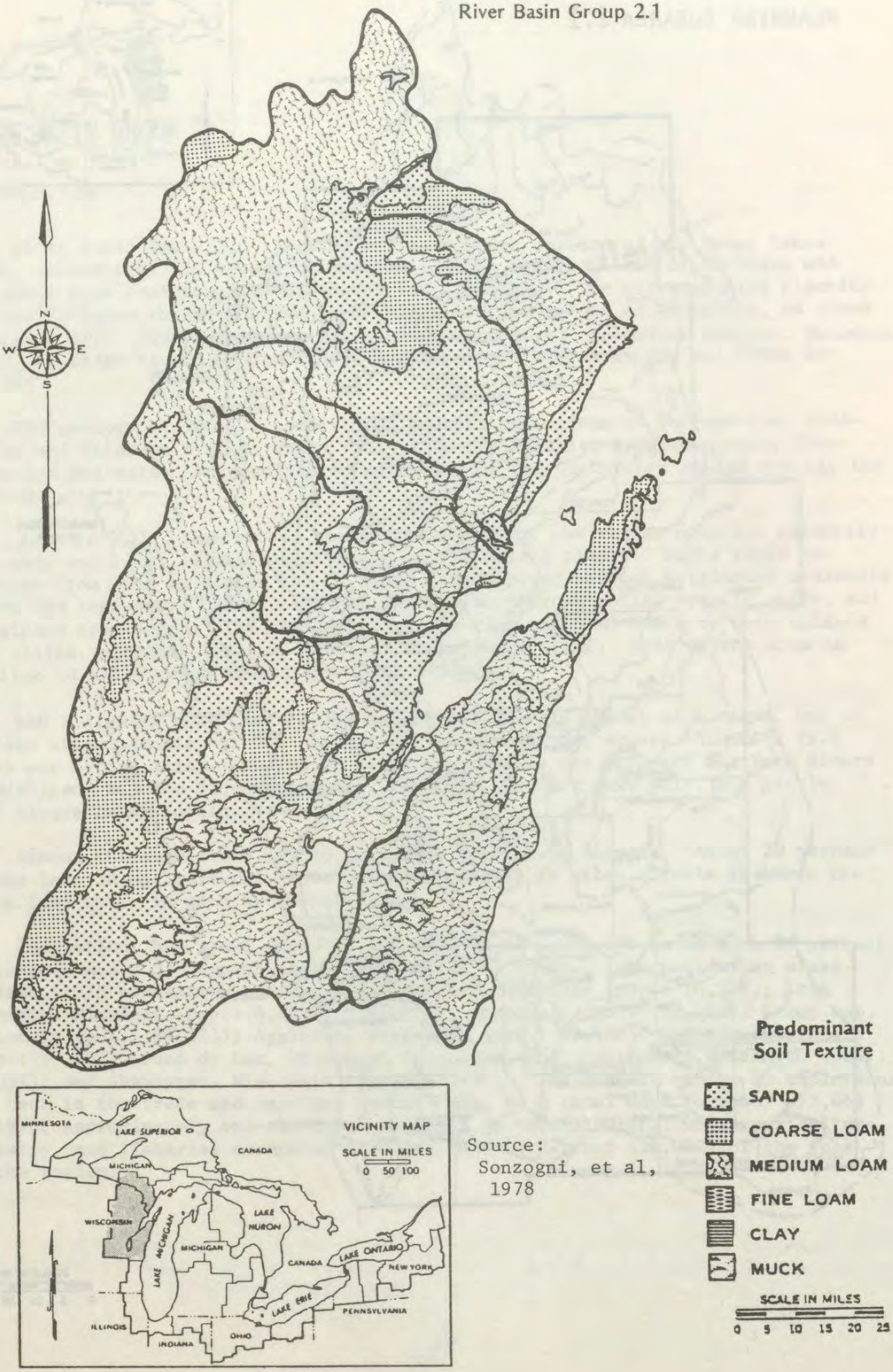


FIGURE 11 SOIL TEXTURE

River Basin Group 2.1



Source: Sonzogni, et al, 1978

TABLE 26

RIVER BASIN GROUP 2.1

LAND COVER SUMMARY

LAND COVER DATA - PART 1

#	NAME	LAND AREA:KM2	INLAND WATER HA	WETLAND HA	%	FOREST (DECID) HA	%	FOREST (CON) HA	%	BRUSHLAND HA	%
21100	MENOMINEE CO	2730.	819.	5203.	1.9	121577.	44.5	105147.	38.5	31489.	11.5
21201	MENOMINEE R	10610.	29708.	157185.	14.8	470464.	44.3	348209.	32.8	53487.	5.0
21302	PESHTIGO	2980.	5662.	26732.	9.0	145203.	48.7	82322.	27.6	19138.	6.4
21401	OCONTO	2750.	4400.	14533.	5.3	135823.	49.4	69309.	25.2	20401.	7.4
21500	SUAMICO COM	1250.	750.	8174.	6.5	50050.	40.0	13833.	11.1	17480.	14.0
21601	FOX	17100.	99180.	65350.	3.8	629904.	36.8	190605.	11.1	321305.	18.8
21700	GREEN BAY CO	6250.	6875.	20222.	3.2	177578.	28.4	59403.	9.5	121967.	19.5
TOTAL	7	43670.	147394.	297399.	6.8	1730599.	39.6	868829.	19.9	585267.	13.4

LAND COVER DATA - PART 2

#	NAME	LAND AREA:KM2	GRASSLAND HA	%	BARREN HA	%	PLOWED FIELD HA	%	RESIDENTIAL HA	%	COMMERCIAL HA	%
21100	MENOMINEE CO	2730.	7667.	2.8	274.	0.1	274.	0.1	1369.	0.5	0.	0.0
21201	MENOMINEE R	10610.	16373.	1.5	1092.	0.1	14190.	1.3	0.	0.0	0.	0.0
21302	PESHTIGO	2980.	13366.	4.5	0.	0.0	11240.	3.8	0.	0.0	0.	0.0
21401	OCONTO	2750.	24035.	8.7	0.	0.0	10899.	4.0	0.	0.0	0.	0.0
21500	SUAMICO COM	1250.	24145.	19.3	0.	0.0	8803.	7.0	2264.	1.8	252.	0.2
21601	FOX	17100.	314044.	18.4	0.	0.0	156115.	9.1	29045.	1.7	3631.	0.2
21700	GREEN BAY CO	6250.	139661.	22.3	632.	0.1	94793.	15.2	10743.	1.7	0.	0.0
TOTAL	7	43670.	539291.	12.3	1997.	0.0	296313.	6.8	43420.	1.0	3882.	0.1

*Total forested land is the sum of the two "forest" categories and "brushland."

Total agricultural land is the sum of "plowed field" and "grassland" classifications.

Total urban land is the sum of "residential" and "commercial" categories.

See Appendix 3 for a description of the information in this table.

Source: Monteith and Jarecki, 1978

POTENTIAL CONTRIBUTING AREA

The Menominee complex is relatively flat with few lakes and no major impoundments. Soils are fine-textured loams over approximately 80 percent of the area. Because the headwaters area of the Ford River and a narrow strip along Green Bay are relatively sandy, they were assumed to make no significant contributions of contaminants. The potential contributing area thus consists of the area with fine-textured soils, an area of about 2,200 square kilometers (840 square miles).

The Menominee River basin has many major impoundments of high estimated trap efficiency. It was assumed that no significant contribution is made by the area upstream of a dam at the confluence of the Menominee and Little Cedar rivers; however, the Little Cedar itself was considered contributing. The potential contributing area is thus confined to about five percent of the hydrologic area, or approximately 600 square kilometers (230 square miles).

The Peshtigo River basin also has several large reservoirs near the mouth. The drainage area downstream of these impoundments has sandy soils and extensive wetlands. It was thus estimated that only about one percent of the total drainage area contributes significant amounts of pollutants to Lake Michigan; this area consists of the direct drainage along Green Bay and the riparian lands of the lower Peshtigo. Total potential contributing area is approximately 50 square kilometers (20 square miles).

The Oconto River basin is very similar to the Peshtigo, with large impoundments in the lower reaches. However, a portion of the area near the mouth has loamy soils and was assumed to be potentially contributing. This area is approximately ten percent of the total, or about 250 square kilometers (100 square miles).

Soils in the lower part of the Suamico complex are coarse loams and sand and were assumed to be essentially non-contributing. The upper portion of the complex however is covered predominantly by medium loams and was assumed to be potentially contributing. The potential contributing area thus covers approximately 250 square kilometers (100 square miles), or 20 percent to the complex.

Although the Fox River basin has a drainage area of 17,100 square kilometers (6,570 square miles), only about five percent of this was assumed to be potentially contributing. Lake Winnebego is situated near the mouth, and was assumed to have a high trap efficiency. This limits the potential contributing area to that below the lake outlet, an area of approximately 850 square kilometers (330 square miles).

The Green Bay complex consists of flat to rolling land with predominately loamy soils. Large impoundments are present on the upper reaches of the Manitowoc and Sheboygan Rivers, limiting the contributing areas of each to the downstream portions. The northern end of the Door Peninsula has sandy loam soils and is assumed to make an insignificant pollutant contribution. Wetlands on the northern side of the peninsula are assumed to be non-contributing. The estimated potential contributing area thus includes 75 percent of the hydrologic area, approximately 4,600 square kilometers (1,770 square miles).

Figure 12 shows the potential contributing area of RBG 2.1.

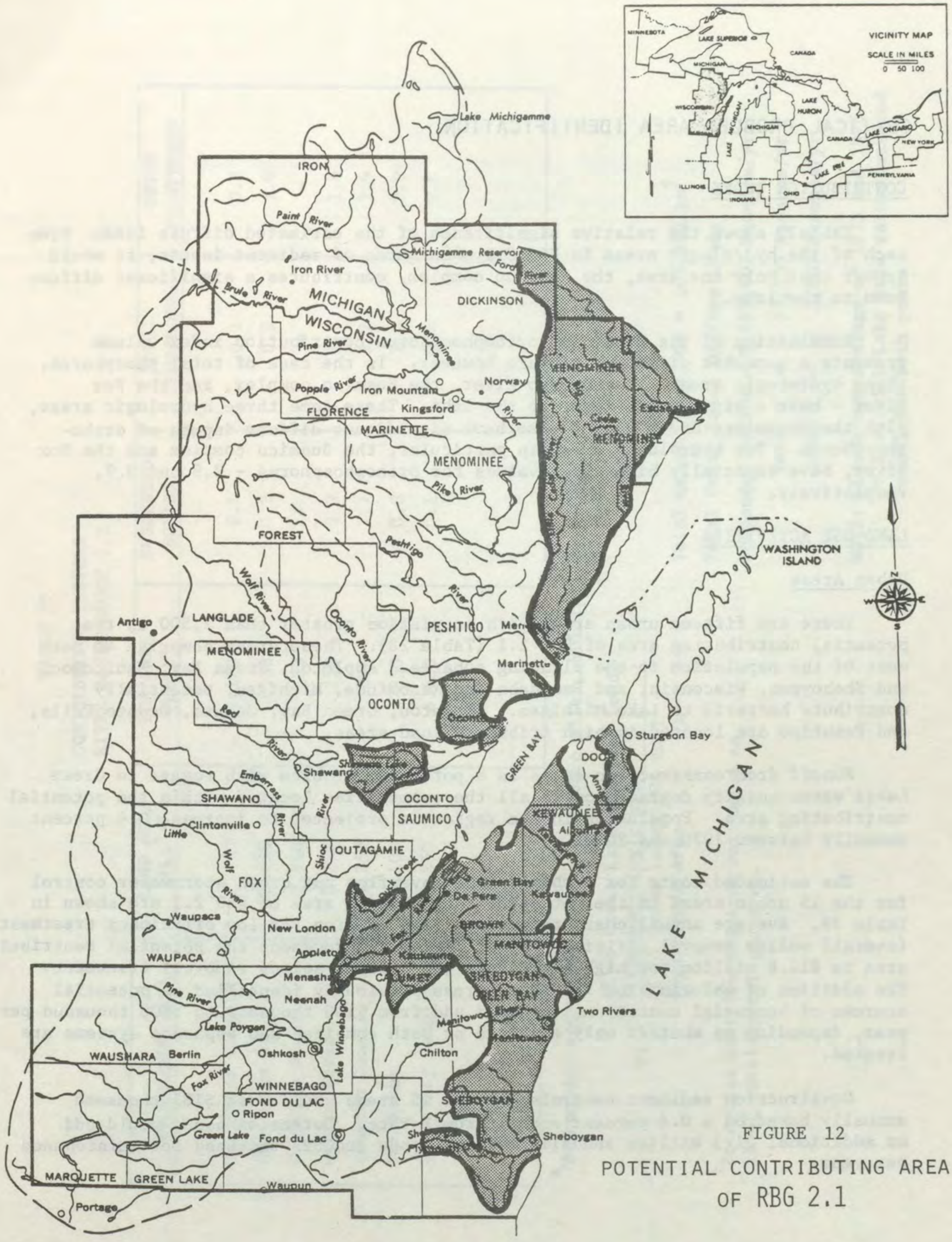


FIGURE 12
POTENTIAL CONTRIBUTING AREA
OF RBG 2.1

CRITICAL PROBLEM AREA IDENTIFICATION

CONTRIBUTION INDEX

Table 27 shows the relative significance of the estimated diffuse loads from each of the hydrologic areas in RBG 2.1. In terms of sediment inputs, it would appear that only one area, the Suamico complex, contributes a significant diffuse load to the lake.

Examination of the total and orthophosphorus contribution index values presents a somewhat different picture however. In the case of total phosphorus, three hydrologic areas - the Oconto River, the Suamico complex, and the Fox River - have a significant input to the lake. These same three hydrologic areas, plus the Menominee River basin, also have significant diffuse inputs of orthophosphorus. Two hydrologic areas in particular, the Suamico complex and the Fox River, have especially high index values for orthophosphorus - 2.9 and 3.9, respectively.

LAND USE ACTIVITIES

Urban Areas

There are fifteen urban areas with population greater than 2,500 in the potential contributing area of RBG 2.1 (Table 28). These areas comprise 40 percent of the population in the planning subarea. Appleton, Green Bay, Manitowoc, and Sheboygan, Wisconsin, and Escanaba and Menominee, Michigan, potentially contribute bacteria to Lake Michigan. Appleton, Green Bay, Oconto, Oconto Falls, and Peshtigo are located in high tributary load areas.

Runoff from construction sites is a potential problem with regard to Great Lakes water quality degradation in all the communities located within the potential contributing area. Population in the region is projected to increase 0.4 percent annually between 1970 and 2020.

The estimated costs for combined sewer overflow and urban stormwater control for the 15 urban areas in the potential contributing area of RBG 2.1 are shown in Table 29. Average annual costs range from \$2.6 million for low efficiency treatment (overall solids removal efficiency of 21 percent) throughout the potential contributing area to \$12.6 million for high efficiency (81 percent solids removal) treatment. The addition of chlorination for those areas previously identified as potential sources of bacterial contamination would add from \$100 thousand to \$800 thousand per year, depending on whether only combined or both combined and separate systems are treated.

Construction sediment controls for the 15 areas would cost \$181 thousand annually based on a 0.4 percent annual growth rate. Detention ponds would add an additional \$1.3 million annually for new ponds and \$27 thousand for maintenance per year.

TABLE 27

CONTRIBUTION INDICES
RIVER BASIN GROUP 2.1

HYDROLOGIC AREA	LAND AREA (km^2)*	PCA AREA (km^2)*	SUSPENDED SOLIDS	TOTAL PHOSPHORUS	ORTHO PHOSPHORUS
Menominee Complex	2,730	2,180	0.1	0.1	0.1
Menominee River	10,610	530	0.3	0.9	1.0
Peshtigo River	2,980	30†	-	-	-
Oconto River	2,750	250	0.3	1.7	1.6
Suamico Complex	1,250	250	1.7	2.2	2.9
Fox River	17,100	850	0.8	1.3	3.9
Green Bay Complex	6,250	4,620	0.1	0.2	0.8

*To convert square kilometers to square miles, multiply by 0.386

$$CI = \frac{\text{(\% of Great Lakes Diffuse Load) (from hydrologic area)}}{\text{(\% of Great Lakes PCA in) (hydrologic area)}}$$

†Potential Contributing Area estimated as 1% of total hydrologic area.

Total Great Lakes PCA = 105,950 km^2

Total Great Lakes Diffuse Loads

Suspended Solids = 9,492,407 Mtonnes/yr.

Total P = 13,155 Mtonnes/yr.

Ortho P = 3,007 Mtonnes/yr.

NOTE: Loads are average of 1975 and 1976 values with Lake Erie values assured equal for both years

TABLE 28

URBAN AREAS IN THE POTENTIAL CONTRIBUTING AREA
OF RIVER BASIN GROUP 2.1

URBAN AREA	HYDROLOGIC AREA	POPULATION (1970)	AREA (ACRES*) (1970)
Escanaba, MI	Menominee Complex 2.1.1	15,368	8,060
Menominee, MI	Menominee River 2.1.2	10,745	2,816
Marinette, WI	Menominee River 2.1.2	13,329	3,967
Peshtigo, WI	Peshtigo River 2.1.3	2,836	3,710
Oconto, WI	Oconto River 2.1.4	4,667	4,160
Oconto Falls, WI	Oconto River 2.1.4	2,517	3,199
Appleton, WI	Fox River 2.1.6	129,532	23,734
Green Bay, WI	Fox River 2.1.6	129,105	49,642
Manitowoc, WI	Sheboygan-Green Bay Complex 2.1.7	33,430	6,590
Sheboygan, WI	Sheboygan-Green Bay Complex 2.1.7	48,484	6,140
Sheboygan Falls,WI	" "	4,771	1,280
Algoma, WI	" "	4,023	1,408
Kewaunee, WI	" "	2,901	2,048
Kiel, WI	" "	2,848	768
Plymouth, WI	" "	5,810	1,408
TOTAL- PCA		400,681	118,930
Planning Subarea 2.1		1,005,065	10,401,900

*To convert acres to hectares, multiply by 0.4047

TABLE 29

URBAN CONTROL SUMMARY FOR RBG 21

NUMBER OF URBAN AREAS: 15

LOW LEVEL OF TREATMENT (<30% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.21

CAPITAL COST	: $	17776480.
ANNUAL OPERATING COST	: $	601167.
AVERAGE ANNUAL COST*	: $	2559569.

MEDIUM LEVEL OF TREATMENT (30% TO 60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.42

CAPITAL COST	: $	33064672.
ANNUAL OPERATING COST	: $	880278.
AVERAGE ANNUAL COST*	: $	4522953.

HIGH LEVEL OF TREATMENT (>60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.81

CAPITAL COST	: $	86553856.
ANNUAL OPERATING COST	: $	3072142.
AVERAGE ANNUAL COST*	: $	12607623.

CHLORINATION (MEDIUM AND HIGH LEVEL TREATMENT ONLY)

	COMBINED SEWER ONLY	COMBINED AND STORM SEWERS
CAPITAL:	792571.	6254759.
O&M :	30645.	145938.
ANNUAL*:	117961.	835013.

*Average annual cost equals capital amortized over 25 years at 10 percent interest per year plus annual operation and maintenance cost.

The estimated capital costs for applying urban stormwater and combined sewer controls to all urban areas throughout RBG 2.1 range from $31.9 million to $155.3 million, as shown in Table 30. Operating and maintenance costs vary from $1.1 million to $5.4 million annually. The average annual costs for urban stormwater controls throughout RBG 2.1 would thus vary from $4.6 million to $22.5 million. Chlorination was not included.

In similar fashion, construction sediment control costs throughout RBG 2.1 would be $245 thousand annually. Detention pond costs for newly developed areas would cost $1.8 million dollars annually plus $36.6 thousand for maintenance per year. The total discounted cost is $24.8 million for both construction controls and detention ponds.

Agricultural Areas

There are 468 thousand hectares (1,155 thousand acres) of cropland within the potential contributing area of RBG 2.1 (see Table 31). Forty-seven percent of this cropland, or 219 thousand hectares (541 thousand acres), requires treatment. According to Conservation Needs Inventory data, 754 thousand hectares (1,862 thousand acres) out of a total 1,342 thousand hectares (3,316 thousand acres) of cropland in this planning subarea required treatment in 1968.

The potential contributing area accounts for 769 cattle feedlot operations, eight swine and four poultry operations (Table 32). Only 18 percent of the cattle feedlots have waste controls. About 75 percent of the swine operations and 50 percent of the poultry operations have waste controls.

Agricultural runoff and intensive livestock operations within this region may have a significant impact on Lake Michigan water quality.

As the figures in Table 31 show, the application of best management practices to all lands needing treatment in the potential contributing area would have a one-time cost of $28.9 million, with recurring costs of $1.2 million per year. The average annual cost is $4.4 million. Limiting BMPs to only the fine-textured soils (205 thousand hectares) would reduce the average annual cost to $4.1 million, with one-time and recurring costs of $26.2 million and $1.2 million, respectively.

The costs of applying best management practices to all land identified as needing erosion control in the 1968 Conservation Needs Inventory were estimated to be $99.2 million one-time, and $4.1 million per year recurring for an average annual cost of $15.0 million per year.

Table 32 shows that the installation of animal waste controls for all identified feedlot operations in the potential contributing area would cost $12.4 million, or $1.4 million per year. The cost of such controls for all feedlot operations in Planning Subarea 2.1 identified in the Inventory of Land Use (IJC, 1976b) was estimated to be $21.8 million, or $2.4 million per year in average annual terms.

TABLE 30

ESTIMATED COST OF CONTROLS FOR ALL URBAN AREAS, RBG 2.1

TREATMENT LEVEL		COST IN PCA ($ millions)	ADJUSTED AREA IN PCA (ACRES*)	COST PER ACRE ($)	TOTAL URBAN ACREAGE	ADJUSTED** URBAN ACREAGE	RBG COST ($ millions)
LOW	Capital	17.78	25,220	705	160,900	45,280	31.9
	O&M	0.60	25,220	25	160,900	45,280	1.1
MEDIUM	Capital	33.06	25,220	1,310	160,900	45,280	59.3
	O&M	0.88	25,220	35	160,900	45,280	1.6
HIGH	Capital	86.55	25,220	3,430	160,900	45,280	155.3
	O&M	3.07	25,220	120	160,900	45,280	5.4

*To convert acres to hectares, multiply by 0.4047

**Composite urban area adjustment factor = 0.28

Average Annual Cost:

Low:	$4.6 million
Medium:	8.1 million
High:	22.5 million

TABLE 31

COSTS FOR INSTALLING AGRICULTURAL BEST MANAGEMENT PRACTICES IN THE POTENTIAL CONTRIBUTING AREA (PCA) OF RIVER BASIN GROUP 2.1

COUNTY	TOTAL ACRES* IN POTENTIAL CONTRIBUTING AREA	ACRES IN PCA NEEDING TREATMENT	COSTS FOR ALL SOILS ($ millions)		COSTS FOR FINE-TEXTURED SOILS ($ millions)	
			One-Time	Recurring	One-Time	Recurring
MICHIGAN						
Delta	25,000	6,000	0.06	0.02	0.06	0.02
Dickinson	2,300	500	0.01	**	0.01	**
Menominee	94,090	23,523	0.22	0.09	0.19	0.06
WISCONSIN						
Brown	160,500	88,500	4.31	0.38	4.31	0.38
Calumet	24,900	1,245	0.06	0.01	0.06	0.01
Door	25,000	12,000	1.16	0	0.72	0
Kewaunee	128,162	61,101	3.36	0	3.36	0
Manitowoc	204,880	92,103	5.70	0	5.70	0
Oconto	44,900	14,935	1.33	0	0	0
Outgamie	286,010	167,798	7 80	0.70	7.80	0.70
Shawano	44,000	10,000	0.89	0	0	0
Sheboygan	115,543	63,583	3.99	0	3.99	0
Winnebago	115	10	0	0	0	0
TOTAL	1,155,400	541,324	28.88	1.20	26.18	1.17

*To convert acres to hectares, multiply by 0.4047

**Cost is negligible

TABLE 32

COST FOR INSTALLING AGRICULTURAL WASTE MANAGEMENT SYSTEMS IN POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 2.1

COUNTY	TOTAL NUMBER OF FEEDLOT OPERATIONS ≥100 ANIMAL UNITS IN PCA			NUMBER OF FEEDLOT OPERATIONS IN PCA NEEDING TREATMENT			TOTAL COST ($ thousands)		
	CATTLE	SWINE	POULTRY	CATTLE	SWINE	POULTRY	CATTLE (at $ * per system)	SWINE (at $ * per system)	POULTRY (at $ * per system)
MICHIGAN									
Delta	6	0	0	5	0	0	50	0	0
Dickinson	0	0	0	0	0	0	0	0	0
Menominee	27	0	0	15	0	0	150	0	0
WISCONSIN									
Brown	48	1	0	40	0	0	800	0	0
Calumet	25	3	1	15	0	0	300	0	0
Door	75	0	0	65	0	0	1,300	0	0
Kewaunee	200	0	0	190	0	0	3,800	0	0
Manitowoc	100	1	0	70	1	0	1,400	12	0
Oconto	105	0	1	94	0	0	1,880	0	0
Outagamie	60	0	1	30	0	0	600	0	0
Shawano	95	0	0	87	0	0	1,740	0	0
Sheboygan	28	0	0	20	0	0	400	0	0
Winnebago	0	0	0	0	0	0	0	0	0
TOTAL	769	5	3	631	1	0	12,420	12	0

*Michigan: $10,000/system for cattle
6,000/system for swine
3,000/system for poultry

*Wisconsin: $20,000/system for cattle
12,000/system for swine
7,000/system for poultry

On-Site Waste Disposal

Nonsewered nonfarm residences account for 26 percent of the total housing units in the planning subarea, or 83,117 units. Of this, 94 percent are in rural areas. The number of nonsewered households is projected to increase 14 percent between 1970 and 1990.

Table 33 shows the estimated distribution of units located within the potential contributing area. Nearly half (48 percent) of the nonsewered housing units in the potential contributing area are located in the Sheboygan-Green Bay complex (includes half of Brown County); about 27 percent are located in the Menominee complex and 15 percent in the Fox-Wolf River basin (includes half of Brown County).

There are many instances throughout this region where poorly drained or shallow soils or a high water table do not permit proper operation of septic tanks.

The estimated capital investment required to alleviate problems with failing septic systems in the potential contributing area is \$4.8 million, with an additional \$125 thousand per year in operating and maintenance costs (Table 33). The average annual cost is \$660 thousand per year.

Extrapolating these figures to the entire planning subarea yields an estimated capital cost of \$12.7 million and operating costs of \$340 thousand per year. The average annual cost was estimated to be \$1.4 million per year.

Other Problems

On an average annual basis, eleven harbors are dredged in RBG 2.1. Seventy-eight percent of the annual average dredge spoil removed between 1961 and 1970 in this region, or 196,860 cubic meters (297,333 cubic yards), contained polluted sediments requiring confinement. Two of the harbors, Green Bay and Menominee currently have confined disposal sites. All the sites are located along the Great Lakes shoreline, with Brown County generating 90,430 cubic meters (118,192 cubic yards) on an average annual basis between 1961 and 1970, or 46 percent of the polluted spoil requiring confinement in the region.

TABLE 33

ON-SITE WASTE DISPOSAL, RBG 2.1

COUNTY	TOTAL NUMBER OF SYSTEMS	PERCENT OF COUNTY IN PCA	ESTIMATED NUMBER OF SYSTEMS IN PCA	NUMBER FAILING	CAPITAL COST ($\$X10^6$)	OPERATING COST ($\$X10^3$)	AVERAGE ANNUAL ($\$X10^6$)
MICHIGAN							
Menominee	4,196	100	4,200	500	0.85	22.4	0.12
Dickinson	2,666	10	270	30	0.05	1.3	0.01
WISCONSIN							
Brown	4,386	75	3,290	590	1.00	26.4	0.14
Calumet	2,019	16	320	60	0.10	2.7	0.01
Door	4,343	20	870	160	0.27	7.2	0.04
Kewaunee	1,422	75	1,070	190	0.32	8.5	0.04
Manitowoc	1,184	80	950	170	0.29	7.6	0.04
Oconto	3,866	10	390	70	0.12	3.1	0.02
Outagamie	5,229	25	1,310	240	0.41	10.8	0.06
Shawano	4,786	10	480	90	0.15	4.0	0.02
Sheboygan	5,411	67	3,620	650	1.10	29.1	0.15
Winnebago	6,236	5	310	60	0.10	2.7	0.01
TOTAL	-	-	17,080	2,810	4.76	125.8	0.66

RIVER BASIN GROUP 2.2

DESCRIPTION

River Basin Group 2.2 covers the southwest portion of the Great Lakes Basin and drains an area of 5,633 square kilometers (2,175 square miles) of Wisconsin, Illinois, and Indiana lying along the Lake Michigan shoreline. As shown in Figure 13, the corresponding planning subarea includes seven counties in Wisconsin, six in Illinois, and four in Indiana. Of these 17 counties, only Ozaukee and Milwaukee counties in Wisconsin are completely in the RBG. The Chicago-Milwaukee complex is the sole hydrologic area in 2.2.

The bedrock geology of the region includes formations of the Precambrian, Cambrian, Ordovician, Silurian, Devonian, Mississippian, and Pennsylvania systems. The bedrock in the western portion principally is composed of dolomite while the southern area bedrock is mostly shale. Near-surface bedrock exposures contain deposits of coal and other minerals available for future extraction. A mantle of unconsolidated sediments of the Quaternary system cover the bedrock.

As Figure 14 shows, soils range from loams and clays with some organics in the north to predominantly sand, especially around the southern rim of Lake Michigan.

Mineral production includes clay, bituminous coal, peat, sand and gravel, and stone (limestone and dolomite).

The RBG has only 3,974 stream kilometers (2,470 stream miles), with a mean stream density of 0.7 kilometers of stream per square kilometer (1.1 mile per square mile). The major rivers are the Milwaukee, Menomonee, Root, and Galien Rivers, and Trail Creek. The Chicago Sanitary and Ship Canal removes most of Chicago's waste and reduces the natural drainage area to Lake Michigan significantly. Almost the entire coastline from Milwaukee, Wisconsin to Michigan City, Indiana is industrialized.

Table 34 shows the major land cover of RBG 2.2.

Thirty-two percent of the Great Lakes Basin population lives in this planning subarea. Since 1940, the population has increased by approximately one-third, from 6,034,291 to 9,491,743 in 1970. Ninety-four percent of the people live in urbanized areas, making it the most highly urbanized section of the lake basin. Major cities include Milwaukee, Wisconsin and Chicago, Illinois (not considered part of the basin), and many other smaller cities, notably (1975 population estimates): Kenosha (pop.: 80,727), Racine (pop.: 94,744), in Wisconsin; Waukegan (pop.: 65,133), Highland Park (pop.: 31,810), North Chicago (pop.: 42,639), and other Chicago suburbs in Illinois; and Gary (pop.: 167,546), Hammond (pop.: 104,892), and Michigan City (pop.: 41,166) in Indiana.

FIGURE 13

PLANNING SUBAREA 2.2

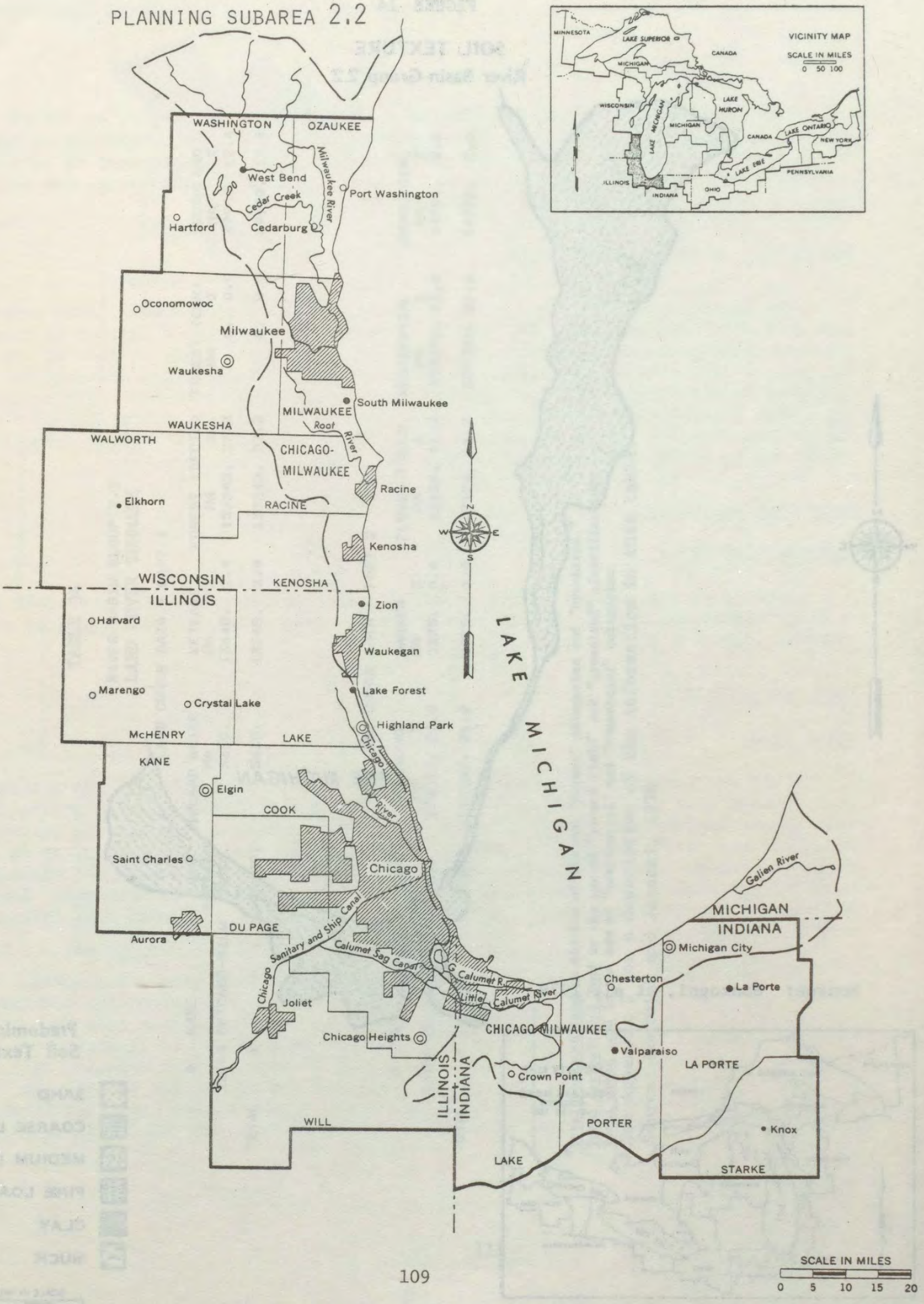
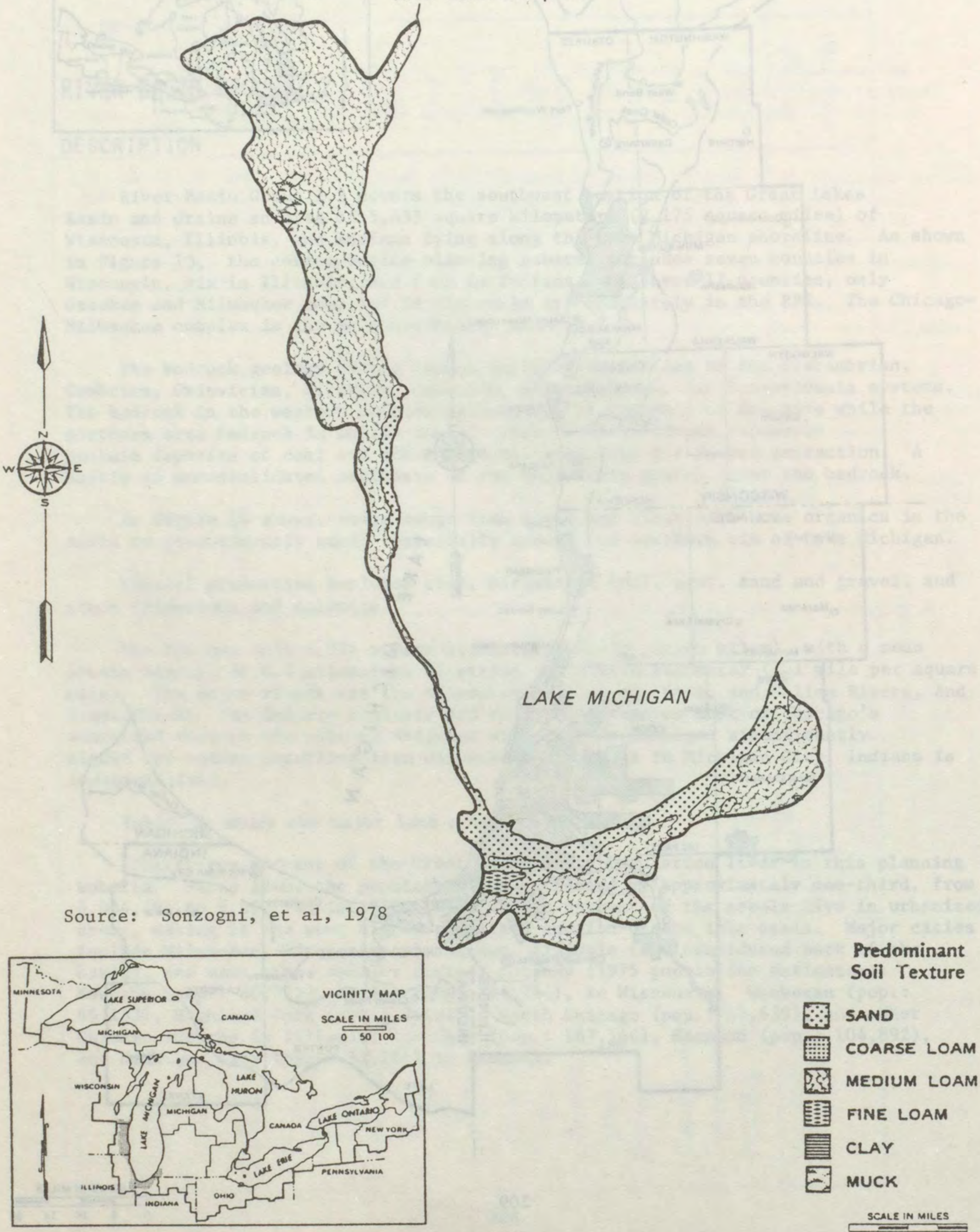


FIGURE 14

SOIL TEXTURE

River Basin Group 2.2



Source: Sonzogni, et al, 1978

TABLE 34

RIVER BASIN GROUP 2.2
LAND COVER SUMMARY

LAND COVER DATA - PART 1

#	NAME	LAND AREA:KM2	INLAND WATER HA	WETLAND HA	%	FOREST (DECID) HA	%	FOREST (CON) HA	%	BRUSHLAND HA	%
22100	CHICAGO-MILW	5630.	5630.	13648.	2.4	153545.	27.3	0.	0.0	69948.	12.4
TOTAL	1	5630.	5630.	13648.	2.4	153545.	27.3	0.	0.0	69948.	12.4

LAND COVER DATA - PART 2

#	NAME	LAND AREA:KM2	GRASSLAND HA	%	BARREN HA	%	PLOWED FIELD HA	%	RESIDENTIAL HA	%	COMMERCIAL HA	%
22100	CHICAGO-MILW	5630.	118287.	21.0	2275.	0.4	63124.	11.2	127386.	22.6	14786.	2.6
TOTAL	1	5630.	118287.	21.0	2275.	0.4	63124.	11.2	127386.	22.6	14786.	2.6

*Total forested land is the sum of the two "forest" categories and "brushland."
Total agricultural land is the sum of "plowed field" and "grassland" classifications.
Total urban land is the sum of "residential" and "commercial" categories.

See Appendix 3 for a description of the information in this table.

Source: Monteith and Jarecki, 1978

Total employment in Planning Subarea 2.2 was 3,918,980 in 1970, or 34% of the total employment in the Great Lakes region. Employment in manufacturing has risen appreciably since 1940 to 38.3 percent of the total. Employment in agriculture, forestry and fisheries was 30,400, only 0.8 percent of the total, and mining industries employed 4,300, only 0.1 percent.

POTENTIAL CONTRIBUTING AREA

The Chicago-Milwaukee complex is characterized by predominantly loamy soils and intensive urbanization. The entire hydrologic area north of Chicago is thus assumed to be potentially contributing, except for a small sandy portion of the headwaters of the Milwaukee River basin. Much of the Chicago area drainage is diverted to the Mississippi and cannot be considered as potentially contributing. Extensive coastal sand dunes further limit the area. However, approximately 80 percent or 4,500 square kilometers (1,730 square miles) of the total area is estimated to be potentially contributing, as Figure 15 indicates.

CRITICAL PROBLEM AREA IDENTIFICATION

CONTRIBUTION INDEX

Because of the unusual nature of RBG 2.2 (it includes several major urban and a large industrial complex within only one hydrologic area), an evaluation of the diffuse tributary loads was not conducted.

LAND USE ACTIVITIES

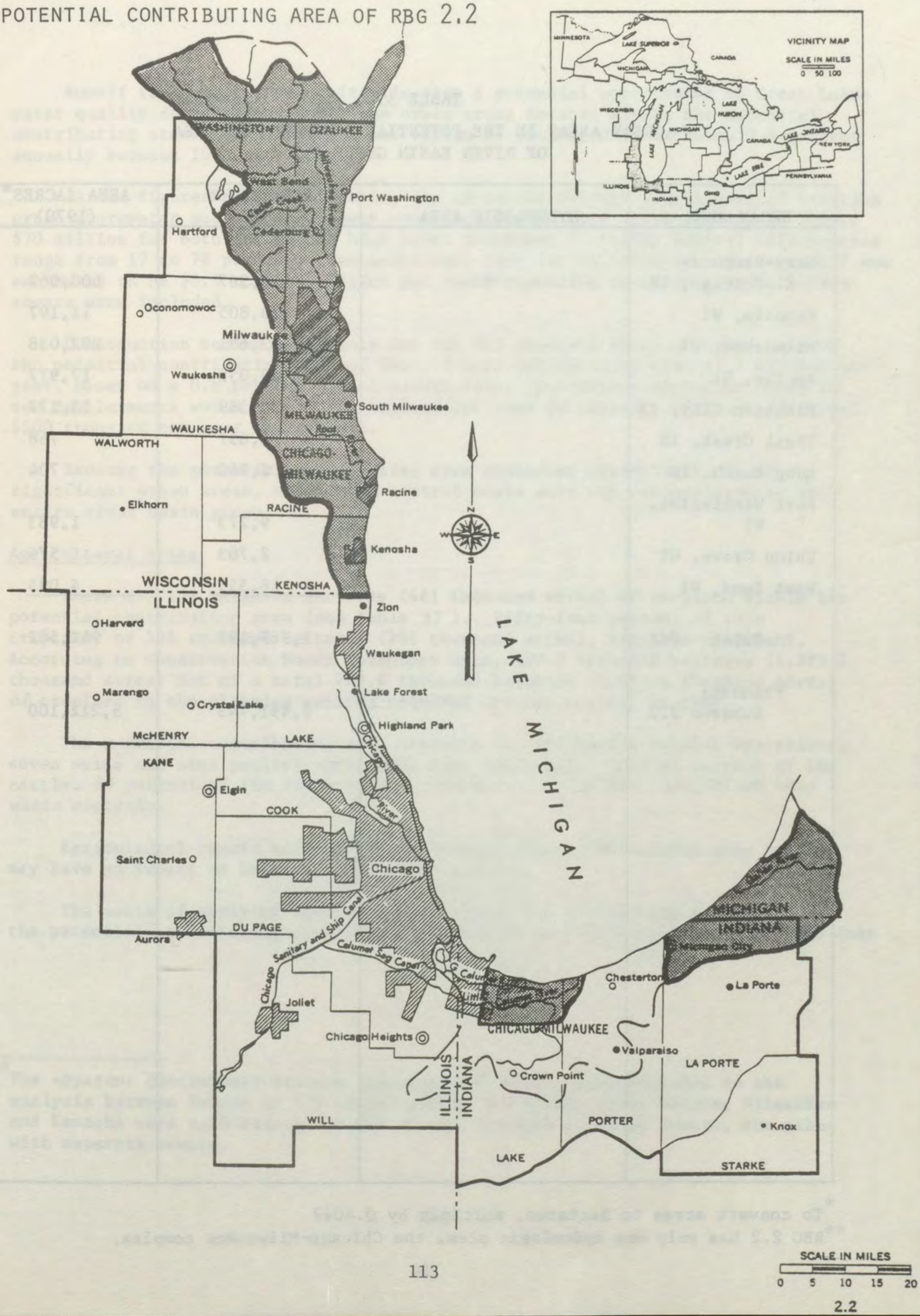
Urban Areas

There are ten urban areas with population greater than 2,500 in the potential contributing area of RBG 2.2, as Table 35 shows. The Chicago, Illinois metropolitan area is not included because the Tunnel and Reservoir Plan is designed to intercept and drain the city's wastewater and stormwater to the Mississippi River, as is explained below. The urban areas listed comprise about one-fifth of the planning subarea's population. Bacteria may be contributed to the lake by Milwaukee, Racine, and Kenosha, in Wisconsin and by Michigan City, and the Gary-Hammond-East Chicago area in Indiana.

The major urbanized areas in the potential contributing area - Milwaukee, Racine, Kenosha, and the Gary-Hammond-East Chicago area - have extensive combined sewer systems. In the Illinois portion of the Chicago metropolitan area the Chicago Underland Tunnel and Reservoir Plan (TARP) is designed to intercept combined sewer overflows, and to store them until treatment plant capacity is available. At that time, the wastewater is treated and discharged inland. In addition, combined sewer overflows in Lake County, Illinois have been significantly reduced by an extensive program of waste diversion to treatment plants discharging to inland streams [NIPC, 1976].

FIGURE 15

POTENTIAL CONTRIBUTING AREA OF RBG 2.2



2.2

TABLE 35

URBAN AREAS IN THE POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 2.2

URBAN AREA	HYDROLOGIC AREA	POPULATION (1970)	AREA (ACRES*) (1970)
Gary-Hammond-E. Chicago, IN	**	633,367	600,067
Kenosha, WI		78,805	11,197
Milwaukee, WI		1,083,631	292,038
Racine, WI		100,052	17,977
Michigan City, IN		39,369	13,177
Trail Creek, IN		2,697	768
Long Beach, IN		2,740	704
Port Washington, WI		9,273	1,983
Union Grove, WI		2,703	576
West Bend, WI		16,555	4,095
TOTAL - PCA		1,969,192	942,582
Planning Subarea 2.2		9,491,743	5,212,100

*To convert acres to hectares, multiply by 0.4047

**RBG 2.2 has only one hydrologic area, the Chicago-Milwaukee complex.

Runoff from construction sites is also a potential contributor to Great Lakes water quality degradation in all the urban areas located within the potential contributing area. Population in the region is projected to increase 0.8 percent annually between 1970 and 2020.

As the figures in Table 36 show, the estimated average annual cost of treating urban stormwater and combined sewer overflows varies from $19.6 million to almost $70 million for both medium and high level treatment.* Solids removal efficiencies range from 17 to 78 percent. The additional cost for chlorination of the runoff was estimated to be $0.5 to $5.0 million per year, depending on whether or not storm sewers were included.

Construction sediment controls for the 943 thousand acres of urban land in the potential contributing area of RBG 2.2 were estimated to cost $2.9 million per year, based on a 0.8 percent annual growth rate. Stormwater detention ponds in new developments would cost $25.0 million per year to install, with an additional $500 thousand per year maintenance.

Because the potential contributing area contained essentially all of the significant urban areas, urban area control costs were not extrapolated to the entire river basin group.

<u>Agricultural Areas</u>

There are 194 thousand hectares (481 thousand acres) of cropland within the potential contributing area (see Table 37). Fifty-four percent of this cropland, or 106 thousand hectares (261 thousand acres), requires treatment. According to Conservation Needs Inventory data, 407.9 thousand hectares (1,255.2 thousand acres) out of a total 790.8 thousand hectares (1,954.1 thousand acres) of cropland in the planning subarea required erosion control in 1968.

The potential contributing area accounts for 196 cattle feedlot operations, seven swine and nine poultry operations (see Table 38). Only 12 percent of the cattle, 29 percent of the swine and 56 percent of the poultry operations have waste controls.

Agricultural runoff and intensive livestock operations within this region may have an impact on Lake Michigan water quality.

The costs of applying best management practices to all cropland in the potential contributing area were estimated to be $23.3 million in one-time cost

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*The apparent discrepancy between the number of urban areas included in the analysis between Tables 35 (10 areas) and 36 (12 areas) arose because Milwaukee and Kenosha were each treated as two areas, one with combined sewers, the other with separate sewers.

TABLE 36

URBAN CONTROL SUMMARY FOR RBG 22

NUMBER OF URBAN AREAS: 12

LOW LEVEL OF TREATMENT (<30% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.17

CAPITAL COST	: $	140198688.
ANNUAL OPERATING COST	: $	4139195.
AVERAGE ANNUAL COST*	: $	19584624.

MEDIUM LEVEL OF TREATMENT (30% TO 60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.60

CAPITAL COST	: $	500656128.
ANNUAL OPERATING COST	: $	12958544.
AVERAGE ANNUAL COST*	: $	68114912.

HIGH LEVEL OF TREATMENT (>60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.78

CAPITAL COST	: $	494920448.
ANNUAL OPERATING COST	: $	12996251.
AVERAGE ANNUAL COST*	: $	67520720.

CHLORINATION (MEDIUM AND HIGH LEVEL TREATMENT ONLY)

	COMBINED SEWER ONLY	COMBINED AND STORM SEWERS
CAPITAL:	2603124.	36659696.
O&M :	196567.	958841.
ANNUAL*:	483348.	4997573.

*Average annual cost equals capital amortized over 25 years at 10 percent interest per year plus annual operation and maintenance cost.

TABLE 37

COSTS FOR INSTALLING AGRICULTURAL BEST MANAGEMENT PRACTICES
IN THE POTENTIAL CONTRIBUTING AREA (PCA) OF RIVER BASIN GROUP 2.2

COUNTY	TOTAL ACRES* IN POTENTIAL CONTRIBUTING AREA	ACRES IN PCA NEEDING TREATMENT	COSTS FOR ALL SOILS ($ millions)		COSTS FOR FINE-TEXTURED SOILS ($ millions)	
			One-Time	Recurring	One-Time	Recurring
WISCONSIN						
Fond du Lac	42,000	15,120	0.03	0.10	0.02	0.06
Kenosha	15,000	7,000	1.40	0	0	0
Milwaukee	18,750	10,875	0.96	0	0	0
Ozaukee	74,863	43,932	4.61	0	2.09	0
Racine	65,000	35,000	7.00	0	0	0
Sheboygan	51,352	24,410	1.28	0	0.91	0
Waukesha	2,580	1,187	0.09	0	0.02	0
Washington	114,290	76,585	6.98	0	3.21	0
INDIANA						
Lake	3,370	2,670	0.04	0.02	0.01	**
Porter	800	623	0.01	**	**	**
LaPorte	28,500	21,459	0.57	0.11	0	0
MICHIGAN						
Berrien	64,000	22,400	0.29	0.09	0.23	0.05
TOTAL	480,505	261,261	23.26	0.32	6.49	0.11

*To convert acres to hectares, multiply by 0.4047

**Cost is negligible

TABLE 38

COST FOR INSTALLING AGRICULTURAL WASTE MANAGEMENT SYSTEMS
IN POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 2.2

COUNTY	TOTAL NUMBER OF FEEDLOT OPERATIONS >100 ANIMAL UNITS IN PCA			NUMBER OF FEEDLOT OPERATIONS IN PCA NEEDING TREATMENT			TOTAL COST ($ thousands)		
	CATTLE	SWINE	POULTRY	CATTLE	SWINE	POULTRY	CATTLE (at $ * per system)	SWINE (at $ * per system)	POULTRY (at $ * per system)
WISCONSIN									
Fond du Lac	12	4	2	9	3	2	180	36	14
Ozaukee	61	1	0	55	1	0	1,100	12	
Racine	12	0	6	10	0	1	200		7
Sheboygan	12	2	0	7	1	0	140	12	
Washington	86	0	1	83	0	1	1,660		7
MICHIGAN									
Berrien	13	0	0	8	0	0	80		
TOTAL	196	7	9	172	5	4	3,360	60	28

*Wisconsin: Cattle: $20,000
Swine: 12,000
Poultry: 7,000

*Michigan: Cattle: $10,000
Swine: 6,000
Poultry: 3,000

and $320 thousand per year in recurring costs. The average annual cost is thus $2.9 million. The costs if BMPs were limited to the fine-textured soils (39 thousand hectares) were estimated to be $6.5 million and $110 thousand per year, one-time and recurring, respectively. The annual cost in this case would be $830 thousand per year. Finally, the costs of BMP application to all lands needing treatment throughout the planning subarea were estimated to be $111.7 million and $1.5 million, one-time recurring, or an average annual cost of $13.8 million.

Animal waste control systems in the potential contributing area were estimated to cost $3,450 thousand: $3,360 thousand for cattle, $60 thousand for swine, and $28 thousand for poultry (see Table 38). In contrast, the estimated costs of installing systems for all operations requiring them throughout the planning subarea (not including Illinois) were $9,300 thousand for cattle, $1,100 thousand for swine, and $50 thousand for poultry. In average annual terms, the costs are $380 thousand and $1.2 million, respectively.

On-Site Waste Disposal

Of the total housing stock in the region, only eight percent, or 252,260 residential units were classified as nonsewered in the 1970 Census of Housing. Of this, 46 percent were in rural areas. Only about 14 percent of all the nonsewered units may be located within the potential contributing area as shown in Table 39. Wisconsin accounts for nearly 70 percent of the nonsewered units in the potential contributing area. The number of nonsewered households is projected to increase 15 percent between 1970 and 1990.

There are instances where a high water table, poorly drained soils, and a lack of proper maintenance have resulted in septic tank failures. In particular, portions of Washington, Ozaukee, Waukesha, Milwaukee and Kenosha counties in Wisconsin (especially the Root River basin) have septic tank problems [GLBC, 1976]. To a lesser degree, problems are found in portions of the potential contributing area of Lake County, Illinois and in the Indiana counties listed in Table 39.

As Table 39 shows, the estimated costs of correcting septic tank problems in the potential contributing area are $10.7 million in capital costs and $390 thousand per year in operating and maintenance costs. The average annual cost is thus $1.6 million per year. Extrapolating these results to all of planning subarea 2.2, the estimated capital costs are $75.8 million, with annual operating costs of $2.8 million. The average annual cost would be $11.2 million.

Other Problems

Based on the period 1961-1970, 91 percent of the average annual dredge spoil, or 382,990 cubic meters (500,645 cubic yards) contains polluted sediments requiring confinement. RBG 2.2 has 10 dredge spoil disposal sites all along Lake Michigan, three of which are located in Cook County, Illinois. The U.S. Army Corps of Engineers now disposes all polluted dredge spoil in diked areas although unpolluted spoil may still be deposited in a designated mid-lake area [NIPC, 1976]. Both total and polluted spoil are projected to decrease by more than 11 percent between 1970 and 1990.

TABLE 39

ON-SITE WASTE DISPOSAL, RBG 2.2

COUNTY	TOTAL NUMBER OF SYSTEMS	PERCENT OF COUNTY IN PCA	ESTIMATED NUMBER OF SYSTEMS IN PCA	NUMBER FAILING	CAPITAL COST ($X10^6)	OPERATING COST ($X10^3)	AVERAGE ANNUAL ($X10^6)
ILLINOIS							
Lake	25,183	13	3,270	390	0.73	26.6	0.11
INDIANA							
Lake	24,897	20	4,980	600	1.13	40.9	0.16
La Porte	11,735	22	2,580	310	0.58	21.1	0.08
Porter	13,636	5	680	80	0.15	5.5	0.02
WISCONSIN							
Kenosha	7,118	20	1,420	260	0.49	17.7	0.07
Milwaukee	7,020	100	7,020	1,260	2.37	85.9	0.35
Ozaukee	4,380	100	4,380	790	1.48	53.9	0.22
Racine	8,470	45	3,810	690	1.30	47.1	0.19
Washington	7,053	50	3,530	640	1.20	43.6	0.18
Waukesha	28,973	13	3,770	680	1.28	46.4	0.19
TOTAL	-	-	35,440	5,700	10.71	388.7	1.57

RIVER BASIN GROUP 2.3

DESCRIPTION

River Basin Group 2.3 is located in the south central portion of the Great Lakes Basin and drains those portions of Michigan and Indiana bordering the southeastern shore of Lake Michigan, an area of 33,556 square kilometers (12,956 square miles). Planning Subarea 2.3 consists of 19 Michigan counties and 6 Indiana counties (see Figure 16). There are five hydrologic areas in RBG 2.3: St. Joseph River, Black River complex (South Haven), Kalamazoo River, Black River complex (Ottawa County) and Grand River.

The sedimentary rocks in this region range upward from the Cambrian to the Jurassic systems. These rock formations yield oil and gas from deep wells, gypsum from underground mines, and limestone, sandstone, and shale from surface quarries and pits. Overlying the bedrock are unconsolidated sediments of the Quarternary system.

As Figure 17 illustrates, the southern part of the region is dominated by nearly level to hilly areas of sandy soils with some loam and clay soils near Lake Michigan. The northeast portion consists largely of loams. The northwest is mostly hilly with sandy soils interspersed with silts and clays. Along Lake Michigan the soils are sandy with prominent dunes. This area is used for dairy and livestock and general farming. The climate and sandy soil are especially suitable for fruit and truck crops.

This RBG contains nearly 17,700 stream kilometers (11,000 stream miles) including the following major rivers: St. Joseph, Elkhart, Kalamazoo, Black, Red Cedar, Grand and Paw Paw. Average stream density is 0.5 kilometer of stream per kilometer (0.8 mile per square mile).

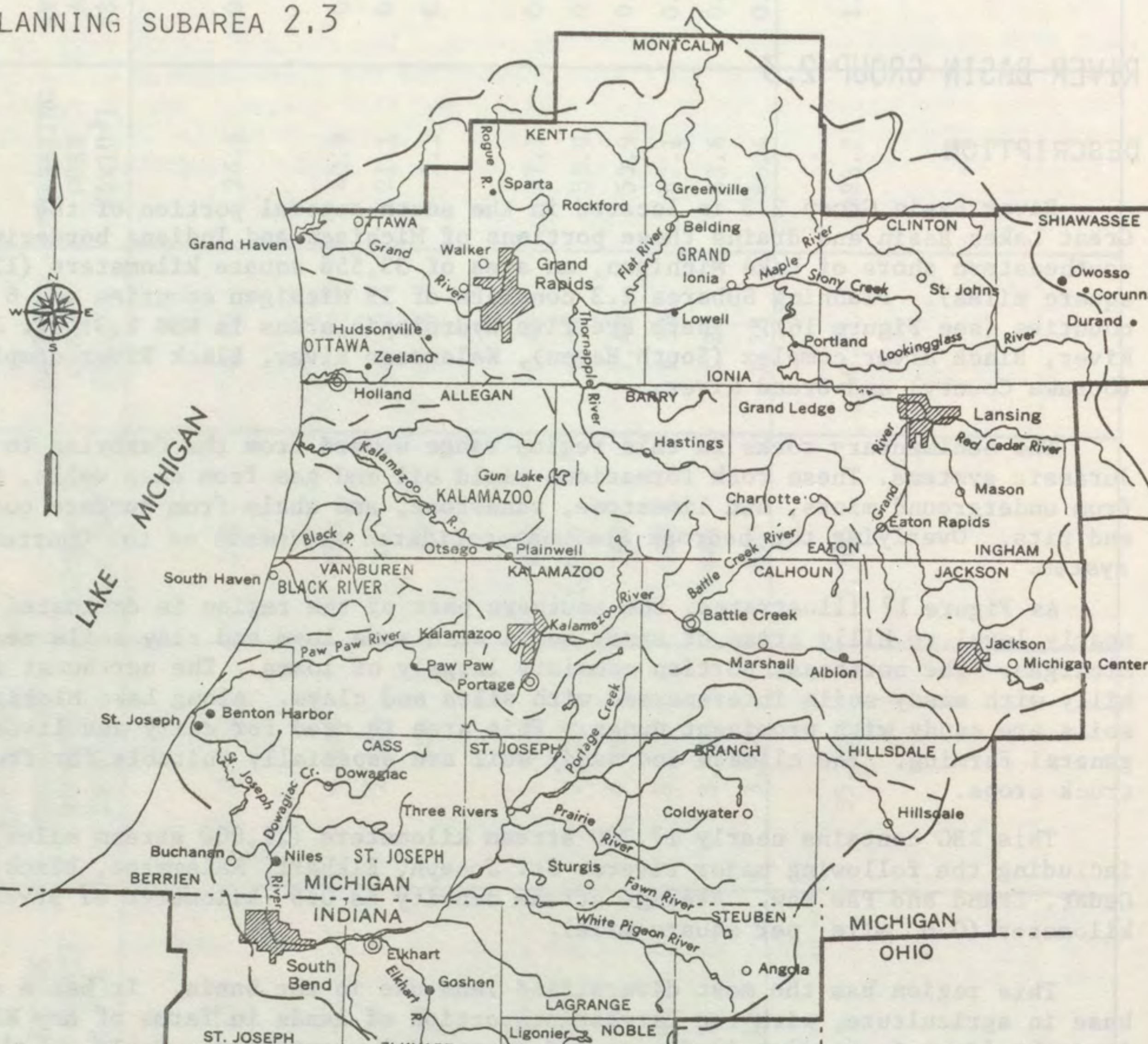
This region has the most diversified land use in the basin. It has a solid base in agriculture, with the largest proportion of lands in farms of any RBG. It ranks first in acreage in fruits and commercial vegetables. Table 40 shows the major land cover types in RBG 2.3.

Between 1940 and 1970 the planning subarea's population increased from approximately 1.5 to 2.5 million persons, an increase of 68.3 percent compared to an increase of 56 percent in the Great Lakes as a whole. Total employment increased 86 percent from 1940 to 1970, a rate of growth almost 20% higher than that of the Great Lakes. Manufacturing industries employed approximately 36 percent of the total, or 345,000 persons. The largest share of the population is employed in services and related industries, due to the large number of medium-size towns requiring appropriate service industries.

Major urban areas include (1975 population estimates): Elkhart (pop.: 43,959); and South Bend (pop.: 117,478), in Indiana; Benton Harbor (pop.: 15,675), Niles (pop.: 13,750), Battle Creek (pop.: 43,338), Lansing (pop.: 126,805), East Lansing (pop.: 50,425), Jackson (pop.: 43,994), Kalamazoo (pop.: 79,542) and Grand Rapids (pop.: 187,946), all in Michigan.

FIGURE 16

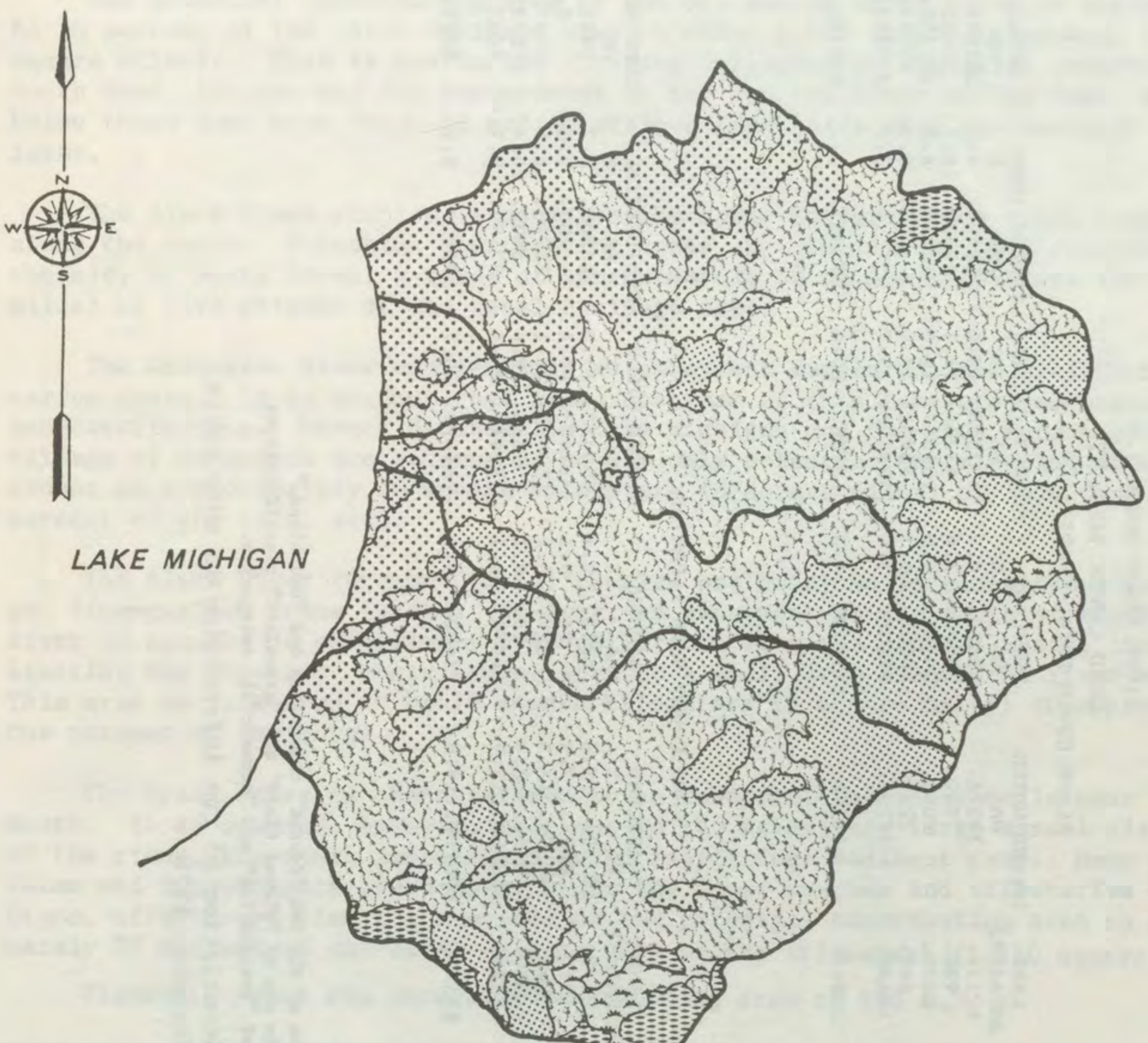
PLANNING SUBAREA 2.3



2.3

FIGURE 17

SOIL TEXTURE
River Basin Group 2.3



Source: Sonzogni, et al, 1978

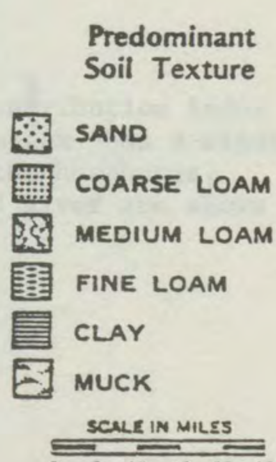


TABLE 40

RIVER BASIN GROUP 2.3

LAND COVER SUMMARY

LAND COVER DATA - PART 1

#	NAME	LAND AREA:KM2	INLAND WATER HA	WETLAND HA	%	FOREST (DECID) HA	%	FOREST (CON) HA	%	BRUSHLAND HA	%
23101	ST JOSEPH	12110.	19376.	50458.	4.2	157528.	13.0	50458.	4.2	301519.	24.9
23200	BLACK SH COM	930.	930.	3570.	3.8	17755.	19.1	17379.	18.7	33442.	36.0
23301	KALAMAZOO	5200.	8840.	20631.	4.0	101567.	19.5	22218.	4.3	152350.	29.3
23401	BLACK R OTTA	660.	2244.	10658.	16.1	15851.	24.0	0.	0.0	18516.	28.1
23501	GRAND	14660.	11728.	57635.	3.9	376845.	25.7	0.	0.0	302953.	20.7
TOTAL	5	33560.	43118.	142952.	4.3	669545.	20.0	90055.	2.7	808780.	24.1

LAND COVER DATA - PART 2

#	NAME	LAND AREA:KM2	GRASSLAND HA	%	BARREN HA	%	PLOWED FIELD HA	%	RESIDENTIAL HA	%	COMMERCIAL HA	%
23101	ST JOSEPH	12110.	152606.	12.6	1231.	0.1	450433.	37.2	44305.	3.7	2461.	0.2
23200	BLACK SH COM	930.	6576.	7.1	94.	0.1	13433.	14.4	752.	0.8	0.	0.0
23301	KALAMAZOO	5200.	69298.	13.3	529.	0.1	120081.	23.1	31740.	6.1	1587.	0.3
23401	BLACK R OTTA	660.	5466.	8.3	68.	0.1	8335.	12.6	6832.	10.4	273.	0.4
23501	GRAND	14660.	263052.	17.9	1478.	0.1	372411.	25.4	87192.	5.9	4433.	0.3
TOTAL	5	33560.	496998.	14.8	3400.	0.1	964694.	28.7	170820.	5.1	8755.	0.3

* <u>Total forested land</u> is the sum of the two "forest" categories and "brushland."
<u>Total agricultural land</u> is the sum of "plowed field" and "grassland" classifications.
<u>Total urban land</u> is the sum of "residential" and "commercial" categories.

See Appendix 3 for a description of the information in this table.
Source: Monteith and Jarecki, 1978

POTENTIAL CONTRIBUTING AREA

The potential contributing area of the St. Joseph River basin is estimated to be 30 percent of the total drainage area or about 3,600 square kilometers (1,380 square miles). This is due to the limiting influence of the large reservoir above South Bend, Indiana and the impoundment on the Paw Paw River at Paw Paw. Areas below these dams have fine- to medium-grained loam soils with few wetlands and lakes.

The Black River complex is dominated by sandy soils, with a small loamy area along the coast. Potential contributing areas are confined to this section plus the city of South Haven, a total of approximately 50 square kilometers (20 square miles) or five percent of the total drainage area.

The Kalamazoo River empties into an embayment separated from Lake Michigan by narrow dunes. It is assumed that areas upstream of this lake are essentially non-contributing. Direct drainage to Lake Michigan and the area encompassing the village of Saugatuck are assumed to be the only potential contributing area; these amount to approximately 10 square kilometers (5 square miles) or less than one percent of the total area.

The Black River (Ottawa County) complex has sandy soils along the lake shore and fine-grained loams inland. However, an embayment at the mouth of the Black River is assumed to effectively trap pollutants from the central basin, thus limiting the potential contributing area to a small area around the river mouth. This area is estimated to be 10 square kilometers (5 square miles) or approximately one percent of the total.

The Grand River is characterized by an embayment and sandy soils near the mouth. It is assumed, however, that due to the relatively large annual discharge of the river, the mouth impoundment is an inefficient sediment trap. Many other lakes and impoundments are present along the upper reaches and tributaries of the Grand, effectively limiting the size of the potential contributing area to approximately 20 percent of the basin or about 299 square kilometers (1,110 square miles).

Figure 18 shows the potential contributing area of RBG 2.3.

CRITICAL PROBLEM AREA IDENTIFICATION

CONTRIBUTION INDEX

As Table 41 shows, of those hydrologic areas for which a contribution index value was calculated, only one--the Black River (South Haven) complex--has a significant input of sediment to the lakes. In terms of total and orthophosphorus, however, both the Black River (South Haven) complex and the Grand River are shown to be significant diffuse source phosphorus contributors.

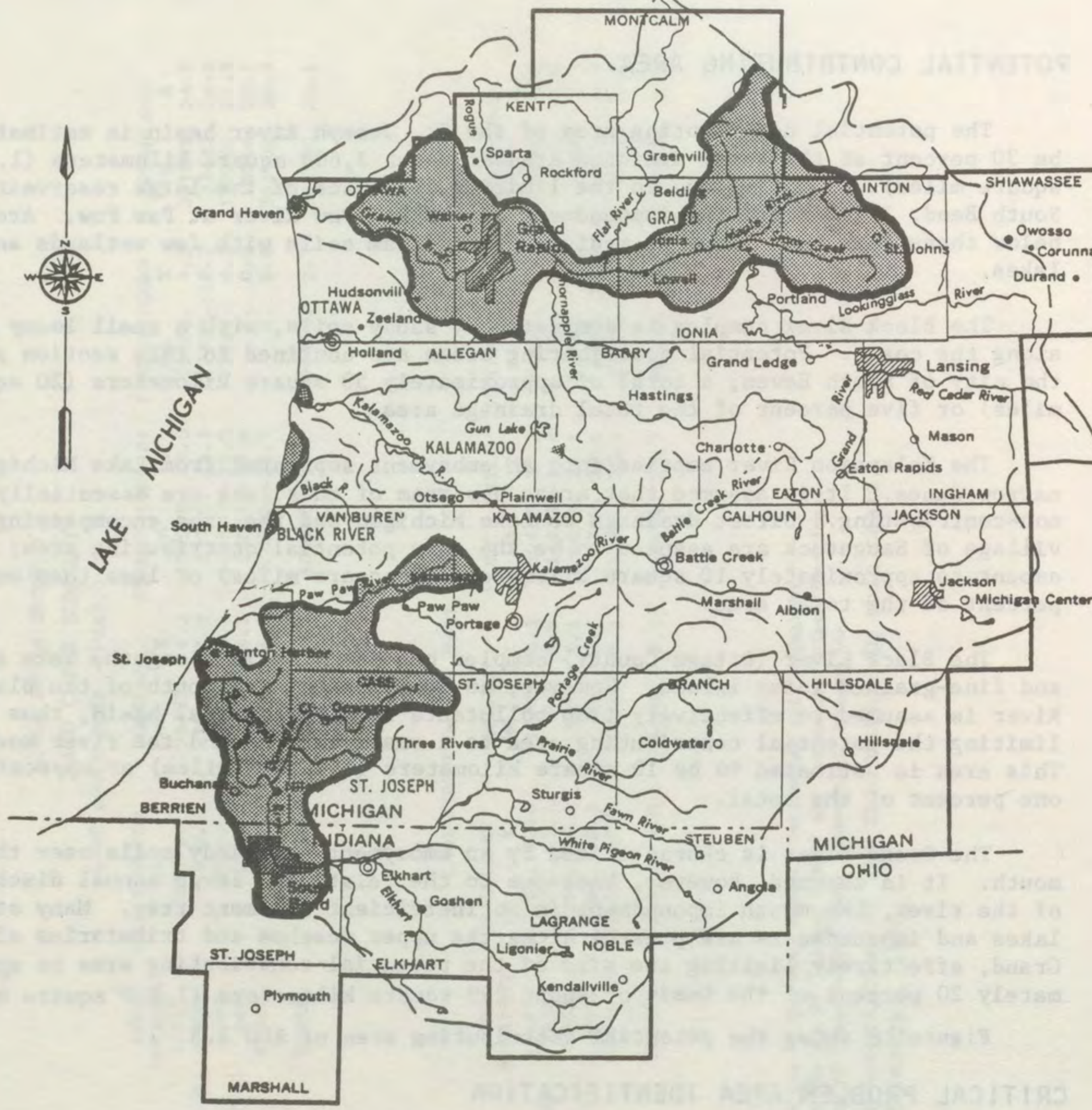
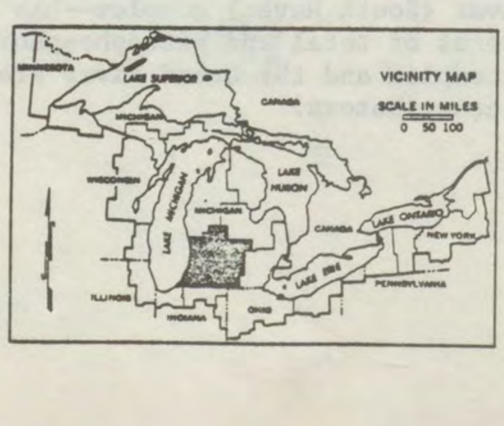


FIGURE 18

POTENTIAL CONTRIBUTING AREA OF RBG 2.3



2.3

TABLE 41

CONTRIBUTION INDICES
RIVER BASIN GROUP 2.3

HYDROLOGIC AREA	LAND AREA (km^2)*	PCA AREA (km^2)*	SUSPENDED SOLIDS	TOTAL PHOSPHORUS	ORTHO PHOSPHORUS
Saint Joseph River	12,110	3,630	0.3	0.5	0.5
Black River (S. Haven) Complex	930	50	1.0	2.6	2.9
Kalamazoo River	5,200	50†	–	–	–
Black River (Ottawa Co.) Complex	660	10†		–	–
Grand River	14,660	2,930	0.4	2.2	1.6

*To convert square kilometers to square miles, multiply by 0.386

$$CI = \frac{\text{(\% of Great Lakes Diffuse Load)} \atop \text{(from hydrologic area)}}{\text{(\% of Great Lakes PCA in)} \atop \text{(hydrologic area)}}$$

†PCA assumed to be 1% of total drainage area

Total Great Lakes PCA = 105,950 km^2

Total Great Lakes Diffuse Loads

Suspended Solids = 9,492,407 Mtonnes/yr.

Total P = 13,155 Mtonnes/yr.

Ortho P = 3,007 Mtonnes/yr.

NOTE: Loads are average of 1975 and 1976 values with Lake Erie values assured equal for both years

LAND USE ACTIVITIES

Urban Areas

There are 15 urban areas with population greater than 2,500 in the potential contributing area of RBG 2.3 (Table 42). These comprise 32 percent of the planning subarea's population.

Only South Bend, Indiana and Grand Rapids, Michigan may contribute bacteria to the lake. Grand Rapids, Grand Haven, Spring Lake, St. John's, Ionia, Lowell, and South Haven, Michigan are located in high load areas. Most of the largest urban areas have some combined sewers.

Construction site runoff from all the urban areas in the potential contributing area may contribute to Great Lakes pollution. Population is projected to increase 0.8 percent annually between 1970 and 2020.

The average annual cost of controlling urban stormwater and combined sewer overflows in the 15 urban areas in the potential contributing area was estimated to range from $8.9 million for low efficiency (18 percent solids removal) treatment, to $22.3 million for high efficiency removal (85 percent). The addition of chlorination for those areas considered to be potential sources of bacteria would add from $250 to $680 thousand per year (see Table 43).

The cost of providing construction sediment controls for the urban areas within the PCA was estimated to be almost $600 thousand per year. Detention ponds in all new developments would cost $4.5 million per year for new ponds plus $90 thousand per year maintenance.

Table 44 shows the estimated costs of applying urban stormwater and combined sewer controls to all urban areas in RBG 2.3. Average annual costs range from $18.4 million to $45.7 million. Costs for chlorination have not been included. Construction sediment controls would cost $960 thousand per year. Detention ponds would cost $7.2 million per year to install and $140 thousand per year to maintain.

Agricultural Areas

There are 295 thousand hectares (729 thousand acres) of cropland within the potential contributing area of RBG 2.3 (see Table 45). Fifty-seven percent of this cropland, or 168 thousand hectares (416 thousand acres), requires treatment. According to Conservation Needs Inventory data, 1,448 thousand hectares (3,579 thousand acres) out of a total 2,175 thousand hectares (5,375 thousand acres) of cropland in the planning subarea required erosion control treatment in 1968.

The potential contributing area accounts for 247 cattle and 14 swine feedlot operations. Only 28% of the cattle feedlots and half of the swine operations have waste controls.

TABLE 42

URBAN AREAS IN THE POTENTIAL CONTRIBUTING AREA
OF RIVER BASIN GROUP 2.3

URBAN AREA	HYDROLOGIC AREA		POPULATION (1970)	AREA (ACRES*) (1970)
South Bend, IN	St. Joseph River	2.3.1	205,997	57,064
South Bend Metropolitan, MI	St. Joseph River	2.3.1	12,988	8,699
Grand Rapids, MI	Grand River	2.3.5	321,433	93,529
Benton Harbor, MI	St. Joseph River	2.3.1	16,481	2,302
St. Joseph, MI	St. Joseph River	2.3.1	11,042	2,366
Grand Haven, MI	Grand River	2.3.5	11,844	3,327
Spring Lake, MI	Grand River	2.3.5	3,034	961
Buchanan, MI	St. Joseph River	2.3.1	4,645	1,279
Dowagiac, MI	St. Joseph River	2.3.1	6,583	1,662
St. John's, MI	Grand River	2.3.5	6,672	1,919
Ionia, MI	Grand River	2.3.5	6,361	1,601
Lowell, MI	Grand River	2.3.5	3,068	1,919
Hartford, MI	St. Joseph River	2.3.1	2,508	640
South Haven, MI	Black River	2.3.2	6,471	1,536
Niles, MI	St. Joseph River	2.3.1	12,988	3,328
TOTAL - PCA			632,115	182,132
Planning Subarea 2.3			2,529,869	8,955,400

*To convert acres to hectares, multiply by 0.4047

TABLE 43

URBAN CONTROL SUMMARY FOR RBG 23

NUMBER OF URBAN AREAS: 15

LOW LEVEL OF TREATMENT (<30% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.18

CAPITAL COST	: $	62858960.
ANNUAL OPERATING COST	: $	1935194.
AVERAGE ANNUAL COST*	: $	8860251.

MEDIUM LEVEL OF TREATMENT (30% TO 60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.54

CAPITAL COST	: $	129020896.
ANNUAL OPERATING COST	: $	2210998.
AVERAGE ANNUAL COST*	: $	16424996.

HIGH LEVEL OF TREATMENT (>60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.85

CAPITAL COST	: $	167522960.
ANNUAL OPERATING COST	: $	3807875.
AVERAGE ANNUAL COST*	: $	22263568.

CHLORINATION (MEDIUM AND HIGH LEVEL TREATMENT ONLY)

	COMBINED SEWER ONLY	COMBINED AND STORM SEWERS
CAPITAL:	1357980.	4410221.
O&M :	96115.	198449.
ANNUAL*:	245721.	684315.

* Average annual cost equals capital amortized over 25 years at 10 percent interest per year plus annual operation and maintenance cost.

TABLE 44

ESTIMATED COST OF CONTROLS FOR ALL URBAN AREAS, RBG 2.3

TREATMENT LEVEL		COST IN PCA ($ millions)	ADJUSTED AREA IN PCA (ACRES*)	COST PER ACRE ($)	TOTAL URBAN ACREAGE	ADJUSTED** URBAN ACREAGE	RBG COST ($ millions)
LOW	Capital	62.86	49,640	1,270	292,200	102,270	129.9
	O&M	1.93	49,640	40	292,200	102,270	4.1
MEDIUM	Capital	129.02	49,640	2,600	292,200	102,270	265.9
	O&M	2.21	49,640	45	292,200	102,270	4.6
HIGH	Capital	167.52	49,640	3,370	292,200	102,270	344.6
	O&M	3.81	49,640	75	292,200	102,270	7.7

*To convert acres to hectares, multiply by 0.4047

**Composite urban area adjustment factor = 0.35

Average Annual Cost:

Low:	$18.4	million
Medium:	33.9	million
High:	45.7	million

TABLE 45

COSTS FOR INSTALLING AGRICULTURAL BEST MANAGEMENT PRACTICES IN THE POTENTIAL CONTRIBUTING AREA (PCA) OF RIVER BASIN GROUP 2.3

COUNTY	TOTAL ACRES* IN POTENTIAL CONTRIBUTING AREA	ACRES IN PCA NEEDING TREATMENT	COSTS FOR ALL SOILS ($ millions)		COSTS FOR FINE-TEXTURED SOILS ($ millions)	
			One-Time	Recurring	One-Time	Recurring
INDIANA						
St. Joseph	24,120	18,216	0.28	0.14	0.07	0.06
MICHIGAN						
Allegan	8,955	1,885	0.03	0.01	0.03	0.01
Berrien	136,000	47,600	0.47	0.19	0.15	0.03
Cass	97,000	42,000	0.31	0.17	0	0
Clinton	143,470	121,070	3.22	0.42	3.22	0.42
Gratiot	10,820	1,082	0.03	**	0.03	**
Ionia	80,000	50,000	0.84	0.17	0.44	0.06
Kalamazoo	3,000	1,000	0.01	**	0	0
Kent	35,000	14,000	0.20	0.05	0.02	**
Montcalm	55,825	23,825	0.34	0.08	0	0
Ottawa	75,000	55,000	0.82	0.19	0.24	0.05
Van Buren	60,000	40,000	0.33	0.17	0	0
TOTAL	729,190	415,678	6.88	1.59	4.20	0.63

*To convert acres to hectares, multiply by 0.4047

** Cost is negligible

Agricultural runoff and intensive livestock operations within this region may have a significant impact on Lake Michigan water quality.

Table 45 shows the estimated costs of applying best management practices to all cropland on medium- and fine-textured soils in the potential contributing area. One-time costs are $6.9 million, with annual recurring costs of $1.6 million. The average annual cost is thus $2.4 million. Limiting the use of BMPs to only the fine-textured soils (69 thousand hectares) would reduce the one-time and recurring costs to $4.2 million and $0.6 million, respectively. The annual cost would be $1.1 million. The estimated costs for applying BMPs to all lands in Planning Subarea 2.3 identified as needing erosion controls in the 1968 Conservation Needs Inventory are $59.1 million one-time and $13.6 million recurring, for an average annual cost of $20.1 million.

As Table 46 shows, the addition of agricultural waste management controls to those operations needing them would cost $249 thousand; $207 thousand for cattle, and $42 thousand for swine. Extrapolating these results to all operations in Planning Subarea 2.3 yields an estimated cost of $21.2 million: $18.3 million for cattle, $2.6 million for swine, and $243 thousand for poultry. In average annual terms, the potential contributing area and extrapolated costs are $30 thousand and $2.3 million, respectively.

On-Site Waste Disposal

Of the total number of housing units in Planning Subarea 2.3, 41 percent (or 327,298) were nonsewered in the 1970 Census. About 20 percent of the nonsewered housing stock in the region, or almost 67,000 units, may be located within the potential contributing area (Table 47). The St. Joseph River basin at 57 percent and the Grand River basin at 42 percent, account for almost all the nonsewered units in the potential contributing area. The number of nonsewered households in this region is projected to increase 20 percent between 1970 and 1990.

As the figures in Table 47 show, the average annual cost of correcting on-site disposal problems in the potential contributing area of RBG 2.3 is $2.2 million: $15.6 million capital costs, with $0.5 million per year operating and maintenance. Extrapolating these estimates to all on-site systems in Planning Subarea 2.3 yields capital and operating costs of $54.4 and $1.8 million, respectively. The average annual cost is $7.8 million.

Other Problems

On an average annual basis, five harbors in RBG 2.3 are dredged of 286,830 cubic meters (374,940 cubic yards) of material. Of this, 34 percent contains polluted sediments requiring confinement. Two harbors, Grand Haven (accounting for over half of the polluted dredge spoil in the region) and Holland, currently use a diked system. Both total and polluted spoil are projected to decrease about seven percent between 1970 and 1990.

Polluted dredge spoil disposal is considered to have a significant effect on Lake Michigan water quality. The major problems are: Benton Harbor/St. Joseph with 13,640 average annual cubic meters (17,830 cubic yards) of polluted spoil from

TABLE 46

COST FOR INSTALLING AGRICULTURAL WASTE MANAGEMENT SYSTEMS IN POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 2.3

COUNTY	TOTAL NUMBER OF FEEDLOT OPERATIONS >100 ANIMAL UNITS IN PCA			NUMBER OF FEEDLOT OPERATIONS IN PCA NEEDING TREATMENT			TOTAL COST ($ thousands)		
	CATTLE	SWINE	POULTRY	CATTLE	SWINE	POULTRY	CATTLE (at $10,000 per system)	SWINE (at $6,000 per system)	POULTRY (at $3,000 per system)
INDIANA									
St. Joseph	7	14	0	4	7	0	40	42	0
MICHIGAN									
Allegan	2	0	0	0	0	0	0	0	0
Berrien	7	0	0	6	0	0	60	0	0
Cass	29	0	0	18	0	0	180	0	0
Clinton	63	0	0	57	0	0	57	0	0
Gratiot	9	0	0	8	0	0	8	0	0
Ionia	50	0	0	42	0	0	42	0	0
Kalamazoo	2	0	0	2	0	0	2	0	0
Kent	12	0	0	4	0	0	4	0	0
Montcalm	4	0	0	4	0	0	4	0	0
Ottawa	30	0	0	20	0	0	20	0	0
Van Buren	32	0	0	12	0	0	12	0	0
TOTAL	247	14	0	177	7	0	207	42	0

TABLE 47

ON-SITE WASTE DISPOSAL, RBG 2.3

COUNTY	TOTAL NUMBER OF SYSTEMS	PERCENT OF COUNTY IN PCA	ESTIMATED NUMBER OF SYSTEMS IN PCA	NUMBER FAILING	CAPITAL COST ($X10^6)	OPERATING COST ($X10^3)	AVERAGE ANNUAL COST ($X10^6)
INDINA							
St. Joseph	19,279	28	5,400	650	1.17	37.7	0.07
MICHIGAN							
Berrien	26,567	70	18,600	2,230	4.01	129.3	0.57
Cass	10,978	50	5,490	660	1.19	38.3	0.17
Clinton	7,642	35	2,680	320	0.57	18.5	0.08
Kent	36,577	33	12,070	1,450	2.61	84.0	0.37
Allegan	13,726	8	1,100	130	0.23	7.5	0.03
Ionia	6,235	50	3,120	370	0.66	21.4	0.09
Montcalm	7,546	30	2,260	270	0.48	15.6	0.07
Ottawa	21,441	50	10,720	1,290	2.32	74.8	0.33
St. Joseph	8,101	50	4,050	590	0.88	28.4	0.12
Van Buren	11,104	60	6,660	800	1.44	46.4	0.20
TOTAL			72,150	8,660	15.56	501.9	2.20

1961-1970; and South Haven with 8,860 cubic meters (11,582 cubic yards). These account for 23 percent of the region's average annual volume of dredge spoil.

Problems have occurred in the area with liquid and deepwell disposal of toxic substances. Although groundwater contamination is known to have taken place, the effect of these operations on Lake Michigan is unknown. There also may be problems associated with the disposal of brines from the almost 1,500 oil and gas wells in RBG 2.3.

RIVER BASIN GROUP 2.4

DESCRIPTION

River Basin Group 2.4 drains into northeastern Lake Michigan and consists of eight hydrologic areas covering more than 33,670 square kilometers (13,000 square miles) all within Michigan. Three counties of the corresponding planning subarea are located in the upper peninsula and eighteen counties are in the northern half of the lower peninsula (see Figure 19). The hydrologic areas are: Muskegon River, Sable complex, Manistee River, Traverse complex, Seul-Choix Groscap complex, Manistique River, Bay De Noc complex and Escanaba River.

Except for a relatively thin and discontinuous layer of Mesozaic rocks, all of the sedimentary formations in RBG 2.4 are of Paleozaic age. Oil, gas, salt, and brine are extracted from the formations through wells; surface quarries and pits yield limestone, dolomite and shale. Overlying sediments are of glacial origin. These sediments contain sand and gravel and peat deposits which are mined in surface pits.

As Figure 20 illustrates, soils are primarily sandy with some scattered areas of loams and organics. Rock outcrops and shallow soils occur. Fragipans are common in the north.

There are over 16,000 stream kilometers (10,000 stream miles) here. Most streams are short with small drainage basins. Mean stream density is only 0.5 kilometer of stream per square kilometer (0.8 mile per square mile). Major streams include the Muskegon, Manistee, Manistique, and Escanaba Rivers.

Much of the northern portion is in second growth forest. Fruit, vegetable, dairy and livestock production are dominant agricultural operations. Year-round recreation is an important land use. Table 48 shows the major land cover in each of the eight hydrologic areas.

Population in the area has increased from approximately 368,700 in 1940 to about 496,500 in 1970. Forty-two percent of the population is urban. Important urban areas are (1975 population estimates): Traverse City (pop.: 19,637), Escanaba (pop.: 14,708), Petoskey (pop.: 6,184), Manistee (pop.: 8,046), Ludington (pop.: 9,545), Big Rapids (pop.: 14,867), and Muskegon (pop.: 44,176). Between 1940 and 1970 employment rose from 110,700 to 171,900. Manufacturing-related employment amounted to 56,700 in 1970, just under 33 percent of total employment. This is about two percent lower than the Lake Michigan average, but eight percent higher than the national average. Employment in agriculture, forestry and fisheries, has declined steadily over the past thirty years to approximately 6,500 in 1970. This is 3.8 percent of the total employment, which is more than twice the basin average, but slightly below the national average.

FIGURE 19

PLANNING SUBAREA 2.4

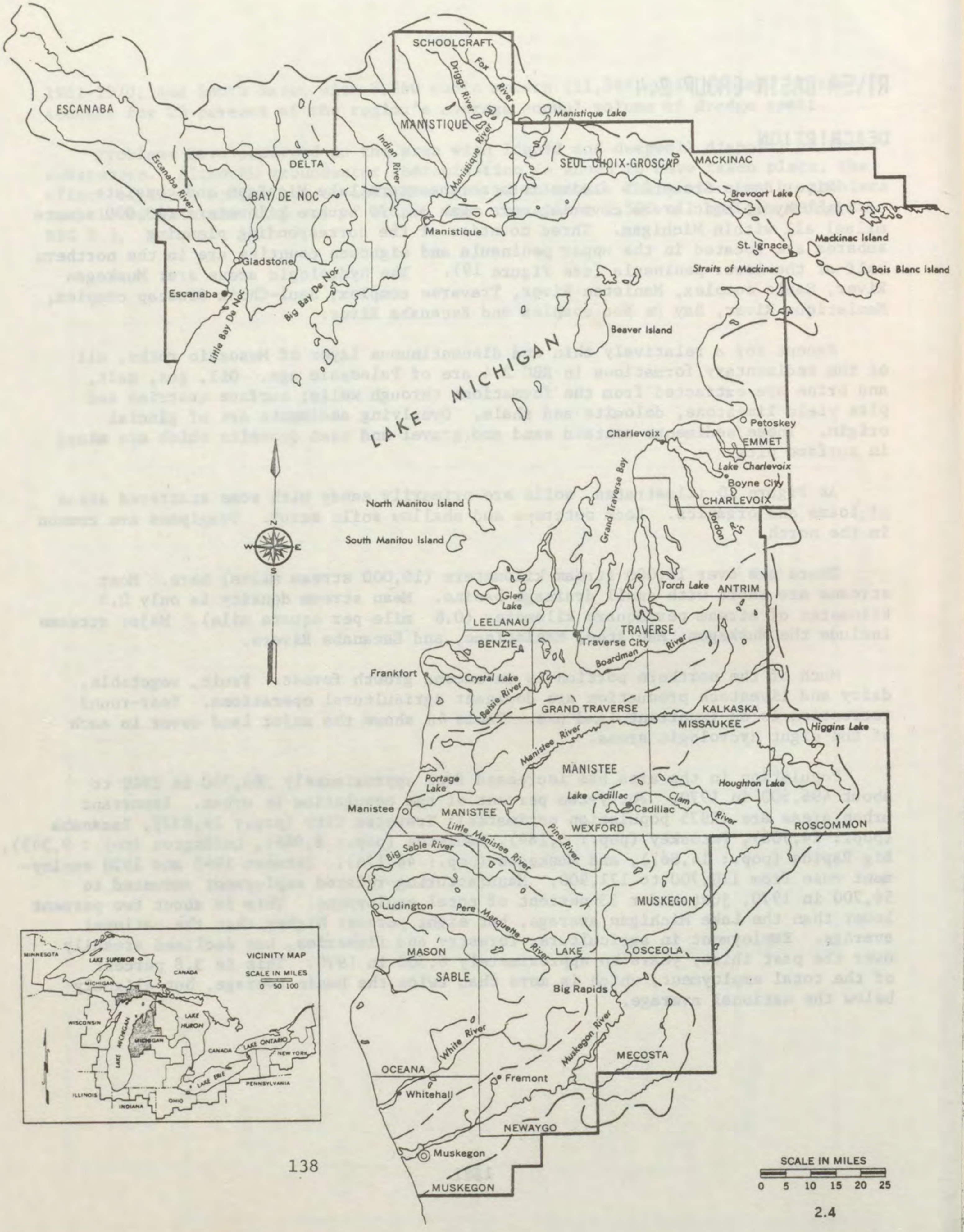
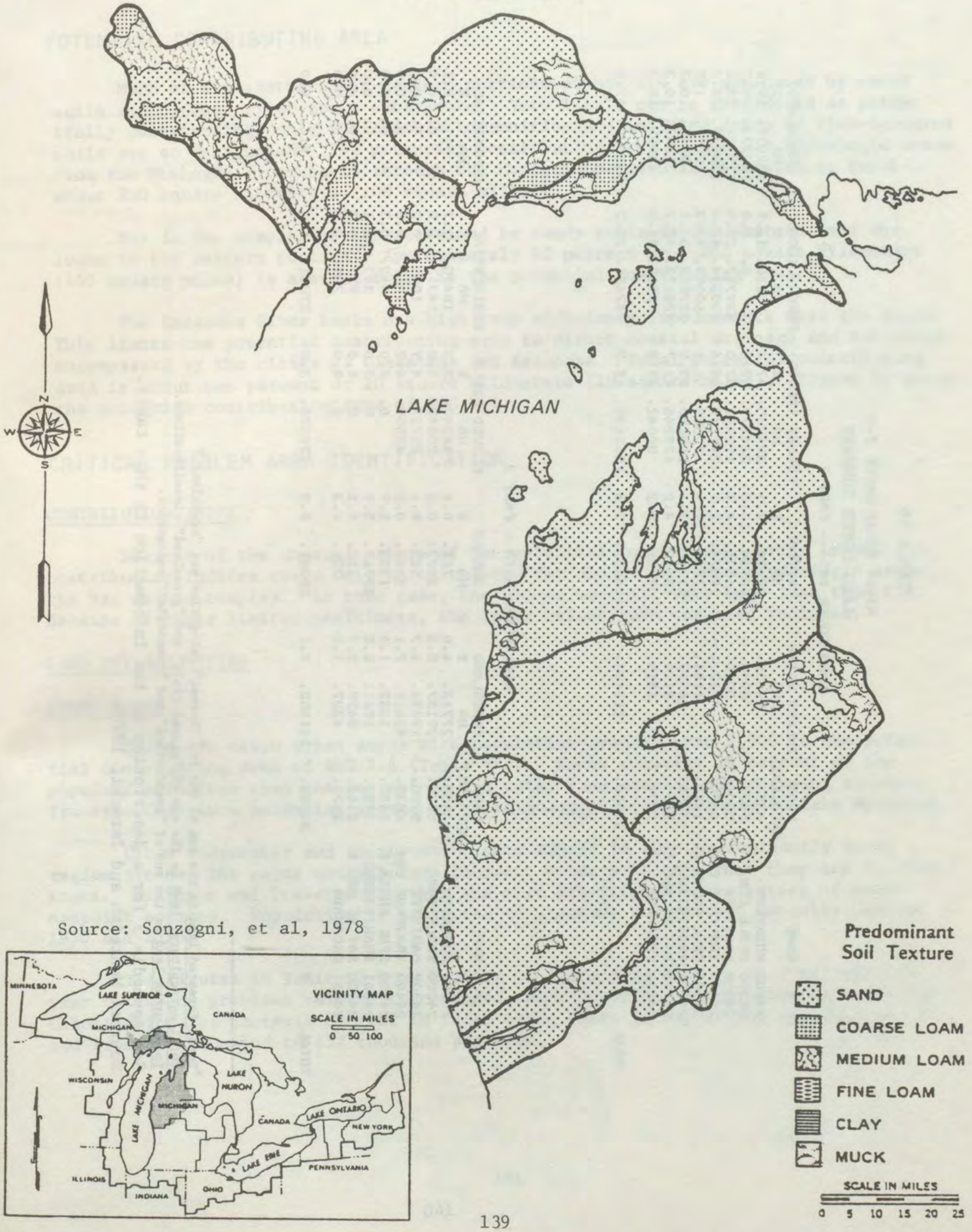


FIGURE 20

SOIL TEXTURE

River Basin Group 2.4



Source: Sonzogni, et al, 1978

TABLE 48

RIVER BASIN GROUP 2.4

LAND COVER SUMMARY

LAND COVER DATA - PART 1

#	NAME	LAND AREA:KM2	INLAND WATER HA	WETLAND HA	%	FOREST (DECID) HA	%	FOREST (CON) HA	%	BRUSHLAND HA	%
24102	MUSKEGON	6850.	24660.	48320.	7.1	324735.	47.4	95218.	13.9	132879.	19.4
24200	SABLE COM	5030.	8048.	66964.	13.3	264279.	52.5	0.	0.0	102236.	20.3
24302	MANISTEE	5200.	5200.	21535.	4.1	192242.	37.0	139717.	26.9	119758.	23.0
24400	TRAVERSE COM	6830.	47127.	19074.	2.8	291247.	42.6	120314.	17.6	158462.	23.2
24500	SEUL-CHOIX C	1420.	6106.	3858.	2.7	72558.	51.1	60094.	42.3	2077.	1.5
24601	*MANISTIQUE	3750.	16500.	11768.	3.1	208290.	55.5	127877.	34.1	2746.	0.7
24700	BAY DE NOC C	3100.	2170.	13112.	4.2	129245.	41.7	126123.	40.7	31843.	10.3
24801	ESCANABA	2370.	3318.	9855.	4.2	80042.	33.8	98309.	41.5	43025.	18.2
TOTAL 8		34550.	113129.	194486.	5.6	1562635.	45.2	767651.	22.2	593025.	17.2

LAND COVER DATA - PART 2

#	NAME	LAND AREA:KM2	GRASSLAND HA	%	BARREN HA	%	PLOWED FIELD HA	%	RESIDENTIAL HA	%	COMMERCIAL HA	%
24102	MUSKEGON	6850.	27713.	4.0	711.	0.1	36240.	5.3	18475.	2.7	711.	0.1
24200	SABLE COM	5030.	29137.	5.8	1022.	0.2	25048.	5.0	14313.	2.8	0.	0.0
24302	MANISTEE	5200.	19434.	3.7	525.	0.1	25737.	4.9	1051.	0.2	0.	0.0
24400	TRAVERSE COM	6830.	48419.	7.1	1467.	0.2	42550.	6.2	1467.	0.2	0.	0.0
24500	SEUL-CHOIX C	1420.	1632.	1.1	1335.	0.9	0.	0.0	445.	0.3	0.	0.0
24601	*MANISTIQUE	3750.	1961.	0.5	21967.	5.9	0.	0.0	392.	0.1	0.	0.0
24700	BAY DE NOC C	3100.	8429.	2.7	312.	0.1	0.	0.0	937.	0.3	0.	0.0
24801	ESCANABA	2370.	4327.	1.8	721.	0.3	0.	0.0	721.	0.3	0.	0.0
TOTAL 8		34550.	141052.	4.1	28061.	0.8	129575.	3.8	37801.	1.1	711.	0.0

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*Total forested land is the sum of the two "forest" categories and "brushland."
Total agricultural land is the sum of "plowed field" and "grassland" classifications.
Total urban land is the sum of "residential" and "commercial" categories.

See Appendix 3 for a description of the information in this table.

Source: Monteith and Jarecki, 1978

POTENTIAL CONTRIBUTING AREA

Much of the southern and eastern portions of RBG 2.4 are dominated by sandy soils and drowned river mouth embayments. Very little can be considered as potentially contributing: only the coastal communities and isolated areas of fine-textured soils are so designated. The potential contributing area of the six hydrologic areas from the Muskegon River basin through the Manistique basin is estimated to total about 250 square kilometers (100 square miles).

Bay de Noc complex is characterized by sandy soils in the eastern half and loams in the western portion. Approximately 40 percent or 1,200 square kilometers (460 square miles) is assumed to be in the potential contributing area.

The Escanaba River basin has high trap efficiency impoundments near the mouth. This limits the potential contributing area to direct coastal drainage and the areas encompassed by the cities of Gladstone and Escanaba. Total potential contributing area is about one percent or 20 square kilometers (10 square miles). Figure 21 shows the potential contributing area of RBG 2.4.

CRITICAL PROBLEM AREA IDENTIFICATION

CONTRIBUTION INDEX

Because of the unusual nature of the potential contributing areas in RBG 2.4, contribution indices could only be calculated for one of the seven hydrologic areas, the Bay de Noc complex. In this case, the values were all very much less than 1.0. Because of their limited usefulness, the index values have not been included.

LAND USE ACTIVITIES

Urban Areas

There are seven urban areas with population greater than 2,500 in the potential contributing area of RBG 2.4 (Table 49). These comprise 29 percent of the population in less than one percent of the total land area of the planning subarea. Traverse City is a potential source of bacteriological contaminants to Lake Michigan.

Urban stormwater and construction site runoff in this predominantly rural region are not the major contributors to Great Lakes pollution that they are in other areas. Muskegon and Traverse City are the most significant contributors of these nonpoint sources. Population is projected to increase 0.5 percent annually between 1970 and 2020.

The figures in Table 50 show a range of costs from $2.4 to $4.7 million per year to reduce problems related to combined sewer overflows and stormwater discharge. Chlorination for bacteria control in those areas where it may affect the lake would add from $27 thousand to $52 thousand per year.

FIGURE 21

POTENTIAL CONTRIBUTING AREA OF RBG 2.4

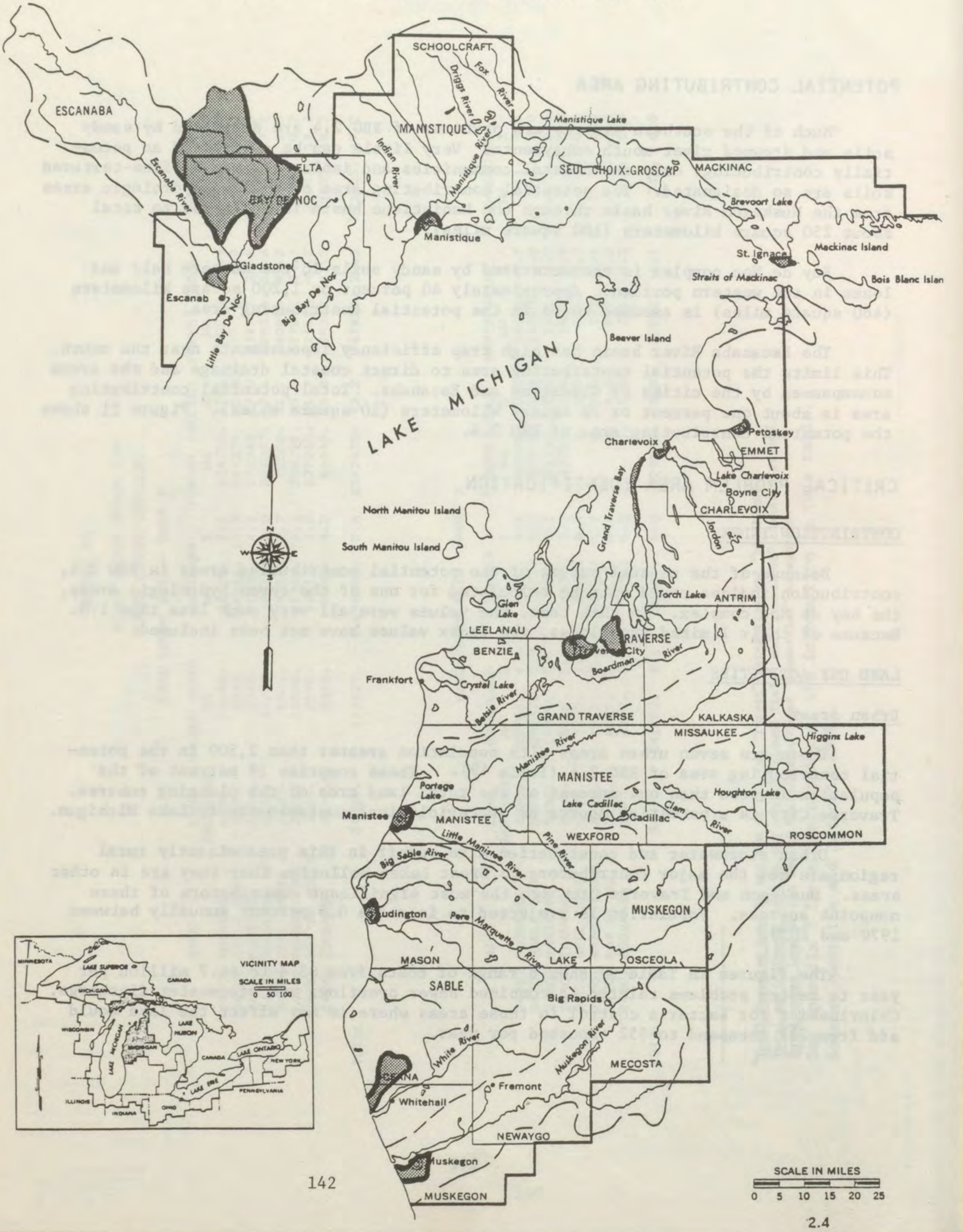


TABLE 49

URBAN AREAS IN THE POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 2.4

URBAN AREA	HYDROLOGIC AREA		POPULATION (1970)	AREA (ACRES*) (1970)
Muskegon, MI	Muskegon River	2.4.1	92,625	33,459
Charlevoix, MI	Traverse Complex	2.4.4	3,519	1,151
Petoskey, MI	Traverse Complex	2.4.4	6,342	2,559
Traverse City, MI	Traverse Complex	2.4.4	18,048	4,989
Manistee, MI	Manistee River	2.4.3	7,723	2,176
Ludington, MI	Sable Complex	2.4.2	9,021	2,048
Manistique, MI	Sable Complex	2.4.2	4,324	2,112
TOTAL - PSA			141,602	48,494
Planning Subarea 2.4			496,540	8,094,200

*To convert acres to hectares, multiply by 0.4047

TABLE 50

URBAN CONTROL SUMMARY FOR RBG 24

NUMBER OF URBAN AREAS: 7

LOW LEVEL OF TREATMENT (<30% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.18

CAPITAL COST	: $	16533280.
ANNUAL OPERATING COST	: $	560247.
AVERAGE ANNUAL COST*	: $	2381688.

MEDIUM LEVEL OF TREATMENT (30% TO 60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.59

CAPITAL COST	: $	32624048.
ANNUAL OPERATING COST	: $	606871.
AVERAGE ANNUAL COST*	: $	4201003.

HIGH LEVEL OF TREATMENT (>60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.67

CAPITAL COST	: $	34616496.
ANNUAL OPERATING COST	: $	851308.
AVERAGE ANNUAL COST*	: $	4664944.

CHLORINATION (MEDIUM AND HIGH LEVEL TREATMENT ONLY)

	COMBINED SEWER ONLY	COMBINED AND STORM SEWERS
CAPITAL:	190138.	372256.
O&M :	6397.	11313.
ANNUAL*:	27344.	52324.

*Average annual cost equals capital amortized over 25 years at 10 percent interest per year plus annual operation and maintenance cost.

Extrapolating these figures to all urban areas with more than 2,500 persons in Planning Subarea 2.4 yields the capital and operating costs shown in Table 51. Based on them, average annual costs range from $3.0 million to $5.9 million. Chlorination has not been included.

Construction sediment controls in the seven urban areas in the potential contributing area would cost $34 thousand per year. Construction of detention ponds in new developments would cost an additional $590 thousand per year, with $12 thousand per year maintenance.

Costs for the above practices for all urban areas with more than 2,500 persons in Planning Subarea 2.4 were estimated to be the following: $43 thousand per year for construction sediment controls, $748 thousand per year for new detention ponds, $15 thousand per year for detention pond maintenance.

Agricultural Areas

There are 19.8 thousand hectares (48.9 thousand acres) of cropland within the potential contributing area of RBG 2.4 (see Table 52). Twenty-three percent of this cropland, or 4.6 thousand hectares (11.4 thousand acres), requires treatment. According to Conservation Needs Inventory data, 432 thousand hectares (1,067 thousand acres) out of a total 599.6 thousand hectares (1,481.5 thousand acres) of cropland in the planning subarea required erosion control in 1968.

The potential contributing area accounts for 22 cattle feedlot operations, only six of which have waste controls (see Table 53).

Agricultural runoff and intensive livestock operations within this region may have an impact, although minor, on Lake Michigan water quality.

As the figures in Table 52 show, the application of best management practices on cropland within the potential contributing area would have a one-time cost of $150 thousand. In contrast, the use of BMPs on all lands identified as requiring erosion controls in the 1968 Conservation Needs Inventory would have one-time costs of $14.0 million, with $4.6 million recurring costs, an average annual cost of $6.1 million.

Installation of waste management systems for those cattle operations in the potential contributing area needing treatment would cost $160 thousand, or $18 thousand per year in average annual terms. Extrapolating these figures to all operations in the planning subarea, a total cost of $2.4 million, or $260 thousand per year, was found: $2.3 million for cattle, $69 thousand for swine, and $41 thousand for poultry.

On-Site Waste Disposal

Of the total number of housing units in Planning Subarea 2.4, 57 percent (103,408) were nonsewered in the 1970 Census. About 89 percent of these were in rural areas.

TABLE 51

ESTIMATED COST OF CONTROLS FOR ALL URBAN AREAS, RBG 2.4

TREATMENT LEVEL		COST IN PCA ($X10^6$ \$)	ADJUSTED AREA IN PCA (ACRES)	COST PER ACRE (\$)	TOTAL URBAN ACREAGE	ADJUSTED URBAN ACREAGE	RBG COST
LOW	Capital	16.53	16,990	970	61,480	21,480	20.8
	O&M	0.56	16,990	35	61,480	21,480	0.75
MEDIUM	Capital	32.62	16,990	1,920	61,480	21,480	41.2
	O&M	0.61	16,990	35	61,480	21,480	0.75
HIGH	Capital	34.61	16,990	2,040	61,480	21,480	43.8
	O&M	0.85	16,990	50	61,480	21,480	1.07

*To convert acres to hectares, multiply by 0.4047

**Urban area adjustment factor = 0.35

Average Annual Cost:

Low: \$ 3.0 million
Medium: 5.3 million
High: 5.9 million

TABLE 52

COSTS FOR INSTALLING AGRICULTURAL BEST MANAGEMENT PRACTICES IN THE POTENTIAL CONTRIBUTING AREA (PCA) OF RIVER BASIN GROUP 2.4

COUNTY	TOTAL ACRES* IN POTENTIAL CONTRIBUTING AREA	ACRES IN PCA NEEDING TREATMENT	COSTS FOR ALL SOILS ($ millions)		COSTS FOR FINE-TEXTURED SOILS ($ millions)	
			One-Time	Recurring	One-Time	Recurring
MICHIGAN						
Alger	19,040	500	**	**	0	0
Delta	7,604	1,904	0.03	0.01	0	0
Grand Traverse	8,000	2,000	0.02	0.01	0	0
Marquette	800	25	**	**	0	0
Muskegon	5,000	1,500	0.02	0.01	0	0
Oceana	8,500	5,500	0.08	0.02	0	0
TOTAL	48,944	11,429	0.15	0.05	0	0

*To convert acres to hectares, multiply by 0.4047

**Cost is negligible

TABLE 53

COST FOR INSTALLING AGRICULTURAL WASTE MANAGEMENT SYSTEMS
IN POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 2.4

COUNTY	TOTAL NUMBER OF FEEDLOT OPERATIONS >100 ANIMAL UNITS IN PCA			NUMBER OF FEEDLOT OPERATIONS IN PCA NEEDING TREATMENT			TOTAL COST ($ thousands)		
	CATTLE	SWINE	POULTRY	CATTLE	SWINE	POULTRY	CATTLE (at $10,000 per system)	SWINE (at $6,000 per system)	POULTRY (at $3,000 per system)
MICHIGAN									
Alger	8	0	0	7	0	0	70	0	0
Delta	3	0	0	3	0	0	30	0	0
Grand Traverse	7	0	0	3	0	0	30	0	0
Oceana	4	0	0	3	0	0	30	0	0
TOTAL	22	0	0	16	0	0	160	0	0

Due to the urban nature of the potential contributing area and the predominance of nonsewered housing in rural areas, only about 5 percent of the nonsewered housing (5,450 units) may affect Lake Michigan water quality (Table 53). The number of these units is projected to increase about 13 percent between 1970 and 1990. Within RBG 2.4, there are instances of septic tank failure. In Muskegon County (which accounts for nearly 40 percent of the nonsewered housing in the potential contributing area) and Oceana County (which accounts for another 5 percent), inadequate septic systems have been reported [GLBC, 1976]. These occurrences may result in degradation of Lake Michigan water quality.

The estimated capital cost of alleviating septic tank failure problems in the potential contributing area is $1.1 million (Table 54). Operating and maintenance costs would add $32 thousand per year for an average annual cost of $130 thousand. Similar figures for all parts of the planning subarea are $19.8 million capital costs, $585 thousand operating costs, and $2.8 million per year average annual.

Other Problems

Problems have been identified with the movement of contaminants through ground and surface water from solid waste disposal sites in Muskegon County [WMSRDC, 1977]. Groundwater contamination has resulted from the leaching to toxicants at several liquid waste disposal sites around Muskegon. The impacts, especially in the long term, of these problems on Lake Michigan cannot be determined at this time.

Oil and gas production in RBG 2.4 may also result in brine contamination of surface and ground waters. Problems have occurred in the past with abandoned wells [GLBC, 1976].

TABLE 54

ON-SITE WASTE DISPOSAL, RBG 2.4

COUNTY	TOTAL NUMBER OF SYSTEMS	PERCENT OF COUNTY IN PCA	ESTIMATED NUMBER OF SYSTEMS IN PCA	NUMBER FAILING	CAPITAL COST ($X10^6$)	OPERATING COST ($X10^3$)	AVERAGE ANNUAL COST ($X10^6$)
MICHIGAN							
Antrim	5,098	5	250	30	0.05	1.4	0.01
Charlevoix	3,430	5	170	20	0.03	0.9	*
Delta	5,307	25	1,330	160	0.27	7.6	0.04
Emmet	3,648	5	180	20	0.03	0.9	*
Grand Traverse	6,415	10	640	80	0.14	3.8	0.02
Manistee	4,482	5	220	30	0.03	1.4	*
Mason	4,621	5	230	30	0.03	1.4	*
Muskegon	21,343	10	2,130	260	0.44	12.3	0.06
Oceana	4,268	5	210	30	0.03	1.4	*
Schoolcraft	1,786	5	90	10	0.02	0.5	*
TOTAL	-	-	5,450	670	1.07	31.6	0.13

*Cost not significant

5 LAKE HURON BASIN

LAKE BASIN SUMMARY

BASIN DESCRIPTION

The United States portion of the Lake Huron basin covers an area of approximately 41,960 square kilometers (16,200 square miles) of land, all in the State of Michigan. The major sources of inflow are the outlets from Lake Superior and Lake Michigan. This hydrologic region is divided into two river basin groups (RBG): RBG 3.1 in the northeastern part of the lower peninsula plus the eastern end of the upper peninsula; and RBG 3.2, which includes the Saginaw River basin and "Thumb" region of Michigan. Figure 22 is a map of the Lake Huron basin.

The basin is characterized by hilly glacial moraines in the western and southern portions and flat, glacial lake plains in the east. Most of the basin is covered with thick glacial sediments; only in the eastern part are the glacial deposits thin with exposed bedrock in places.

Soils here vary widely. In the northern portion the podzol soils, those developed under cool, moist climate from siliceous parent material, cover most of the area. Typically, these soils are low in lime content, with low fertility, and subject to severe drainage restrictions.

The soils of the southern portion show little resemblance to the bedrock material. Instead, their character is determined by differences in the glacial mantle. Deposits range from the lacustrine clays to outwashes of nearly pure sand and contain a large variety of mineral materials. In addition, the long-term action of climate, cover, and topography have resulted in soils of great variety in terms of parent material, texture, and soil profile development. Slightly over 50 percent of the land in this part of the basin is subject to drainage or flooding problems. About 24 percent of the cropland is subject to drainage problems; half of which is considered to be severe.

Minerals found in the north include gypsum, petroleum and natural gas, sand and gravel, shale, and limestone. The minerals in the south include clay, peat, petroleum, natural gas, salt, sand, gravel and limestone. In addition, cement and lime are manufactured from both local and imported raw materials. Bromine, calcium compounds, iodine, manganese, and potash (salines) are extracted or manufactured from the natural brines.

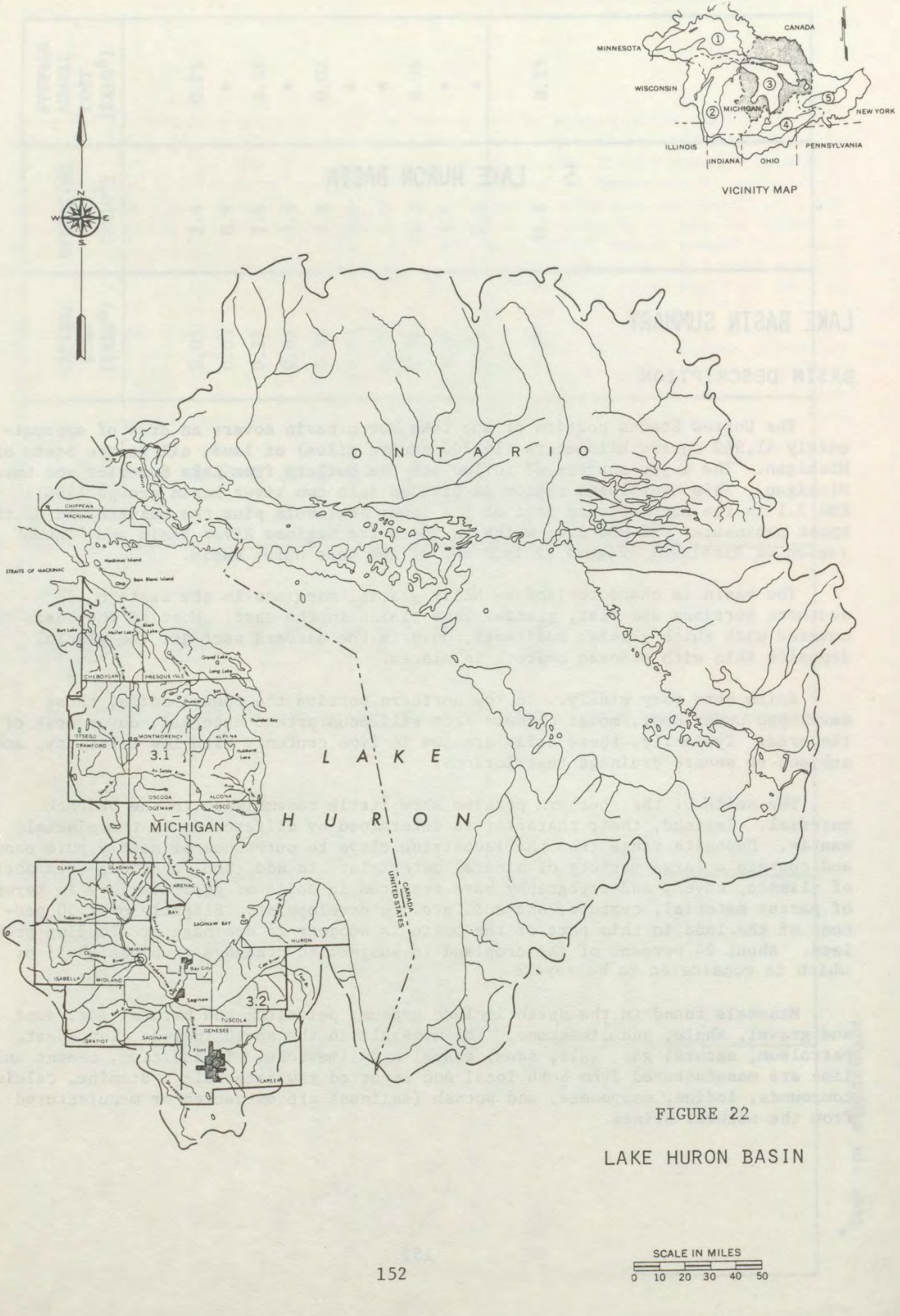


FIGURE 22

LAKE HURON BASIN

The basin's population density is a moderately low 38 people per square kilometer (99 per square mile). The estimated 1975 population of Lake Huron counties was 1,308,800, an increase of 44 percent from the 1940 population of 732,000 persons. In the 11 northern counties only Alpena, Cheboygan, Iosco, Otsego, and Presque Isle supported population centers large enough to be classified urban. The remaining four counties had less than 10,000 persons each. To the south there is a great difference between sparsely settled Gladwin County and thickly settled Genesee County. The latter, with a population density of about 690 persons per square mile, is the second most densely populated county in Michigan. There are three Standard Metropolitan Statistical Areas (SMSA) in the Lake Huron basin. These are Flint, Saginaw, and Bay City, all in the southern part.

The economy in the north is dependent on agriculture and recreation. That of the south is focused on intensive, heavy manufacturing and chemical industries although prime agricultural land in the "Thumb" and in the southwestern corner is economically important.

Because inflow to Lake Huron is primarily from relatively clean Lake Superior and northern Lake Michigan, water quality is generally good throughout most of the lake . Stream water quality is good throughout the upper portion, although there are localized reaches of substandard quality caused by effluent from primary treatment plants, industrial discharges, seepage from septic tanks, or discharge of raw sewage. In the southern portion, the entire length of the Saginaw River is substandard in quality. In addition, Saginaw Bay and a few of the more heavily used harbors do show strong evidence of excess waste loading, although these loads have little demonstrable effect on the open lake.

PROBLEM AREA SUMMARY

The estimated potential contributing area totals 10,795 square kilometers (4,170 square miles), or more than one-fourth of the total lake basin area. Most of this is located in the southern portion.

An assessment of diffuse tributary sediment and phosphorus loadings to the lake has identified the following hydrologic areas as having significant inputs of one or both of these contaminants: the Les Cheneau and Rifle-AuGres complexes, and the Saginaw River basin.

The following critical problem areas were identified on the basis of land use activities.

URBAN AREAS

Sixteen urban areas with a total population of 505,460 covering 150,285 acres were identified in the potential contributing area of Lake Huron. The annual growth rate varied from two percent in the north (RBG 3.1) to one percent in the south (RBG 3.2).

Average annual costs for combined sewer and stormwater treatment for those cities in the potential contributing area range from $6.0 million to $18.3 million. The addition of chlorination to the medium and high efficiency alternatives would cost from $0.2 to $0.8 million per year, depending upon whether or not it is limited to combined sewer overflows. Control costs for all basin urban areas with more than 2,500 persons would range from $6.4 million to $19.9 million.

Construction sediment controls on construction activities for those cities in the potential contributing area were estimated to be almost $700 thousand annually, with the use of detention ponds adding $3.9 million a year in construction costs and $80 thousand annually in operating and maintenance costs. The annual cost for sediment controls in all basin urban areas was estimated to be $750 thousand. Detention ponds would cost $4.2 million for annual construction and $85 thousand for annual maintenance.

AGRICULTURAL AREAS

Agriculture is a significant land use in the Lake Huron basin, particularly in RBG 3.2. Cropland on moderate- and fine-textured soils accounts for 626 thousand hectares (1,548 thousand acres) in the Lake Huron potential contributing area, of which 280 thousand hectares (691 thousand acres) require erosion control practices. These best management practices would require an estimated one-time investment of $15.4 million, with annual recurring costs of $2.7 million. The average annual cost is thus $4.4 million. Limiting the treatment to fine-textured soils would reduce the annual cost to $2.7 million, with one-time and recurring costs of $10.6 million and $1.5 million, respectively. Expansion to all basin cropland requiring erosion treatment results in costs of $42.7 million one-time, $7.6 million recurring, and an average annual cost of $12.3 million.

About 430 cattle feedlot operations in the potential contributing area need waste controls at a cost of $4.3 million. A total cost of $6.0 million was extrapolated for all intensive livestock operations in the lake basin which do not now have controls. The average annual cost of waste controls would be $470 thousand in the potential contributing area and $660 thousand throughout the basin.

ON-SITE WASTE DISPOSAL

Approximately 8,600 septic tanks may be failing in the potential contributing area. Measures to alleviate resulting problems would have an estimated capital cost of $15.1 million and annual operating and maintenance expenses of $450 thousand, for an average annual cost of $2.2 million. The costs for alleviating problems in the basin were estimated to be $32.7 million capital and $960 thousand recurring, or $4.6 million per year in average annual terms.

The costs for urban agricultural and on-site waste disposal remedial measures are summarized in Table 55.

OTHER PROBLEMS

Other problems identified in the Lake Huron basin include the disposal of polluted dredge spoil; and the leaching of contaminants from municipal and county landfills, industrial waste disposal sites and active and abandoned oil and gas wells.

TABLE 55

COST

SUMMARY FOR LAKE

HURON

REMEDIAL MEASURES	CAPITAL COST ($ millions)	OPERATING, MAINTENANCE AND RECURRING COST ($ millions)	AVERAGE ANNUAL COST ($ millions)
Urban Areas			
Low Level Treatment	41.9	1.4	6.0
Medium Level Treatment	135.0	3.2	18.1
High Level Treatment	134.0	3.5	18.3
Chlorination -			
Combined only	1.2	0.1	0.2
Both	5.8	0.2	0.8
Sediment Controls	-	0.7	0.7
Detention Ponds	-	4.0	4.0
Agricultural Areas			
Best Management Practices:			
All Soils	15.4	2.7	4.4
Fine Soils	10.6	1.5	2.7
Animal Waste Controls	4.3	-	0.5
On-Site Waste Disposal	15.1	0.5	2.2

RIVER BASIN GROUP 3.1

DESCRIPTION

River Basin Group 3.1 in the north central poriton of the Great Lakes basin, drains an area of 21,077 square kilometers (8,138 square miles) of the Lake Huron basin. As is shown in Figure 23, the corresponding planning subarea is comprised of 11 of Michigan's lower peninsula counties. The RBG is divided into eight hydrologic areas: the St. Marys and Les Cheneau complexes in the upper peninsula; the Cheboygan, Thunder Bay, and Au Sable River basins, and the Presque Isle, Alcona and Rifle-Au Gres complexes, in the Lower Peninsula.

The area is characterized by flat to rolling terrain except in the northwest where hilly, sandy, morainal uplands predominate. The oldest bedrock formations stretch across the northern third of the region. Limestone and shale outcrops occur along with a wide band of undifferentiated bedrock composed of limestone and shale across the northern section. The Michigan formation composed of shale, sandstone, beds of gypsum, and some dolomite limestone outcrop in the southern section.

As Figure 24 illustrates, the soils of RBG 3.1 are mostly of course-textured sand and loamy sand. Medium-textured soils occur in the north while soils in the south range from moderately-fine to coarse, clay loam and sand. Organic deposits occur throughout the area.

Mineral production includes gypsum, petroleum and natural gas, sand and gravel, shale and limestone.

There are over 6,400 kilometers (4,000 miles) of streams in this region. The mean stream density is 0.3 stream kilometers per square kilometer (0.5 mile per square mile). The major rivers are the Munuscong, Pine, Carp, Cheboygan, Ocqueoc, Thunder Bay, Au Sable, Au Gres, and Rifle.

Forested land is prevalent, covering 83 percent of the land. Ten percent is used for agriculture, while less than one percent is urbanized. Table 56 shows the major land cover of each of the eight hydrologic areas.

This RBG ranks last in population among the 15 in the Great Lakes, with a 1970 population of just over 142,000. The 1940 population was 94,611 which indicates a growth rate of less than two percent per year. Approximately 26 percent (1975 population estimates) of the population lived in urban areas in 1970. The major urban areas are (1975 population estimates): Alpena (pop.: 15,219); Cheboygan (pop.: 5,595); and Gaylord (pop.: 3,288). Total employment in 1970 was about 45,600 and, like population, has grown slowly. Although agriculture accounted for about five percent of the employment (compared to two percent for the Great Lakes as a whole), it has decreased 84 percent over the past three decades, from 11,700 in 1940 to only 1,900 in 1970. Employment in manufacturing, 23 percent, is close to the national average but well below the Great Lakes average of 35 percent. Mining accounted for 2.6 percent of the total employment. The resources of the area are used year-round for recreational purposes.

FIGURE 23

PLANNING SUBAREA 3.1

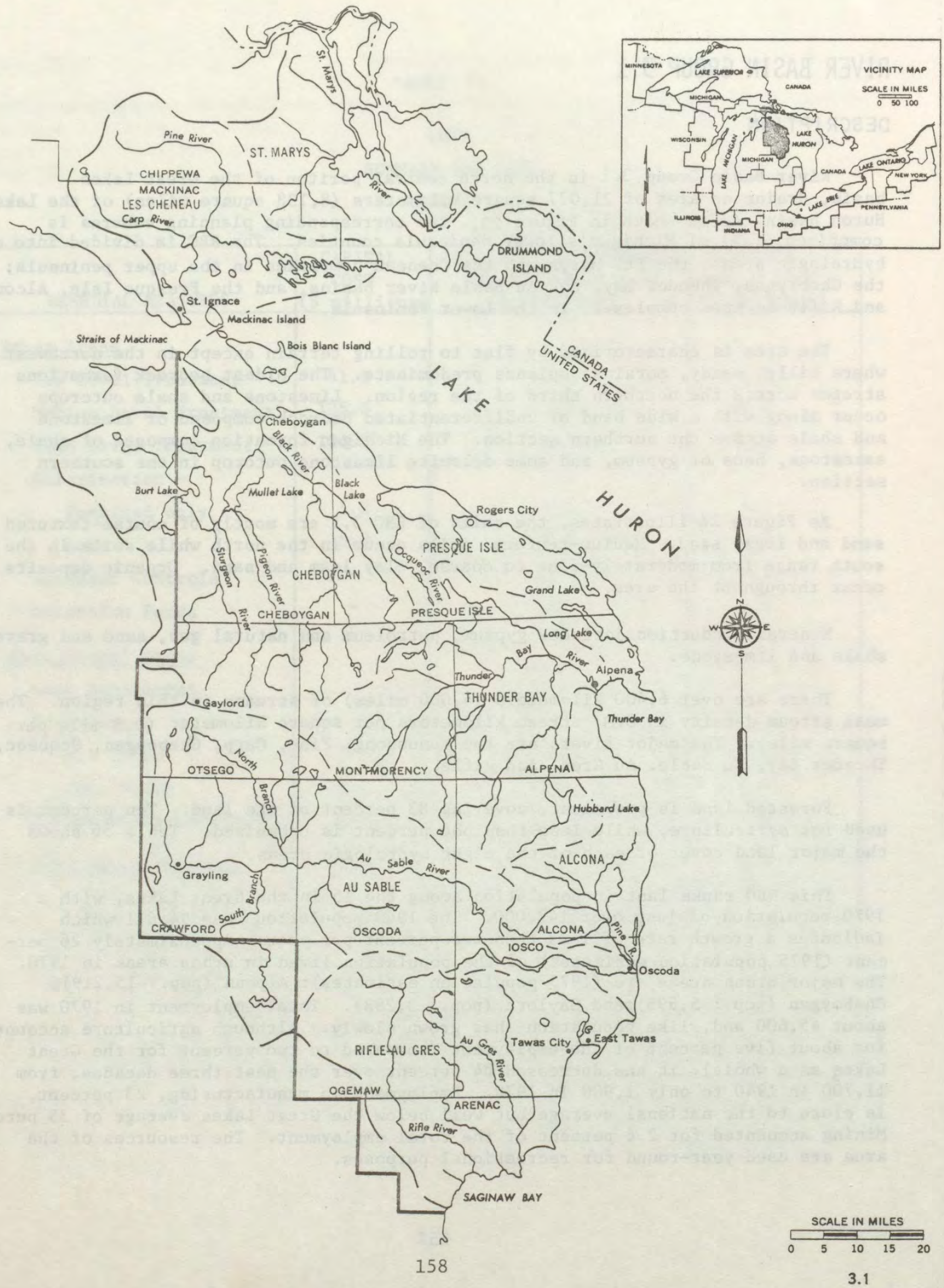


FIGURE 24 **SOIL TEXTURE**

River Basin Group 3.1

Source: Sonzogni, et al., 1978

TABLE 56

RIVER BASIN GROUP 3.1

LAND COVER SUMMARY

LAND COVER DATA - PART 1

#	NAME	LAND AREA:KM2	INLAND WATER HA	WETLAND HA	%	FOREST (DECID) HA	%	FOREST (CON) HA	%	BRUSHLAND HA	%
31100	LES CHENEAUX	3640.	32032.	43105.	11.8	62263.	17.1	177211.	48.7	39912.	11.0
31203	CHEBOYGAN	4090.	23313.	18650.	4.6	149634.	36.6	127081.	31.1	61155.	15.0
31300	PRESQUE ISLE	1450.	5655.	6337.	4.4	26556.	18.3	70161.	48.4	20671.	14.3
31401	THUNDER BAY	3270.	8829.	2016.	0.6	93092.	28.5	109560.	33.5	84018.	25.7
31500	AU SABLE-ALC	5760.	8640.	51460.	8.9	153210.	26.6	262562.	45.6	82453.	14.3
31600	RIFLE-AUGRES	2870.	3444.	2614.	0.9	78431.	27.3	69136.	24.1	89760.	31.3
TOTAL	6	21080.	81913.	124183.	5.9	563186.	26.7	815710.	38.7	377969.	17.9

LAND COVER DATA - PART 2

#	NAME	LAND AREA:KM2	GRASSLAND HA	%	BARREN HA	%	PLOWED FIELD HA	%	RESIDENTIAL HA	%	COMMERCIAL HA	%
31100	LES CHENEAUX	3640.	34724.	9.5	798.	0.2	5588.	1.5	399.	0.1	0.	0.0
31203	CHEBOYGAN	4090.	45107.	11.0	434.	0.1	6506.	1.6	434.	0.1	0.	0.0
31300	PRESQUE ISLE	1450.	12976.	8.9	1056.	0.7	6488.	4.5	754.	0.5	0.	0.0
31401	THUNDER BAY	3270.	21845.	6.7	336.	0.1	15123.	4.6	1008.	0.3	0.	0.0
31500	AU SABLE-ALC	5760.	11111.	1.9	585.	0.1	12865.	2.2	1754.	0.3	0.	0.0
31600	RIFLE-AUGRES	2870.	19463.	6.8	871.	0.3	25853.	9.0	871.	0.3	0.	0.0
TOTAL	6	21080.	145225.	6.9	4080.	0.2	72423.	3.4	5221.	0.2	0.	0.0

*Total forested land is the sum of the two "forest" categories and "brushland."
Total agricultural land is the sum of "plowed field" and "grassland" classifications.
Total urban land is the sum of "residential" and "commercial" categories.
See Appendix 3 for a description of the information in this table.
Source: Monteith and Jarecki, 1978

POTENTIAL CONTRIBUTING AREA

Approximately half of Les Cheneau complex in Michigan's eastern upper peninsula is situated on sandy or sandy loam soils and was assumed to be generally non-contributing. The other 50 percent, or 1,200 square kilometers (460 square miles), has clay or clay-loam soils and was designated as potentially contributing.

The Cheboygan complex was assumed to be generally non-contributing due to the large lakes along the rivers. A small area downstream of Mullett Lake has clay soils and was considered to be a potentially contributing area. This area is approximately 40 square kilometers (15 square miles), less than one percent of the complex.

Wetlands and lakes characterize the Presque Isle complex, thus eliminating much of it from the potential contributing area. Only Rogers City is designated as potentially contributing; it is about 15 square kilometers (6 square miles).

The Thunder Bay River basin has a large proportion of sandy soils, with a series of reservoirs near the mouth estimated to have a high combined trap efficiency. Areas upstream of these dams were assumed to make no significant pollutant contributions, and the potential contributing area is only that in the immediate vicinity of Alpena. Total area is about 30 square kilometers (10 square miles).

The Au Sable-Alcona complex also has large impoundments near the mouth of the Au Sable. Soils are almost entirely coarse-grained. The potential contributing area was assumed to be limited to an area around the City of Oscoda, an area of about 60 square kilometers (25 square miles).

The potential contributing area of the Rifle-Au Gres complex is limited to an area overlain with medium and fine loams adjacent to Saginaw Bay. In addition, the area immediately surrounding Tawas City and East Tawas was included. Total area is about 430 square kilometers (165 square miles).

Figure 25 shows the potential contributing area of RBG 3.1

CRITICAL PROBLEM AREA IDENTIFICATION

CONTRIBUTION INDEX

The calculation of contribution indices for this river basin group is difficult, as four of the six hydrologic areas have estimated potential contributing areas of only 1 percent of their drainage basin. As Table 57 shows, the Les Cheneau and Rifle-Au Gres complexes have significant inputs of suspended solids and orthophosphorus, respectively.

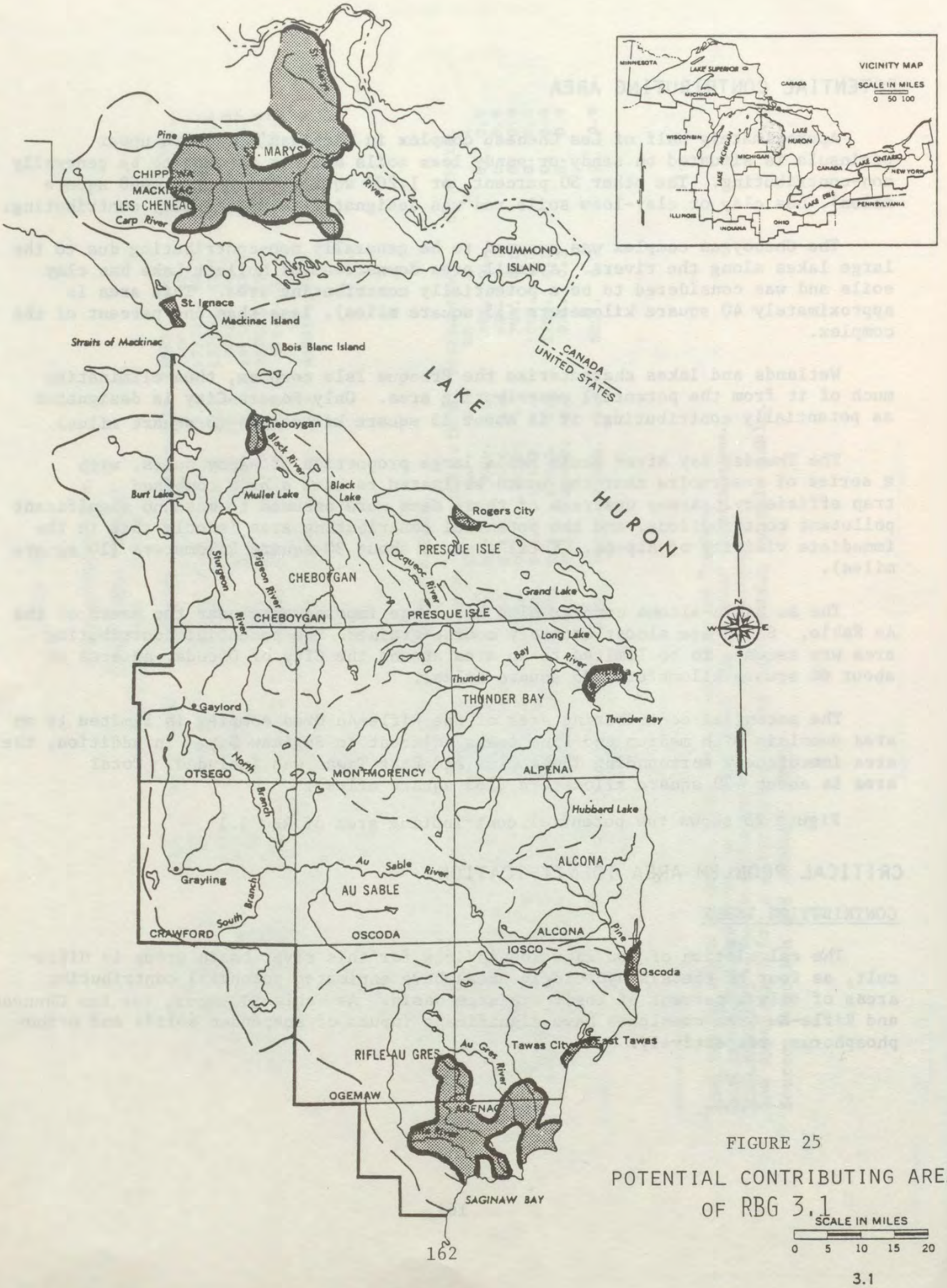


FIGURE 25

POTENTIAL CONTRIBUTING AREA OF RBG 3.1

TABLE 57

CONTRIBUTION INDICES

RIVER BASIN GROUP 3.1

HYDROLOGIC AREA	LAND AREA (km²)*	PCA AREA (km²)*	SUSPENDED SOLIDS	TOTAL PHOSPHORUS	ORTHO PHOSPHORUS
Les Cheneau Complex	3,640	1,200	1.1	0.6	0.9
Cheboygan River	4,090	40†	-	-	-
Presque Isle Complex	1,450	15†	-	-	-
Thunder Bay River	3,270	30†	-	-	-
Au Sable and Alcona Complex	5,760	60†	-	-	-
Rifle-AuGres Complex	2,870	430	0.7	0.8	1.5

*To convert square kilometers to square miles, multiply by 0.386

$$CI = \frac{\text{(\% of Great Lakes Diffuse Load) (from hydrologic area)}}{\text{(\% of Great Lakes PCA in) (hydrologic area)}}$$

†PCA assumed to be 1% of total drainage area.

Total Great Lakes PCA = 105,950 km^2

Total Great Lakes Diffuse Loads

Suspended Solids = 9,492,407 Mtonnes/yr.

Total P = 13,155 Mtonnes/yr.

Ortho P = 3,007 Mtonnes/yr.

NOTE: Loads are average of 1975 and 1976 values with Lake Erie values assured equal for both years

LAND USE ACTIVITIES

Urban Areas

There are four urban areas with population greater than 2,500 in the potential contributing area of RBG 3.1 (Table 58). The largest is Sault Ste. Marie with a population of 15,136 in 1970. These communities comprise 27 percent of the region's population. Alpena and Sault Ste. Marie, Michigan were assumed to contribute bacteria to the lake.

Due to the area's rural nature, urban stormwater and construction site runoff do not greatly affect Great Lakes water quality. Population is projected to increase almost two percent annually between 1970 and 2020.

The estimated costs of combined sewer and stormwater treatment for cities in the potential contributing area of RBG 3.1 are shown in Table 59. Average annual costs for treatment range from $960 thousand for the low efficiency alternative (19 percent solids removal) to $1.9 million for the high efficiency (70 percent) alternative. The addition of chlorination to the medium and high efficiency alternatives would add from $40 to $100 thousand per year, depending on whether or not it is limited to combined sewer overflows.

Construction sediment controls, based on an assumed annual growth rate of 0.1 percent for Sault Ste. Marie and two percent for Alpena, Cheboygan and Rogers City, would cost $180 thousand annually. Detention ponds in new developments would cost an additional $500 thousand for construction and $10 thousand for operation and maintenance annually.

Average annual costs for stormwater and combined sewer controls for all urban areas with more than 2,500 persons in RBG 3.1 range from $1.0 to $2.0 million (Table 60). Clorination costs were not estimated.

Construction sediment controls for all urban areas were estimated to be $190 thousand annually. Detention pond construction and maintenance throughout the RBG would cost $540 thousand and $11 thousand a year, respectively.

Agricultural Areas

There are 22.8 thousand hectares (56.3 thousand acres) of cropland within the potential contributing area of RBG 3.1 (see Table 61). Twenty-three percent of this cropland, or 5.1 thousand hectares (12.7 thousand acres), requires treatment. According to Conservation Needs Inventory data, 133 thousand hectares (328 thousand acres) out of a total 215 thousand hectares (531 thousand acres) of cropland in this planning subarea required erosion control treatment in 1968.

Twenty-eight cattle feedlot operations are located in the potential contributing area. There are no swine or poultry operations (see Table 62). Only 29 percent of the feedlots have waste controls. Based on information in Inventory of Land Use

TABLE 58

URBAN AREAS IN THE POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 3.1

URBAN AREA	HYDROLOGIC AREA	POPULATION (1970)	AREA (ACRES*) (1970)
Alpena. MI	Thunder Bay River 3.1.4	13,805	4,735
Cheboygan, MI	Cheboygan River 3.1.2	5,553	4,414
Rogers City, MI	Presque Isle Complex 3.1.3	4,275	2,688
Sault Ste.Marie, MI	Les Cheneau Complex 3.1.1	15,136	10,048
TOTAL - PCA		38,769	21,885
Planning Subarea 3.1		142,064	4,017,800

*To convert acres to hectares, multiply by 0.4047

TABLE 59

URBAN CONTROL SUMMARY FOR RBG 31

NUMBER OF URBAN AREAS: 4

LOW LEVEL OF TREATMENT (<30% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.19

CAPITAL COST	: $	6728889.
ANNUAL OPERATING COST	: $	222183.
AVERAGE ANNUAL COST*	: $	963493.

MEDIUM LEVEL OF TREATMENT (30% TO 60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.59

CAPITAL COST	: $	11768577.
ANNUAL OPERATING COST	: $	247626.
AVERAGE ANNUAL COST*	: $	1544148.

HIGH LEVEL OF TREATMENT (>60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.70

CAPITAL COST	: $	13564531.
ANNUAL OPERATING COST	: $	382284.
AVERAGE ANNUAL COST*	: $	1876663.

CHLORINATION (MEDIUM AND HIGH LEVEL TREATMENT ONLY)

	COMBINED SEWER ONLY	COMBINED AND STORM SEWERS
CAPITAL:	264965.	733839.
O&M :	10794.	21390.
ANNUAL*:	39985.	102236.

*Average annual cost equals capital amortized over 25 years at 10 percent interest per year plus annual operation and maintenance cost.

TABLE 60

ESTIMATED COST OF CONTROLS FOR ALL URBAN AREAS, RBG 3.1

TREATMENT LEVEL		COST IN PCA ($ millions)	ADJUSTED AREA IN PCA (ACRES*)	COST PER ACRE ($)	TOTAL URBAN ACREAGE	ADJUSTED** URBAN ACREAGE	RBG COST ($ millions)
LOW	Capital	6.73	7,670	880	23,222	8,130	7.2
	O&M	0.22	7,670	30	23,222	8,130	0.2
MEDIUM	Capital	11.77	7,670	1,535	23,222	8.130	12.5
	O&M	0.25	7,670	35	23,222	8,130	0.3
HIGH	Capital	13.56	7,670	1,770	23,222	8,130	14.4
	O&M	0.38	7,670	50	23,222	8,130	0.4

* To convert acres to hectares, multiply by 0.4047

** Urban area adjustment factor = 0.35

Average Annual Cost:

Low: $1.0 million
Medium: 1.7 million
High: 2.0 million

TABLE 61

COSTS FOR INSTALLING AGRICULTURAL BEST MANAGEMENT PRACTICES
IN THE POTENTIAL CONTRIBUTING AREA (PCA) OF RIVER BASIN GROUP 3.1

COUNTY	TOTAL ACRES* IN POTENTIAL CONTRIBUTING AREA	ACRES IN PCA NEEDING TREATMENT	COSTS FOR ALL SOILS ($ millions)		COSTS FOR FINE-TEXTURED SOILS ($ millions)	
			One-Time	Recurring	One-Time	Recurring
MICHIGAN						
Arenac	31,360	10,360	.22	.04	.07	.01
Iosco	7,040	540	.01	**	.01	**
Agemaw	17,850	1,785	.04	.01	.03	**
TOTAL	56,250	12,685	.27	.05	.11	.01

*To convert acres to hectares, multiply by 0.4047

**Cost is negligible

TABLE 62

COST FOR INSTALLING AGRICULTURAL WASTE MANAGEMENT SYSTEMS IN POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 3.1

COUNTY	TOTAL NUMBER OF FEEDLOT OPERATIONS >100 ANIMAL UNITS IN PCA			NUMBER OF FEEDLOT OPERATIONS IN PCA NEEDING TREATMENT			TOTAL COST ($ thousands)		
	CATTLE	SWINE	POULTRY	CATTLE	SWINE	POULTRY	CATTLE (at $10,000 per system)	SWINE (at $6,000 per system)	POULTRY (at $3,000 per system)
MICHIGAN									
Arenac	14	0	0	9	0	0	90	0	0
Chippewa	2	0	0	1	0	0	10	0	0
Mackinac	1	0	0	1	0	0	10	0	0
Iosco	4	0	0	2	0	0	20	0	0
Ogemaw	9	0	0	9	0	0	90	0	0
TOTAL	30	0	0	22	0	0	220	0	0

[IJC, 1976c], some 117 cattle, nine swine, and two poultry feedlots in the planning subarea may not have waste control systems.

Agricultural runoff and intensive livestock operations within this region may have a significant impact on Lake Huron water quality.

Application of best management practices to all moderate- and fine-textured soils in the potential contributing area would have a one-time cost of $270 thousand, and recurring costs of $50 thousand. The average annual cost would be $80 thousand. Costs for BMPs applied to only fine-textured soils (1.6 thousand hectares) were estimated at $110 thousand and $14 thousand, one-time and recurring, respectively, for an average annual cost of $26 thousand. Application of BMPs to all soils in the planning subarea would cost $7.0 million and $1.3 million, one-time and recurring, respectively, or $2.1 million per year in average annual terms.

Installation of waste management systems in the potential contributing area would cost $220 thousand, or $1.2 million for the entire planning subarea. This would be $24 thousand or $132 thousand per year, respectively, in average annual terms.

On-Site Waste Disposal

In 1970 nonsewered, residential units attributed for 70 percent of the total nonfarm housing stock in the area. About 95 percent were located in rural areas.

Table 63 indicates that about 10 percent of the nonsewered housing (or 4,440 units) may be located within the potential contributing area. The majority (64 percent) of these units are located in the Rifle-Au Gres complex and 10 percent are in Chippewa County.

The number of nonsewered units is projected to increase about 27 percent between 1970 and 1990.

The capital investment required to alleviate the problems related to septic system failures in the potential contributing area was estimated to be $700 thousand, with recurring costs of $18 thousand, for an average annual cost of $90 thousand per year. Costs for the planning subarea would be $6.7 million one-time and $176 thousand recurring, or $910 thousand per year average annual.

Other Problems

On an average annual basis, 7 harbors or channels are dredged in RBG 3.1. Sites at Les Cheneau and on the St. Marys River which are not in the counties comprising the planning subarea are included. About 15,068 cubic meters (19,694 cubic yards) or 11 percent of the average annual volume of dredge spoil in the region, requires confinement in diked disposal areas. Those sites with polluted sediments include: Les Cheneau (with 52 percent of the polluted sediments), Hammond Bay, Harrisville, and Au Sable.

Total annual maintenance dredge spoil is projected to nearly double between 1970 and 1990; polluted sediments are projected to increase 125 percent in the same period.

TABLE 63

ON-SITE WASTE DISPOSAL, RBG 3.1

COUNTY	TOTAL NUMBER OF SYSTEMS	PERCENT OF COUNTY IN PCA	ESTIMATED NUMBER OF SYSTEMS IN PCA	NUMBER FAILING	CAPITAL COST ($\$X10^6$)	OPERATING COST ($\$X10^3$)	AVERAGE ANNUAL COST ($\$X10^6$)
Michigan							
Chippewa	4,602	20	920	90	0.13	3.5	0.02
Alpena	4,993	5	250	20	0.03	0.9	*
Avenac	2,987	50	1,490	150	0.25	6.6	0.03
Cheboygan	4,033	5	200	20	0.03	0.9	*
Iosco	7,301	15	1,100	110	0.19	4.9	0.03
Ogemaw	6,295	5	310	30	0.05	1.3	0.01
Presque Isle	2,584	5	130	10	0.02	0.4	*
TOTAL	--	--	4,440	410	0.70	18.5	0.09

*Cost not significant

The disposal of polluted spoil without adequate containment is considered to have an impact on Lake Huron water quality.

No other land-related water quality problems have been identified in RBG 3.1.

RIVER BASIN GROUP 3.2

DESCRIPTION

River Basin Group 3.2, in the central part of the Great Lakes Basin, covers an area of 20,842 square kilometers (8,047 square miles) of the lower Lake Huron drainage basin. The corresponding planning subarea, as shown in Figure 26 consists of 11 counties in the central eastern Lower Peninsula of Michigan. The RBG is divided into three hydrologic areas: the Kawkawlin and Thumb complexes, and the Saginaw River basin.

Glacial features characterize the surface geology of this area, with moraines, till plains, glacial outwash channels and glacial lake beds. In the southern portion the drift is clay, although there is a fairly consistent gravel bed just above the bedrock. The ancestral Great Lakes, much larger than the modern lakes, deposited fine lake clays and sand around Saginaw Bay and produced the broad, flat, poorly drained lands which exist today.

As Figure 27 illustrates, the land bordering Lake Huron is lake plain, and soils are medium-textured, nearly level, and poorly drained, with some areas of coarse-textured soils over the medium-textured material. The far western portion of the area is level to hilly, with coarse-textured, well-drained soils. The rest of the region is a mixture of moderately coarse to medium-textured and well to poorly drained organic soil. Topography ranges from nearly level to sloping. The lake plain soils are highly productive when drained.

Clay, peat, petroleum and natural gas, salt, sand and gravel, and limestone are produced here.

This RBG has 12,870 kilometers (8,000 miles) of streams. Average stream density is 0.62 kilometers of stream per square kilometer (0.99 mile per square mile). The major rivers include the Kawkawlin, Pine, Saginaw, Pigeon, and Willow.

A large portion of the land in this RBG is agricultural (41 percent), or forested (50 percent), while seven percent is urban. Table 64 shows the distribution of major land cover classes in each of the three hydrologic areas.

The 1970 population was 1.1 million compared to 637,000 in 1940. About 61 percent was urban. Important urban centers are (1975 population estimates): Bay City (pop.: 47,215), Flint (pop.: 174,218), Midland (pop.: 37,434) and Saginaw (pop.: 86,202). Employment was 385,000, just over four percent of the Great Lakes total. Growth since 1940 in population and employment has paralleled that of the basin. The industry structure was dominated by manufacturing, which employed 158,000 workers and accounted for almost 41 percent of the total employment, compared to 25 percent nationally and 35 percent in the Great Lakes. Agriculture accounted for less than three percent of the employment, a 78 percent decline since 1940. Mining has also been declining in the region's economy. An increase in the

FIGURE 26

PLANNING SUBAREA 3.2

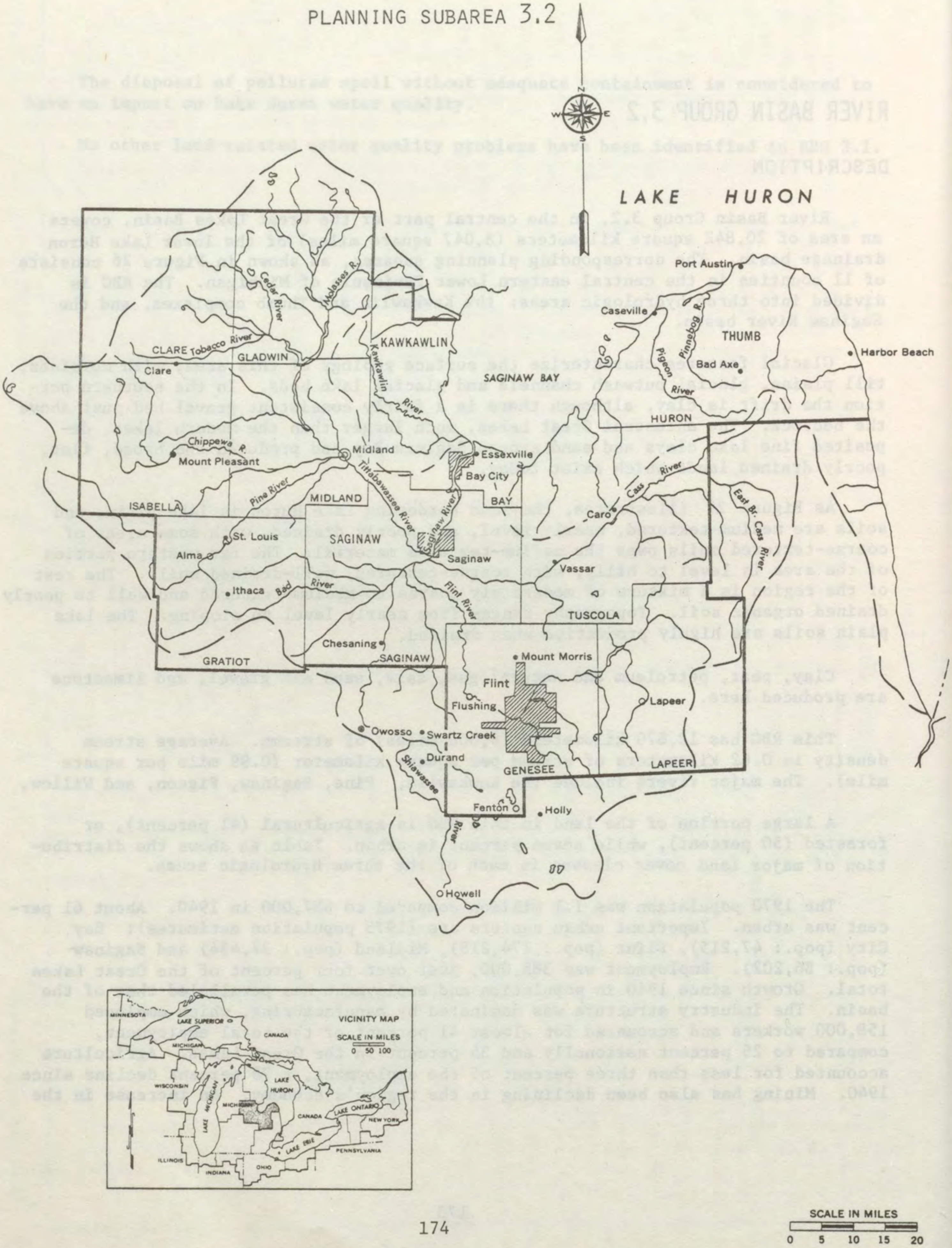
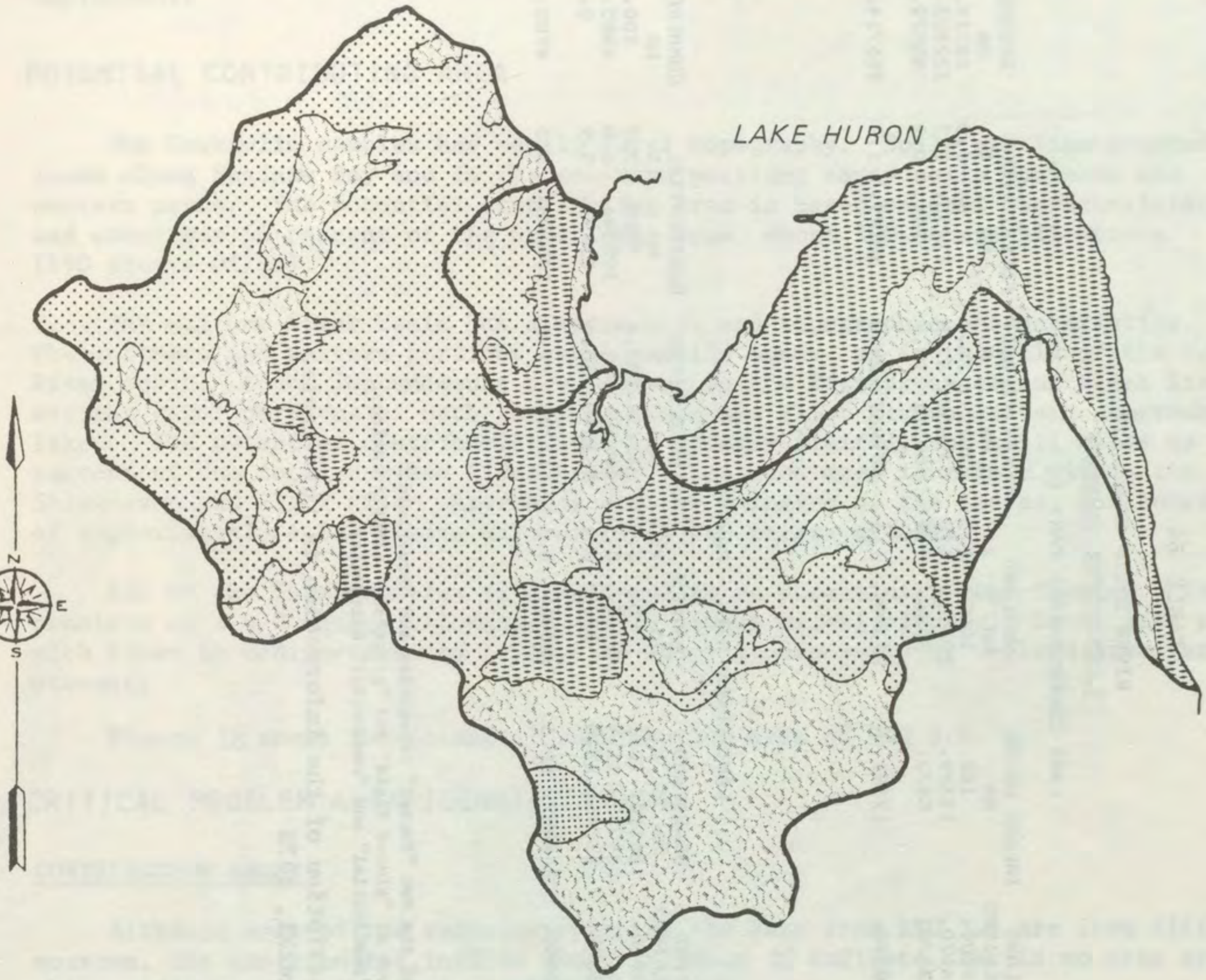


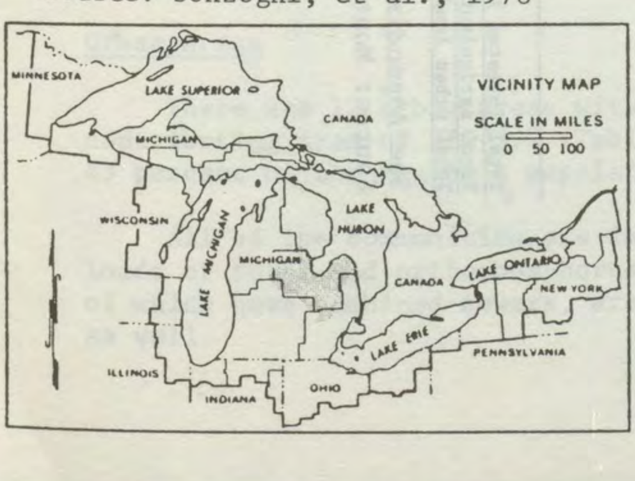
FIGURE 27

SOIL TEXTURE

River Basin Group 3.2



Source: Sonzogni, et al., 1978



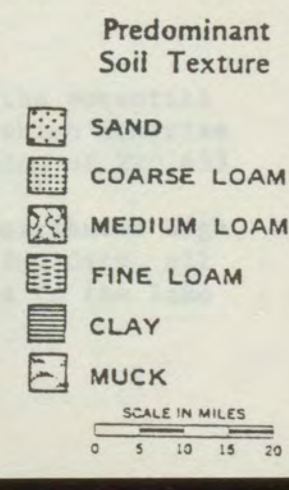


TABLE 64

RIVER BASIN GROUP 3.2
LAND COVER SUMMARY

LAND COVER DATA - PART 1

#	NAME	LAND AREA:KM2	INLAND WATER HA	WETLAND HA	WETLAND %	FOREST (DECID) HA	FOREST (DECID) %	FOREST (CON) HA	FOREST (CON) %	BRUSHLAND HA	BRUSHLAND %
32100	KAWKAWLIN CO	1000.	100.	1001.	1.0	28729.	28.7	0.	0.0	18719.	18.7
32201	SAGINAW	16170.	11319.	29311.	1.8	530858.	32.8	37453.	2.3	322423.	19.9
32300	THUMB COM	3670.	5872.	7086.	1.9	50351.	13.7	746.	0.2	55572.	15.1
TOTAL	3	20840.	17291.	37399.	1.8	609937.	29.3	38199.	1.8	396714.	19.0

LAND COVER DATA - PART 2

#	NAME	LAND AREA:KM2	GRASSLAND HA	GRASSLAND %	BARREN HA	BARREN %	PLOWED FIELD HA	PLOWED FIELD %	RESIDENTIAL HA	RESIDENTIAL %	COMMERCIAL HA	COMMERCIAL %
32100	KAWKAWLIN CO	1000.	10110.	10.1	0.	0.0	33634.	33.6	7708.	7.7	100.	0.1
32201	SAGINAW	16170.	184009.	11.4	1628.	0.1	400586.	24.8	105846.	6.5	4885.	0.3
32300	THUMB COM	3670.	47740.	13.0	373.	0.1	183500.	50.0	21632.	5.9	0.	0.0
TOTAL	3	20840.	241859.	11.6	2001.	0.1	617720.	29.6	135186.	6.5	4985.	0.2

*Total forested land is the sum of the two "forest" categories and "brushland."
Total agricultural land is the sum of "plowed field" and "grassland" classifications.
Total urban land is the sum of "residential" and "commercial" categories.

See Appendix 3 for a description of the information in this table.
Source: Monteith and Jarecki, 1978

importance of service industries is linked to the trend toward increased urbanization. The excellent natural outdoor recreation resources in proximity to major population centers should lead to an increase in demand for recreation and related employment.

POTENTIAL CONTRIBUTING AREA

The Kawkawlin complex has nearly level topography. Soils are fine-grained loams along Saginaw Bay and in the southern portion; sandy soils dominate the western parts. The potential contributing area is based on soil characteristics and comprises 50 percent of the hydrologic area, about 500 square kilometers (190 square miles).

The Saginaw River basin has diverse soil and topographic characteristics. The northern and western portions are generally sandy, as is the bulk of the Cass River basin. Major impoundments are present on the Tittabawassee and Flint Rivers, and the upper portions of both the Shiawassee and Flint Rivers contain numerous lakes. The potential contributing area is greatly limited, but still makes up 30 percent of the total Saginaw River basin. This land area is mainly within the Shiawassee and Flint River watersheds and the mainstem of the Saginaw and consists of approximately 4,850 square kilometers (1,860 square miles).

All of the Thumb complex is considered to be potentially contributing. It consists of 3,670 square kilometers (1,410 square miles) of nearly level lake plain with fine- to medium-textured soils. No major impoundments or wetland areas are present.

Figure 28 shows the potential contributing area of RBG 3.2.

CRITICAL PROBLEM AREA IDENTIFICATION

CONTRIBUTION INDEX

Although most of the sediment entering the lake from RBG 3.2 are from diffuse sources, the contribution indices shown in Table 65 indicate that in no case are those sediment contributions significantly high.

Nonetheless, there are significant diffuse source inputs of total and orthophosphorus from the Saginaw River basin and orthophosphorus from the Thumb complex.

LAND USE ACTIVITIES

Urban Areas

There are 12 urban areas with population greater than 2,500 in the potential contributing area of RBG 3.2 (Table 66). The largest of the areas, which comprise 43 percent of the region's population, is Flint, with a 1970 population of 220,653.

All of the communities are in the Saginaw River basin, which contributes high loads of total and orthophosphorus to the lake. Flint, Saginaw and Bay City, all of which have combined sewers, are potential contributors of bacteria to the lake as well.

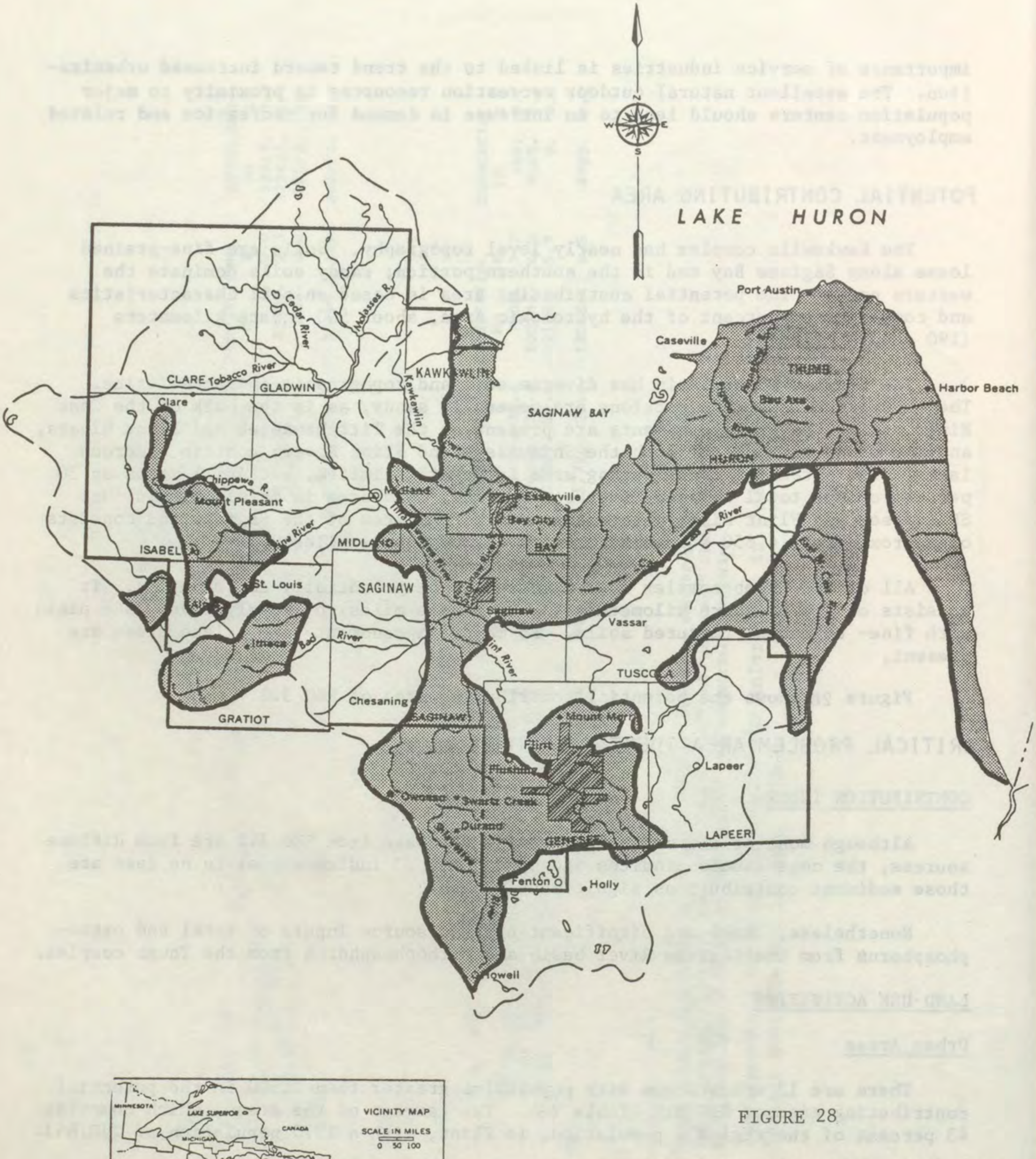


FIGURE 28

POTENTIAL CONTRIBUTING AREA OF RBG 3.2

TABLE 65

CONTRIBUTION INDICES
RIVER BASIN GROUP 3.2

HYDROLOGIC AREA	LAND AREA (km^2)*	PCA AREA (km^2)*	SUSPENDED SOLIDS	TOTAL PHOSPHORUS	ORTHO PHOSPHORUS
Kawkawlin Complex	1,000	500	0.1	0.5	0.6
Saginaw River	16,170	4,850	0.5	1.4	1.8
Thumb Complex	3,670	3,670	0.6	0.6	1.0

*To convert square kilometers to square miles, multiply by 0.386

$$CI = \frac{\text{(\% of Great Lakes Diffuse Load) (from hydrologic area)}}{\text{(\% of Great Lakes PCA in) (hydrologic area)}}$$

Total Great Lakes PCA = 105,950 km^2

Total Great Lakes Diffuse Loads

Suspended Solids = 9,492,407 Mtonnes/yr.

Total P = 13,155 Mtonnes/yr.

Ortho P = 3,007 Mtonnes/yr.

NOTE: Loads are average of 1975 and 1976 values with Lake Erie values assured equal for both years

TABLE 66

URBAN AREAS IN THE POTENTIAL CONTRIBUTING AREA
OF RIVER BASIN GROUP 3.2

URBAN AREA	HYDROLOGIC AREA	POPULATION (1970)	AREA (ACRES*) (1970)
Bay City, MI	Saginaw River 3.2.2	54,439	16,764
Flint, MI	"	220,653	61,670
Saginaw, MI	"	101,221	27,829
Durand, MI	"	3,678	768
Owosso, MI	"	17,179	3,008
Swartz Creek, MI	"	4,928	2,624
Howell, MI	"	5,224	1,984
Corunna, MI	"	17,179	1,983
Burton, MI	"	32,540	6,397
Ithaca, MI	"	2,749	2,559
Chesaning, MI	"	2,876	1,791
Caro, MI	"	4,208	1,023
TOTAL - PCA		466,694	128,400
Planning Subarea 3.2		1,095,493	4,424,100

*To convert acres to hectares, multiply by 0.4047

Construction site runoff from this region may also contribute to Great Lakes pollution. Population is projected to increase one percent annually between 1970 and 2020.

The estimated costs of combined sewer and stormwater treatment for cities in the potential contributing area of RBG 3.2 are shown in Table 67. Average annual treatment costs range from $5.0 million for the low efficiency alternative (18 percent solids removal) to $16.4 million for the medium or high efficiency alternatives (up to 84 percent solids removal). Chlorination would add from $165 to $740 thousand per year to the cost of the medium and high efficiency alternatives, depending upon whether or not it was limited to combined sewer overflows.

Construction sediment control in the potential contributing area, based on an annual growth rate of one percent, would cost $514 thousand a year. Detention pond construction in new developments would cost $3.4 million annually with operating and maintenance costs adding $68 thousand a year.

Estimated average annual stormwater and combined sewer control costs for all RBG 3.2 urban areas with more than 2,500 persons range from $5.4 to $18.2 million (Table 68). Chlorination cost estimates were not included. Construction sediment controls for all urban areas in the RBG would cost $562 thousand annually. Detention pond construction and maintenance throughout the RBG would cost $3.7 million and $74 thousand a year, respectively.

Agricultural Areas

The region's predominant land use, agriculture, presents a significant nonpoint source of water pollution [ECMPDR, 1976]. There are 604 thousand hectares (1,491 thousand acres) of cropland within the potential contributing area of RBG 3.2 (see Table 69). Forty-five percent of this cropland, or 275 thousand hectares (679 thousand acres) requires treatment. According to Conservation Needs Inventory data, 649 thousand hectares (1,604 thousand acres) out of a total 959 thousand hectares (2,370 thousand acres) of cropland in the planning subarea required erosion control treatment in 1968.

There are 560 cattle feedlot operations in the potential contributing area, 28 percent of which have waste controls (Table 70). Based on information in Inventory of Land Use [IJC, 1976c], some 406 cattle, 89 swine, and 49 poultry feedlots in the planning subarea may not have waste controls.

Agricultural runoff and intensive livestock operations within this region may have a significant impact on Lake Huron water quality.

Application of best management practices to all soils in the potential contributing area would have a one-time cost of $15.1 million and recurring costs of $2.7 million, for an average annual cost of $4.4 million. Application of BMPs to only fine-textured soils (172 thousand hectares) would cost $10.5 million one-time and $1.5 million recurring, for an average cost of $2.7 million. Application of BMPs to all soils in the planning subarea would cost $35.7 million one-time and $6.3 million recurring or $10.2 million per year in average annual terms.

TABLE 67

URBAN CONTROL SUMMARY FOR RBG 32

NUMBER OF URBAN AREAS: 12

LOW LEVEL OF TREATMENT (<30% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.18

CAPITAL COST	: $	35173344.
ANNUAL OPERATING COST	: $	1135075.
AVERAGE ANNUAL COST*	: $	5010058.

MEDIUM LEVEL OF TREATMENT (30% TO 60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.61

CAPITAL COST	: $	123170976.
ANNUAL OPERATING COST	: $	2967970.
AVERAGE ANNUAL COST*	: $	16537493.

HIGH LEVEL OF TREATMENT (>60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.84

CAPITAL COST	: $	120397440.
ANNUAL OPERATING COST	: $	3154771.
AVERAGE ANNUAL COST*	: $	16418739.

CHLORINATION (MEDIUM AND HIGH LEVEL TREATMENT ONLY)

	COMBINED SEWER ONLY	COMBINED AND STORM SEWERS
CAPITAL:	977544.	5064893.
O&M :	57674.	182262.
ANNUAL*	165368.	740252.

* Average annual cost equals capital amortized over 25 years at 10 percent interest per year plus annual operation and maintenance cost.

TABLE 68

ESTIMATED COST OF CONTROLS FOR ALL URBAN AREAS, RBG 3.2

TREATMENT LEVEL		COST IN PCA ($ millions)	ADJUSTED AREA IN PCA (ACRES*)	COST PER ACRE ($)	TOTAL URBAN ACREAGE	ADJUSTED** URBAN ACREAGE	RBG COST ($ millions)
LOW	Capital	35.2	45,150	780	140,615	49,215	38.4
	O&M	1.1	45,150	25	140,615	49,215	1.2
MEDIUM	Capital	123.2	45,150	2,730	140,615	49,215	134.4
	O&M	3.0	45,150	70	140,615	49,215	3.4
HIGH	Capital	120.4	45,150	2,670	140,615	49,215	131.4
	O&M	3.2	45,150	70	140,615	49,215	3.4

* To convert acres to hectares, multiply by 0.4047

** Urban area adjustment factor = 0.35

Average Annual Cost:

Low:	$ 5.4 million
Medium:	18.2 million
High:	17.9 million

TABLE 69

COSTS FOR INSTALLING AGRICULTURAL BEST MANAGEMENT PRACTICES IN THE POTENTIAL CONTRIBUTING AREA (PCA) OF RIVER BASIN GROUP 3.2

COUNTY	TOTAL ACRES* IN POTENTIAL CONTRIBUTING AREA	ACRES IN PCA NEEDING TREATMENT	COSTS FOR ALL SOILS ($ millions)		COSTS FOR FINE-TEXTURED SOILS ($ millions)	
			One-Time	Recurring	One-Time	Recurring
MICHIGAN						
Arenac	9,600	1,200	0.02	**	0	0
Bay	126,630	62,428	1.48	0.30	0.83	0.11
Genesee	80,000	40,000	0.71	0.14	0.66	0.13
Gratiot	39,073	5,573	0.11	0.02	0.07	**
Huron	341,508	106,508	3.52	0.54	3.13	0.41
Isabella	42,000	21,000	0.36	0.07	0.16	0.02
Lapeer	21,000	8,000	0.16	0.03	0.13	0.02
Livingston	40,000	15,000	0.18	0.05	0	0
Midland	19,459	4,864	0.13	0.02	0.13	0.02
Oakland	200	0	0	0	0	0
Saginaw	200,000	50,000	1.24	0.22	0.89	0.12
St. Clair	12,000	6,000	0.13	0.02	0.11	0.01
Sanilac	210,000	128,000	2.98	0.45	2.73	0.36
Shiawassee	150,000	110,000	1.66	0.34	0.59	0.08
Tuscola	200,000	120,000	1.60	0.21	2.46	0.48
TOTAL	1,491,470	678,573	15.13	2.66	10.47	1.49

*To convert acres to hectares, multiply by 0.4047

**Cost is negligible

TABLE 70

COST FOR INSTALLING AGRICULTURAL WASTE MANAGEMENT SYSTEMS IN POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 3.2

COUNTY	TOTAL NUMBER OF FEEDLOT OPERATIONS ≥100 ANIMAL UNITS IN PCA			NUMBER OF FEEDLOT OPERATIONS IN PCA NEEDING TREATMENT			TOTAL COST ($ thousands)		
	CATTLE	SWINE	POULTRY	CATTLE	SWINE	POULTRY	CATTLE (at $10,000 per system)	SWINE (at $ 6,000 per system)	POULTRY (at $ 3,000 per system)
MICHIGAN									
Arenac	5	0	0	2	0	0	20	0	0
Bay	4	0	0	4	0	0	40	0	0
Genesee	9	0	0	7	0	0	70	0	0
Gratiot	14	0	0	13	0	0	130	0	0
Huron	250	0	0	225	0	0	2,250	0	0
Isabella	29	0	0	20	0	0	200	0	0
Lapeer	45	0	0	20	0	0	200	0	0
Livingston	80	0	0	15	0	0	150	0	0
Midland	3	0	0	3	0	0	30	0	0
Oakland	0	0	0	0	0	0	0	0	0
Saginaw	10	0	0	10	0	0	100	0	0
St. Clair	6	0	0	5	0	0	50	0	0
Sanilac	50	0	0	40	0	0	400	0	0
Shiawassee	15	0	0	10	0	0	100	0	0
Tuscola	40	0	0	32	0	0	320	0	0
TOTAL	560	0	0	406	0	0	4,060	0	0

Installation of waste management systems where needed in the potential contributing area would cost $4.1 million. The cost of waste management for all intensive livestock operations in the planning subarea was estimated at $4.7 million. Equivalent average annual cost figures are $450 and $520 thousand, respectively.

On-Site Waste Disposal

In 1970, nonsewered residential units accounted for 43 percent of the total nonfarm housing units in Planning Subarea 3.2. About 77 percent were located in rural areas.

Fifty-five percent of the nonsewered housing (or 81,580 units) may be located within the potential contributing area, mostly in the Saginaw River basin. The number of nonsewered housing units is projected to increase over 20 percent between 1970 and 1990.

There are numerous reports of septic tanks degrading water quality as a result of the poor drainage characteristics of the region's soils. Problems occur in Gratiot, Isabella, and Midland Counties [ECMPDR, 1976].

The estimated capital investment required to alleviate problems with failing septic systems within the potential contributing area is $14.4 million, with annual operating and maintenance costs of $430 thousand. The average annual cost would be almost $2.0 million per year (Table 71). The same remedial measures applied to the entire planning subarea were estimated to cost $26.0 million for capital, and $780 thousand for maintenance and operation, or $3.6 million per year average annual.

Other Problems

On an average annual basis there are 7 dredge disposal sites in RBG 3.2. About 545,700 cubic meters (713,230 cubic yards) or almost 80 percent of the annual volume of dredge spoil in the region, requires confinement in diked areas. About 91 percent of the polluted sediments are from the Saginaw River and Harbor. The other sites with polluted spoil--Harbor Beach, Port Austin and Sebewaing--use a diked containment area in Saginaw Bay. Total annual maintenance dredge spoil is projected to increase only 17 percent between 1970 and 1990; polluted sediments may increase 16 percent in the same period.

Because most of the polluted spoil in RBG 3.2 is contained, dredging may have only a minimal impact on Lake Huron water quality.

Leachate problems have occurred at several landfills in the potential contributing area. The Fullerton Township landfill, the Gratiot County landfill, and the City of Ithaca landfill, all in Gratiot County, have reported local groundwater and possible surface water degradation caused by leaching. In Isabella County, the City of Mt. Pleasant landfill may affect nearby surface water, even though it was closed in December 1975 [ECMPDR, 1976]. There are also 72 liquid waste disposal operations, the majority of which employ lagoons. Low permeability of soils in much of the area is cause for concern that these operations may affect water quality. Ninety percent of the sites in the planning subarea are industrial.

TABLE 71

ON-SITE WASTE DISPOSAL, RBG 3.2

COUNTY	TOTAL NUMBER OF SYSTEMS	PERCENT OF COUNTY IN PCA	ESTIMATED NUMBER OF SYSTEMS IN PCA	NUMBER FAILING	CAPITAL COST ($\$X10^6$)	OPERATING COST ($\$X10^3$)	AVERAGE ANNUAL COST ($\$X10^6$)
Michigan							
Bay	11,080	70	7,760	780	1.37	41.4	0.19
Genesee	48,180	80	38,540	3,850	6.77	204.4	0.95
Gratiot	4,840	50	2,420	240	0.42	12.7	0.06
Huron	6,915	100	6,920	690	1.21	36.6	0.17
Isabella	5,185	25	1,300	130	0.23	6.9	0.03
Lapeer	9,819	10	980	100	0.18	5.3	0.02
Midland	8,012	10	800	80	0.14	4.2	0.02
Saginaw	15,774	50	7,890	790	1.39	41.9	0.19
Tuscola	8,274	55	4,550	460	0.81	24.4	0.11
Sanilac	6,766	50	3,380	340	0.58	18.0	0.08
Livingston	12,822	10	1,280	130	0.23	6.9	0.03
Shiawassee	8,751	66	5,760	580	1.02	30.8	0.14
TOTAL	--	--	81,580	8,170	14.35	433.5	1.99

6 LAKE ERIE BASIN

LAKE BASIN SUMMARY

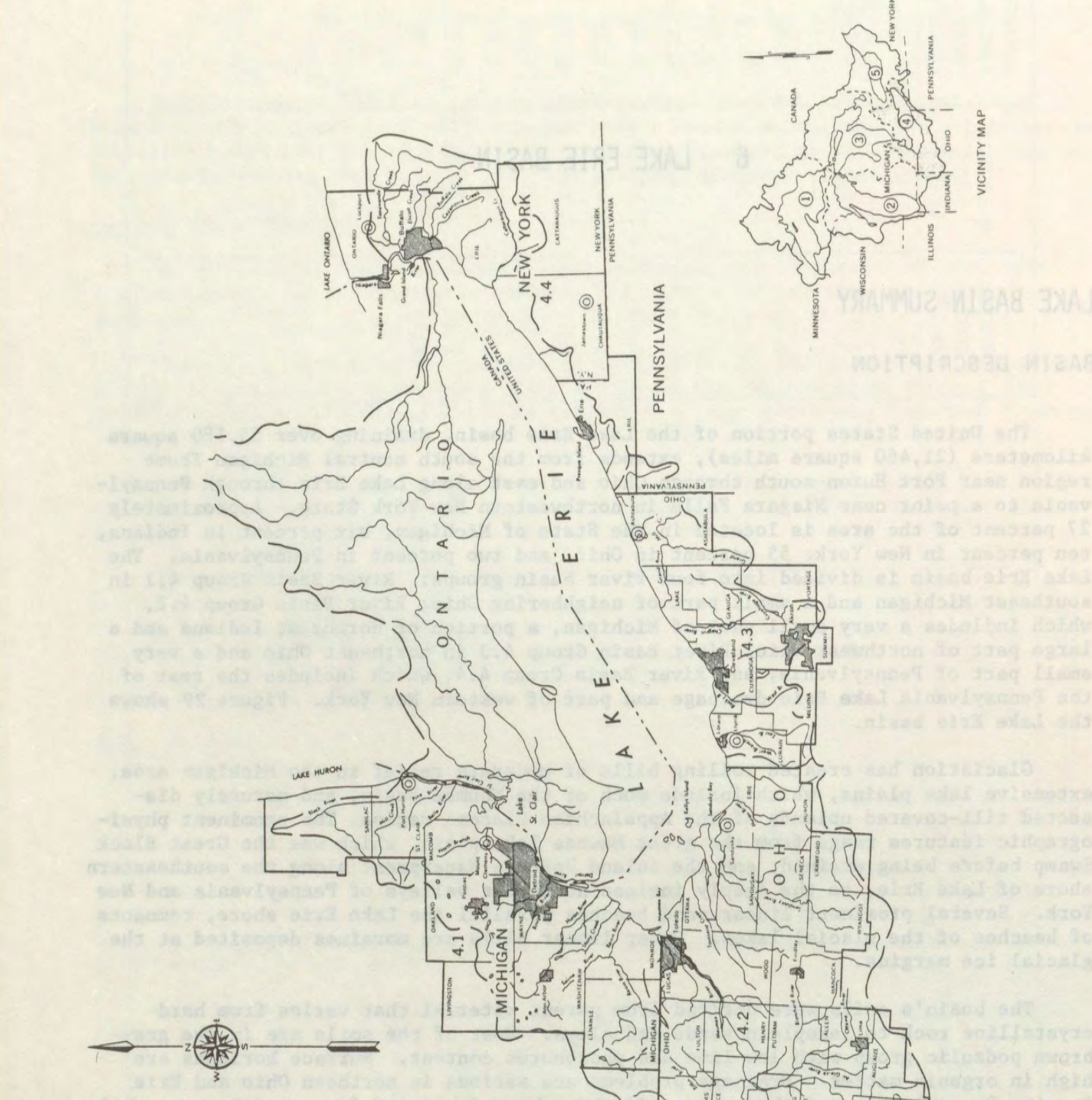
BASIN DESCRIPTION

The United States portion of the Lake Erie basin, draining over 55,580 square kilometers (21,460 square miles), extends from the south central Michigan Thumb region near Port Huron south through Ohio and east along Lake Erie through Pennsylvania to a point near Niagara Falls in northwestern New York State. Approximately 27 percent of the area is located in the State of Michigan, six percent in Indiana, ten percent in New York, 55 percent in Ohio, and two percent in Pennsylvania. The Lake Erie basin is divided into four river basin groups: River Basin Group 4.1 in southeast Michigan and a small part of neighboring Ohio; River Basin Group 4.2, which includes a very small part of Michigan, a portion of northeast Indiana and a large part of northwest Ohio; River Basin Group 4.3 in northeast Ohio and a very small part of Pennsylvania; and River Basin Group 4.4, which includes the rest of the Pennsylvania Lake Erie drainage and part of western New York. Figure 29 shows the Lake Erie basin.

Glaciation has created rolling hills of moderate relief in the Michigan area, extensive lake plains, which include much of the Maumee basin, and maturely dissected till-covered uplands of the Appalachian Plateau region. The prominent physiographic features range from the great Maumee lake plain, which was the Great Black Swamp before being drained, and the inland Portage Escarpment along the southeastern shore of Lake Erie, to the deeply incised headwater valleys of Pennsylvania and New York. Several prominent linear sand beaches parallel the Lake Erie shore, remnants of beaches of the glacial lakes. Other linear hills are moraines deposited at the glacial ice margins.

The basin's soils were derived from parent material that varies from hard crystalline rock to lakeplain sands and clays. Most of the soils are in the gray-brown podzolic group with low lime and phosphorus content. Surface horizons are high in organic matter. Drainage problems are serious in northern Ohio and Erie County, Pennsylvania, or where the soils have been developed from sandstone or shale. Poorly drained soils on flat topography contribute more sediment to flowing waters due to their greater erosion rates than do well drained soils in similar areas.

Mineral resources are primarily non-metallic, consisting largely of oil and gas, sand and gravel, salt, gypsum, clay, and peat. Large salt deposits are located in the western portion, while clay production is predominant in the lakeshore region.



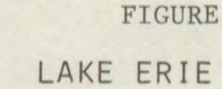


FIGURE 29

LAKE ERIE BASIN

The Lake Erie region is characterized by a diversified economy which relies upon light and heavy industry, manufacturing, agriculture, and tourism and recreation for support. Industrial activity is concentrated in the highly populated metropolitan areas and most is near the lakeshore, since it relies on a plentiful water supply and waterborne commerce. Generally speaking, agricultural production in the western portion of the basin is characterized by dairy products, vegetables, fruits, and field crops, as well as livestock and livestock products. The central and eastern sections are smaller in area with higher urban concentrations and typically generate value through nursery and greenhouse products, vegetables, and specialty crops like grapes, pears, and sweet cherries which are among the most significant.

The overall population density is quite high, with approximately 179 people per square kilometer (466 per square mile). The Lake Erie region is the most populous of the five Great Lakes with a 1975 population estimated at 11,451,320, an increase of thirty-nine percent from the 1940 population of 7,095,000. The major concentrations of people are found in Wayne County, Michigan, Cuyahoga County, Ohio, and Erie County, Pennsylvania. These three counties account for 48 percent of the total U.S. Lake Erie population.

The U.S. Bureau of Census has defined ten standard metropolitan statistical areas (SMSA) within the Lake Erie region. Although SMSAs cover only 10 percent of the land, approximately 80 percent of the population lived in these areas in 1970.

Lake Erie and its associated connecting channels - the St. Clair, Detroit, and Niagara Rivers, and Lake St. Clair - are well known for their serious water quality problems. The concentration of heavy metals in fish in Lake St. Clair and accelerated eutrophication of the western and central basins of Lake Erie are major problems. Phosphorus concentrations in Lake Erie are about six times that of the other lakes. Low dissolved oxygen concentrations and algae blooms are characteristic of many of the basin's surface waters. Relative to the other Great Lakes, however, Lake Erie has the natural ability to flush out polluted material in a short period of time. The open waters of western Lake Erie are eutrophic while there is a gradient from eutrophic to mesotrophic conditions as one moves from the western to the eastern end of the lake.

PROBLEM AREA SUMMARY

The estimated potential contributing area totals 46,530 square kilometers (17,960 square miles), or almost 85 percent of the lake basin. River Basin Group 4.2 alone accounts for over half of that potential contributing area.

The assessment of diffuse tributary sediment and phosphorus loadings to the lake has highlighted the following hydrologic areas as having a significant input of one or both of these contaminants: Clinton River, Rouge complex, Huron River, Swan Creek complex, Maumee River, Sandusky River, Huron-Vermilion complex, Black-Rocky complex, Cuyahoga River, Chagrin complex, Grand River, Ashtabula-Conneaut complex, Erie-Chatauqua complex, Cattaraugus Creek complex and Tonawanda complex.

The following potential critical problem areas and associated remedial costs were identified on the basis of land use activities.

URBAN AREAS

There are 77 urban areas with a total population of 8,431,537 covering 1,654,235 acres identified in the potential contributing area of Lake Erie. The annual growth rate varies from 0.3 percent in RBG 4.4, to 0.6 percent in RBG 4.3, to 0.8 percent in 4.1, to 1.1 percent in 4.2. The western end of the basin is thus expected to grow faster than the eastern half.

Total costs for stormwater and combined sewer controls applied to urban areas in the basin's potential contributing area range from $101.0 to $295.7 million. Chlorination would add from $1.7 to $15.4 million per year to the cost. Treatment costs for all urban areas in the basin were estimated to range from $102.1 to $299.1 million per year.

Construction sediment controls applied to new development in the potential contributing area were estimated to cost $4.7 million annually. Detention ponds in the potential contributing area would cost $35.7 million for annual construction and $720 thousand in annual maintenance. Extrapolation of these figures to all urban areas in the basin showed the following results: $4.8 million annually for construction sediment controls; $36.3 million annually for detention pond construction and $730 thousand per year for detention pond maintenance.

AGRICULTURAL AREAS

There are 2,780 thousand hectares (6,866 thousand acres) of cropland within the potential contributing area of Lake Erie. Sixty-four percent of this cropland, or 1,774 thousand hectares (4,382 thousand acres) requires erosion controls. The application of agricultural best management practices in the potential contributing area would cost $36.9 million one-time, and $14.0 million per year recurring, for an average annual cost of $18.1 million. Limiting these practices to fine-textured soils reduces the costs to $23.9 million one-time, $7.6 million recurring, and $10.2 million average annual. Based on Conservation Needs Inventory data, application of BMPs to all basin cropland needing erosion control treatment would cost $59.9 million and $20.3 million in one-time and recurring costs, respectively, for an average annual cost of $26.9 million.

There are 1,348 intensive livestock operations without waste controls in the Lake Erie potential contributing area. Installation of waste management systems here would cost $16.1 million. Installation to all intensive livestock operations without waste controls in the basin would cost $23.7 million. The equivalent average annual figures are $1.8 and $2.6 million, respectively.

ON-SITE WASTE DISPOSAL

Within the potential contributing area, an estimated 97,400 septic tanks are malfunctioning. To remedy this problem would cost $181.5 million in capital, and $6.2 million in annual operation and maintenance, for an average annual cast of $26.2 million. Extrapolation to the basin would result in costs of $271.4 million, capital, $9.4 million annual operating and maintenance, and $39.3 million average annual.

The costs for urban, agricultural, and on-site waste disposal remedial measures are summarized in Table 72.

OTHER PROBLEMS

Other problems identified in the Lake Erie basin include the disposal of polluted dredge spoil throughout the region, gypsum tailings disposal in Sandusky Bay, and significant riverbank erosion along the Cuyahoga River.

TABLE 72

COST

SUMMARY FOR LAKE

ERIE

REMEDIAL MEASURES	CAPITAL COST ($ millions)	OPERATING, MAINTENANCE AND RECURRING COST ($ millions)	AVERAGE ANNUAL COST ($ millions)
Urban Areas			
Low Level Treatment	743.9	19.0	101.0
Medium Level Treatment	1,805.6	41.2	240.1
High Level Treatment	2,157.3	58.0	295.7
Chlorination -			
Combined only	9.0	0.7	1.7
Both	113.4	2.9	15.4
Sediment Controls	-	4.7	4.7
Detention Ponds	-	36.4	36.4
Agricultural Areas			
Best Management			
Practices:			
All Soils	36.9	14.0	18.1
Fine Soils	23.9	7.6	10.2
Animal Waste Controls	16.1	-	1.8
On-Site Waste Disposal	181.5	6.2	26.2

RIVER BASIN GROUP 4.1

DESCRIPTION

River Basin Group 4.1 is located in the south central portion of the Great Lakes Basin, and covers 13,500 square kilometers (5,200 square miles) of the area draining into the St. Clair River, Lake St. Clair, and the Detroit River. The corresponding planning subarea consists of nine Michigan counties, as shown in Figure 30. Seven hydrologic areas - Black River, St. Clair complex, Clinton River, Rouge complex, Huron River, Swan Creek complex, and Raisin River, comprise this RBG.

The sedimentary bedrock formations of this area are of Paleozoic age. The formations range upward from the Munising formation of the Cambrian system to the Saginaw group of the Pennsylvanian system. Overlying the bedrock formations are the unconsolidated Quaternary sediments of glacial origin.

The northwestern part of this region is strongly rolling while land to the east and southeast is less steeply sloping. Soils are primarily loams, silt loams, silty clay loams, and clay loams. The soils on the lake plains include clay loams, silty clay loams and clay (Figure 31). There is great variability in relief and cover characteristics here. Many areas in the gently sloping lake plains are intensely cultivated and even though the slopes are gentle, erosion rates are high. In addition, much of the rolling land on the more erosive soils is cultivated, with relatively high erosion rates as a result. Important mineral commodities include clay, peat, petroleum and natural gas, salt, sand and gravel, and stone (limestone and dolomite).

The major rivers include: the Black, St. Clair, Clinton, Rouge and Huron Rivers, and the River Raisin.

As Table 73 indicates, forests cover 41 percent of the land; agricultural use covers 37 percent and urbanization is a significant 20 percent.

The planning subarea's population has almost doubled over the last three decades, from 2,697,068 in 1940 to 4,853,097 in 1970. Eighty-nine percent of the population was urban. Major urban areas are (1975 population estimates): Detroit (pop.: 1,335,085), Dearborn (pop.: 98,986), Livonia (pop.: 114,881), Westland (pop.: 92,689), Pontiac (pop.: 76,027), Royal Oak (pop.: 79,191), Southfield (pop.: 75,978), Sterling Heights (pop.: 86,932), Warren (pop.: 172,755), Adrian (pop.: 20,857), Monroe (pop.: 24,612), Port Huron (pop.: 35,739), and Ann Arbor (pop.: 103,542).

The number of people employed in 1970 was more than 1.8 million. Both population and employment have increased more rapidly than in the Great Lakes as a region. About 667,000 workers were employed in the manufacturing sector in 1970 with automotive-related industries predominating. Agriculture accounted for about one percent of employment and mining activity was insignificant.

FIGURE 30

PLANNING SUBAREA 4.1

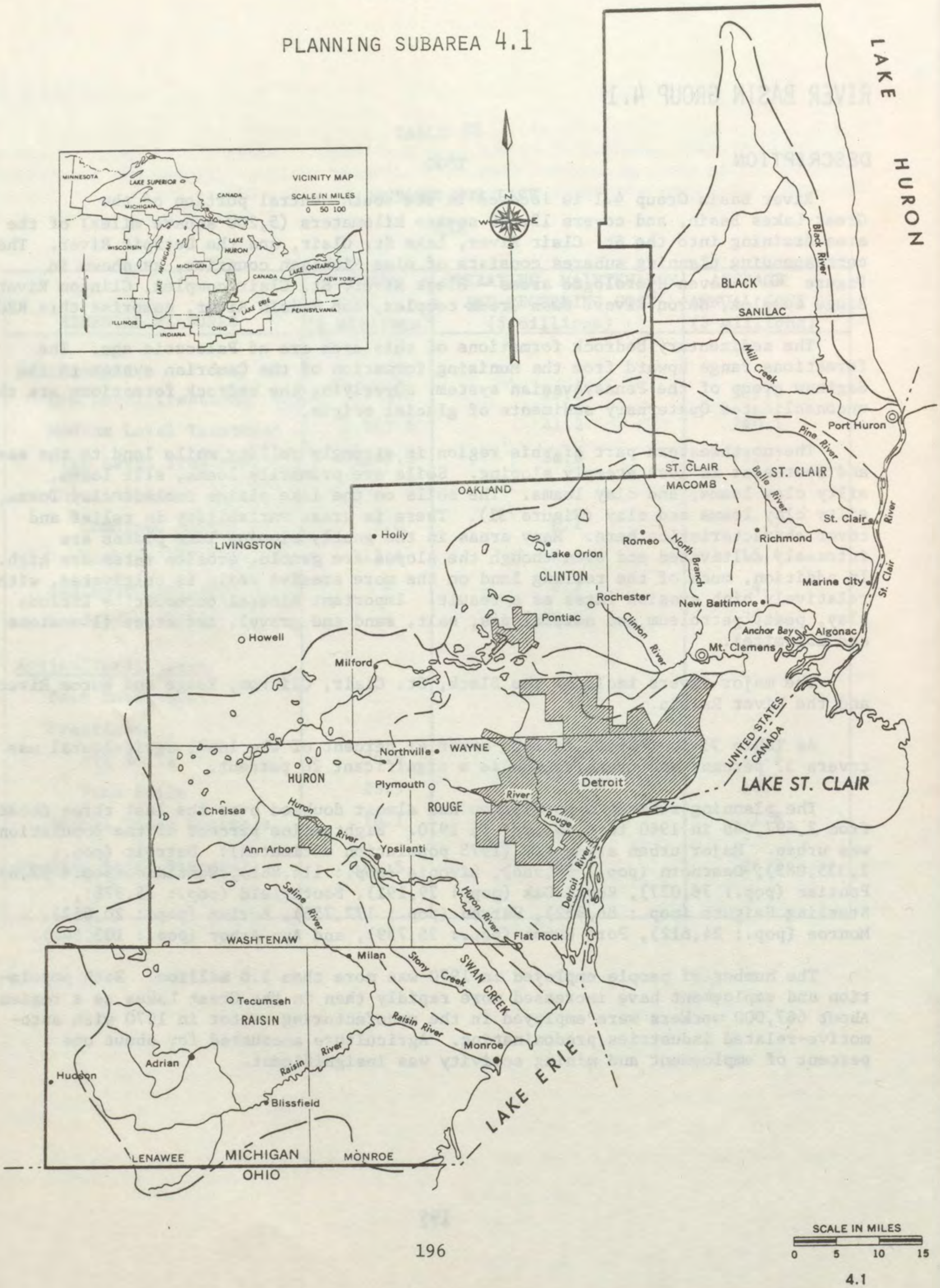
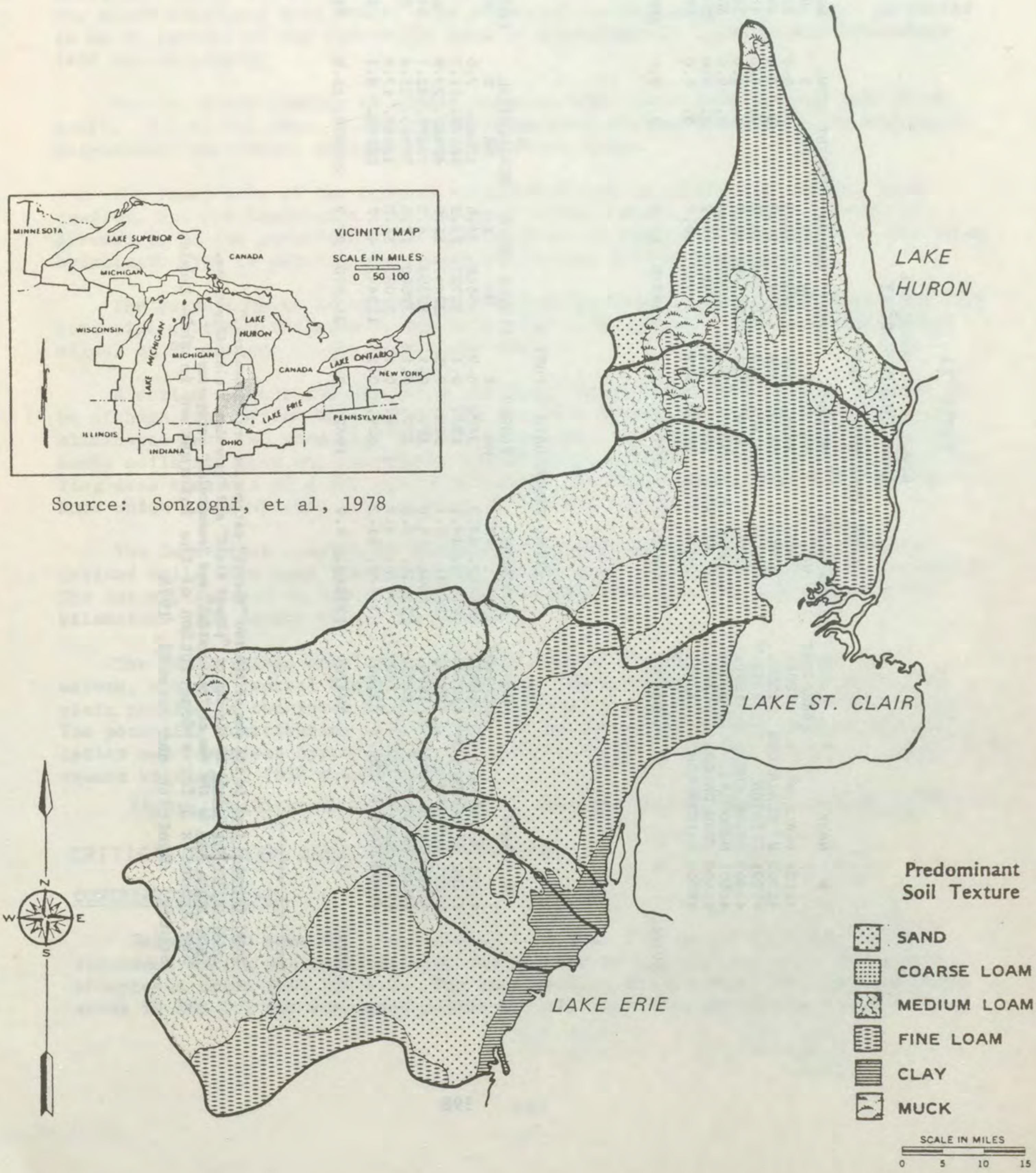


FIGURE 31

SOIL TEXTURE

River Basin Group 4.1



Source: Sonzogni, et al, 1978

TABLE 73

RIVER BASIN GROUP 4.1
LAND COVER SUMMARY

LAND COVER DATA - PART 1

#	NAME	LAND AREA:KM2	INLAND WATER HA	WETLAND HA	%	FOREST (DECID) HA	%	FOREST (CON) HA	%	BRUSHLAND HA	%
41101	BLACK MI	1800.	900.	7236.	4.0	29668.	16.5	0.	0.0	37266.	20.7
41200	ST CLAIR COM	1550.	1240.	5625.	3.6	32812.	21.2	0.	0.0	40312.	26.0
41301	CLINTON	2030.	4872.	4160.	2.0	53246.	26.2	0.	0.0	41182.	20.3
41400	ROUGE COM	1890.	1134.	570.	0.3	19775.	10.5	0.	0.0	34796.	18.4
41501	HURON MI	2200.	7040.	5227.	2.4	60227.	27.4	0.	0.0	68636.	31.2
41600	SWAN CR COM	740.	74.	1037.	1.4	8815.	11.9	0.	0.0	20444.	27.6
41700	RAISIN COM	3260.	2608.	3944.	1.2	34835.	10.7	0.	0.0	67369.	20.7
TOTAL	7	13470.	17868.	27799.	2.1	239378.	17.8	0.	0.0	310007.	23.0

LAND COVER DATA - PART 2

#	NAME	LAND AREA:KM2	GRASSLAND HA	%	BARREN HA	%	PLOWED FIELD HA	%	RESIDENTIAL HA	%	COMMERCIAL HA	%
41101	BLACK MI	1800.	26412.	14.7	362.	0.2	65668.	36.5	12663.	7.0	724.	0.4
41200	ST CLAIR COM	1550.	21875.	14.1	156.	0.1	35937.	23.2	18125.	11.7	156.	0.1
41301	CLINTON	2030.	16431.	8.1	624.	0.3	32447.	16.0	48462.	23.9	6448.	3.2
41400	ROUGE COM	1890.	7606.	4.0	190.	0.1	12359.	6.5	79479.	42.1	34225.	18.1
41501	HURON MI	2200.	21136.	9.6	227.	0.1	37500.	17.0	25000.	11.4	2045.	0.9
41600	SWAN CR COM	740.	3630.	4.9	74.	0.1	27037.	36.5	12889.	17.4	74.	0.1
41700	RAISIN COM	3260.	36478.	11.2	329.	0.1	155442.	47.7	26290.	8.1	1315.	0.4
TOTAL	7	13470.	133568.	9.9	1962.	0.1	366390.	27.2	222908.	16.5	44987.	3.3

---

*Total forested land is the sum of the two "forest" categories and "brushland."
Total agricultural land is the sum of "plowed field" and "grassland" classifications.
Total urban land is the sum of "residential" and "commercial" categories.
See Appendix 3 for a description of the information in this table.
Source: Monteith and Jarecki, 1978

POTENTIAL CONTRIBUTING AREA

Soils in the Black River hydrologic area are predominantly fine- to medium-textured. Sandy soils, lakes and wetlands exist mainly in the headwaters areas of the Black River and Mill Creek. The potential contributing area is thus estimated to be 80 percent of the hydrologic area or approximately 1,160 square kilometers (450 square miles).

The St. Clair complex is almost entirely made up of fine-grained lake plain soils. All of the area, 1,470 square kilometers (560 square miles), is assumed to potentially contribute pollutants to the Great Lakes.

The lower part of the Clinton River watershed is similar to the St. Clair complex, but the headwaters area has many inland lakes. The lower portion is assumed to be the potential contributing area--it comprises 60 percent of the total hydrologic area or about 1,180 square kilometers (450 square miles).

The Rouge complex is similar to the Clinton River basin, but in this case, the potential contributing area is approximately 1,700 square kilometers (650 square miles) or 90 percent of the hydrologic area.

A series of impoundments along the Huron River below Ypsilanti is assumed to be of high trap efficiency. Thus, the upstream portion of the drainage basin is eliminated from the potential contributing area. Another area below the dams has sandy soils and does not contribute significant sediment. The potential contributing area consists of a 100 square kilometer (40 square mile) region below Flat Rock which makes up only five percent of the hydrologic area.

The Swan Creek complex is composed of predominantly level areas of coarse-grained soils with some (approximately 30 percent) fine- and medium-textured soils. The latter, assumed to be the potential contributing area, is about 260 square kilometers (100 square miles) in extent.

The River Raisin complex is characterized by a lake region in the headwaters, a broad central basin with fine- to medium-textured soils, a sandy lake plain portion in the lower basin, and a clay soil area along the Lake Erie shore. The potential contributing area is defined on the basis of soil texture characteristics and comprises approximately 70 percent of the total basin area, or about 2,300 square kilometers (880 square miles).

Figure 32 illustrates the extent of the potential contributing area in RBG 4.1.

CRITICAL PROBLEM AREA IDENTIFICATION

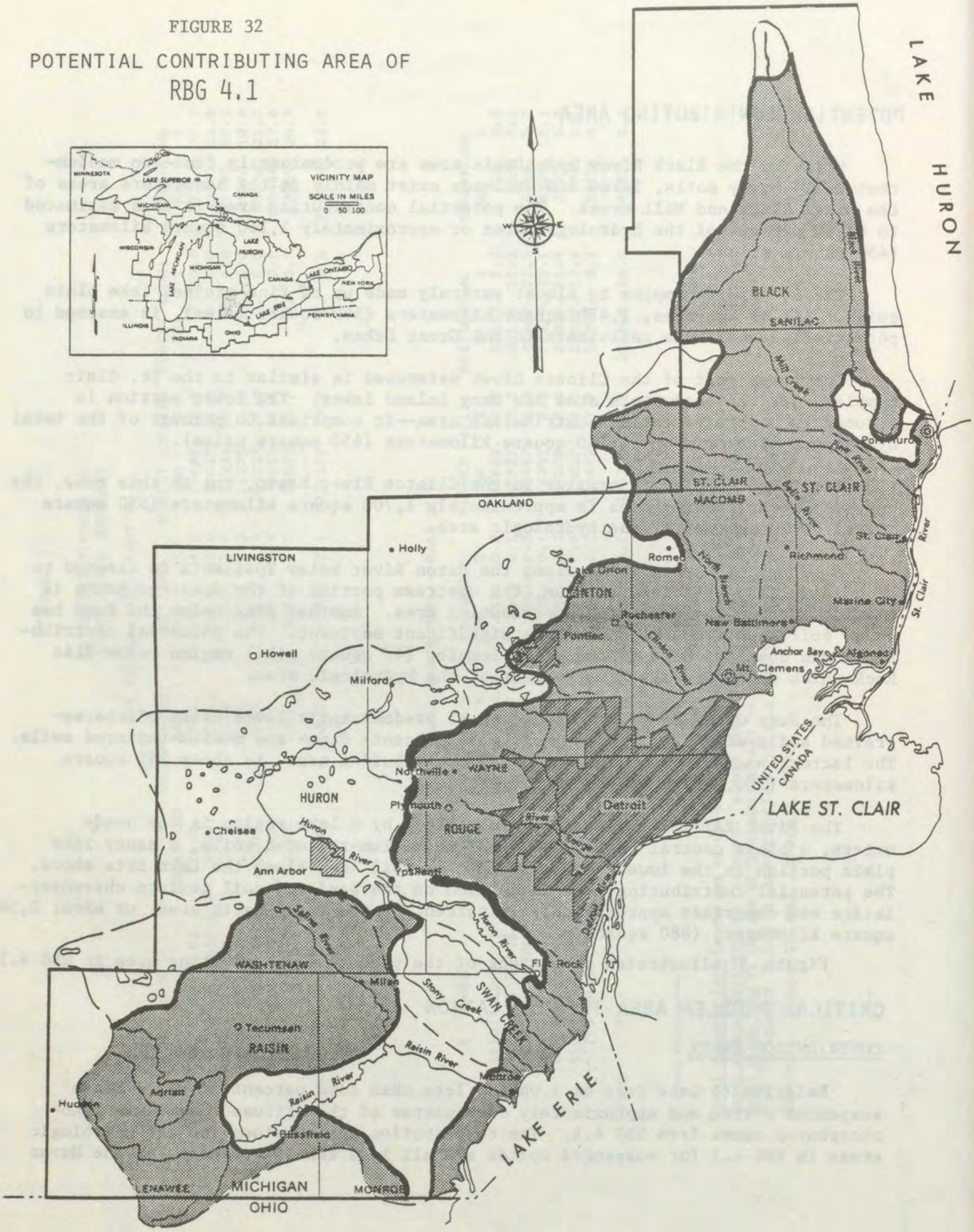
CONTRIBUTION INDEX

Relative to Lake Erie as a whole, less than five percent of the diffuse suspended solids and approximately one-quarter of the diffuse total and orthophosphorus comes from RBG 4.1. The contribution index values for the hydrologic areas in RBG 4.1 for suspended solids are all less than one except for the Huron

FIGURE 32

POTENTIAL CONTRIBUTING AREA OF

RBG 4.1



River (Table 74). It should be noted, however, that the estimated potential contributing area of the Huron is quite small, accounting for only five percent of its total drainage area. Because of this, care should be taken in interpreting the significance of the contribution index values associated with it.

In terms of total and orthophosphorus inputs, several hydrologic areas have significant contributions to the lakes. These include the Clinton River, the Rouge complex, and the Swan Creek complex. Also, total phosphorus contributions from the Huron River appear to be significant, although the caution expressed above must be kept in mind. The three remaining hydrologic areas, the Black River, the St. Clair, and the River Raisin, do not appear to have significant diffuse sediment or phosphorus loadings.

LAND USE ACTIVITIES

Urban Areas

There are 12 urban areas (accounting for 77 percent of the region's population) in the potential contributing area of RBG 4.1 (Table 75). Only Detroit in the Rouge complex is located in a high tributary load area, while Detroit, Port Huron, and Monroe, Michigan are assumed to contribute bacteria to Lake Erie. Raw sewage overflows from combined sewer systems are a problem in Detroit [GLBC, 1976].

Construction site runoff from RBG 4.1 also contributes to Great Lakes pollution. The region's population is projected to increase 0.8 percent annually between 1970 and 2020.

Estimated combined sewer and stormwater control costs are summarized in Table 76.* As these figures show, the average annual cost of reducing pollutant inputs from these sources would range from $42.9 million for a low efficiency (19 percent solids removed) program, to $103.2 million for the medium efficiency (60 percent) program. The annual cost of the high efficiency alternative is slightly lower at $100.5 million. The addition of chlorination in those areas that are potential bacteria sources would add from $0.9 to $3.0 million to the annual cost.

The extrapolation of these figures to all urban areas in Planning Subarea 4.1 is carried out in Table 77. Because the bulk of the urbanized portion of the region lies within the potential contributing area, the cost figures show little change: average annual costs for low efficiency treatment rise less than three percent, from $42.9 million to $44.1 million. Costs for high efficiency treatment increase from $100.5 million to $104.0 million.

*The apparent discrepancy between the number of urban areas included in Tables 75 (12) and 76 (13) arose from the fact that Detroit was treated as two areas, one served solely by combined sewers, the other by separate sewers.

TABLE 74

CONTRIBUTION INDICES
RIVER BASIN GROUP 4.1

HYDROLOGIC AREA	LAND AREA (km^2)*	PCA AREA (km^2)*	SUSPENDED SOLIDS	TOTAL PHOSPHORUS	ORTHO PHOSPHORUS
Black River	1,800	1,160	0.2	0.3	0.7
St. Clair Complex	1,550	1,470	0.1	0.3	0.4
Clinton River	1,550	1,180	0.2	1.0	0.8
Rouge Complex	1,890	1,700	<0.1	1.5	3.4
Huron River	2,200	100	2.1	12.1	-
Swan Creek Complex	740	260	0.3	1.9	1.5
River Raisin	3,260	2,300	0.7	0.8	0.9

*To convert square kilometers to square miles, multiply by 0.386

$$CI = \frac{(\text{\% of Great Lakes Diffuse Load})\ (\text{from hydrologic area})}{(\text{\% of Great Lakes PCA in})\ (\text{hydrologic area})}$$

Total Great Lakes PCA = 105,950 km^2

Total Great Lakes Diffuse Loads

Suspended Solids = 9,492,407 Mtonnes/yr.

Total P = 13,155 Mtonnes/yr.

Ortho P = 3,007 Mtonnes/yr.

NOTE: Loads are average of 1975 and 1976 values with Lake Erie values assured equal for both years

TABLE 75

URBAN AREAS IN THE POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 4.1

URBAN AREA	HYDROLOGIC AREA		POPULATION (1970)	AREA (ACRES*) (1970)
Detroit, MI	Rouge Complex	4.1.4	3,633,676	557,845
Toledo Metro, MI	River Raisin	4.1.7	5,721	4,414
Port Huron, MI	St. Clair Complex	4.1.2	35,794	4,799
St. Clair, MI	St. Clair Complex	4.1.2	4,770	2,048
Adrian, MI	River Raisin	4.1.7	20,382	3,710
Tecumseh, MI	River Raisin	4.1.7	7,120	2,687
Monroe, MI	River Raisin	4.1.7	23,894	5,886
Algonac, MI	St. Clair Complex	4.1.2	3,684	768
Marine City, MI	St. Clair Complex	4.1.2	4,567	1,472
Marysville, MI	St. Clair Complex	4.1.2	5,610	4,285
Milan, MI	River Raisin	4.1.7	4,533	1,023
Saline, MI	River Raisin	4.1.7	4,811	1,601
TOTAL - PCA			3,754,567	590,538
Planning Subarea 4.1			4,853,097	3,980,400

*To convert acres to hectares, multiply by 0.4047

TABLE 76

URBAN CONTROL SUMMARY FOR RBG 41

NUMBER OF URBAN AREAS: 13

LOW LEVEL OF TREATMENT (<30% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.19

CAPITAL COST	: $	321725696.
ANNUAL OPERATING COST	: $	7495743.
AVERAGE ANNUAL COST *	: $	42939664.

MEDIUM LEVEL OF TREATMENT (30% TO 60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.60

CAPITAL COST	: $	802551808.
ANNUAL OPERATING COST	: $	14765067.
AVERAGE ANNUAL COST *	: $	103180736.

HIGH LEVEL OF TREATMENT (>60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.89

CAPITAL COST	: $	781822720.
ANNUAL OPERATING COST	: $	14374305.
AVERAGE ANNUAL COST *	: $	100506288.

CHLORINATION (MEDIUM AND HIGH LEVEL TREATMENT ONLY)

	COMBINED SEWER ONLY	COMBINED AND STORM SEWERS
CAPITAL:	4726367.	19232304.
O&M :	368118.	847011.
ANNUAL*:	888813.	2965799.

* Average annual cost equals capital amortized over 25 years at 10 percent interest per year plus annual operation and maintenance cost.

TABLE 77

ESTIMATED COST OF CONTROLS FOR ALL URBAN AREAS, RBG 4.1

TREATMENT LEVEL		COST IN PCA ($ millions)	ADJUSTED AREA IN PCA (ACRES*)	COST PER ACRE ($)	TOTAL URBAN ACREAGE	ADJUSTED** URBAN ACREAGE	RBG COST ($ millions)
LOW	Capital	321.73	245,060	1,310	612,430	252,720	331.1
	O&M	7.50	245,060	30	612,430	252,720	7.6
MEDIUM	Capital	802.55	245,060	3,270	612,430	252,720	826.4
	O&M	14.76	245,060	60	612,430	252,720	15.2
HIGH	Capital	781.82	245,060	3,190	612,430	252,720	806.2
	O&M	14.37	245,060	60	612,430	252,720	15.2

*To convert acres to hectares, multiply by 0.4047

**Composite urban area adjustment factor = 0.26

Average Annual Cost:

Low:	$ 44.1	million
Medium:	106.2	million
High:	104.0	million

Based on an average annual growth rate of 0.8 percent, it was estimated that construction sediment controls would cost $1.9 million per year, if applied in urban areas within the potential contributing area. Provision of detention ponds in all new developments in the potential contributing area would add $15.0 million per year for constructing new ponds plus $300 thousand per year in maintenance.

The annual costs of applying these measures to all urban areas in Planning Subarea 4.1 were estimated to be as follows: $2.0 million for construction site sediment controls, $15.6 million for new detention ponds, and $311 thousand for detention pond maintenance.

Agricultural Areas

There are 380 thousand hectares (938 thousand acres) of cropland within the potential contributing area of RBG 4.1 (see Table 78). Forty-eight percent of this cropland, or 181 thousand hectares (446 thousand acres), requires treatment. According to Conservation Needs Inventory data, 560 thousand hectares (1,384 thousand acres) out of a total 897 thousand hectares (2,216 thousand acres) of cropland in the planning subarea required erosion control treatment in 1968.

Within the potential contributing area are located 190 cattle feedlot operations (see Table 79). Only 23 percent of those have waste controls.

Agricultural runoff and intensive livestock operations within this region may have a significant impact on Lake Erie water quality.

As the figures in Table 78 show, it would require a one-time investment of $8.0 million, and recurring costs of $1.6 million to apply best management practices to all cropland on medium- to fine-textured soils in the potential contributing area. The average annual cost of this program would be approximately $2.5 million. Limiting the program only to the fine-textured soils (123 thousand hectares) would reduce the average annual cost to $1.7 million, with one-time and recurring costs of $6.7 and $1.0 million, respectively.

In contrast, the estimated cost of applying these practices to all cropland identified as requiring erosion control in the Conservation Needs Inventory of 1968 would be $24.8 million in one-time costs, $5.0 million per year in recurring costs, for an average annual cost of $7.7 million per year.

Table 79 shows that the installation of waste management systems in the potential contributing area would cost an estimated $1.5 million. The estimated cost of such systems for all operations in Planning Subarea 4.1 [based on data in IJC, 1976d] is $4.7 million. The costs are $160 and $520 thousand per year in average annual terms.

On-Site Waste Disposal

Of 203,160 high density, nonsewered, nonfarm housing units in Planning Subarea 4.1 in 1970, nearly half (46 percent) were in urban areas. Nonsewered units account for only 13 percent of the region's nonfarm housing.

TABLE 78

COSTS FOR INSTALLING AGRICULTURAL BEST MANAGEMENT PRACTICES
IN THE POTENTIAL CONTRIBUTING AREA (PCA) OF RIVER BASIN GROUP 4.1

COUNTY	TOTAL ACRES* IN POTENTIAL CONTRIBUTING AREA	ACRES IN PCA NEEDING TREATMENT	COSTS FOR ALL SOILS ($ millions)		COSTS FOR FINE-TEXTURED SOILS ($ millions)	
			One-Time	Recurring	One-Time	Recurring
MICHIGAN						
Lapeer	38,000	19,000	0.21	0.07	0.10	0.01
Lenawee	185,700	124,500	1.58	0.51	1.11	0.22
Macomb	120,000	75,049	1.24	0.24	0.78	0.13
Monroe	85,000	35,000	0.72	0.10	0.72	0.10
St. Clair	201,200	48,000	0.97	0.17	0.93	0.15
Sanilac	246,000	110,700	2.86	0.39	2.80	0.37
Washtenaw	50,000	30,000	0.37	0.12	0.26	0.05
Wayne	12,000	4,000	0.05	0.02	0.04	0.01
TOTAL	937,900	446,249	8.00	1.62	6.74	1.04

*To convert acres to hectares, multiply by 0.4047

TABLE 79

COST FOR INSTALLING AGRICULTURAL WASTE MANAGEMENT SYSTEMS IN POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 4.1

COUNTY	TOTAL NUMBER OF FEEDLOT OPERATIONS ≥100 ANIMAL UNITS IN PCA			NUMBER OF FEEDLOT OPERATIONS IN PCA NEEDING TREATMENT			TOTAL COST ($ thousands)		
	CATTLE	SWINE	POULTRY	CATTLE	SWINE	POULTRY	CATTLE (at $10,000 per system)	SWINE (at $6,000 per system)	POULTRY (at $3,000 per system)
MICHIGAN									
Lapeer	25	0	0	12	0	0	120	0	0
Lenawee	86	0	0	76	0	0	760	0	0
Macomb	8	0	0	5	0	0	50	0	0
Monroe	10	0	0	2	0	0	2	0	0
St. Clair	13	0	0	11	0	0	110	0	0
Sanilac	44	0	0	39	0	0	390	0	0
Washtenaw	4	0	0	2	0	0	20	0	0
TOTAL	190	0	0	147	0	0	1,470	0	0

Table 80 approximates their distribution within the potential contributing area, which may account for 51 percent of nonsewered housing in the region. Over half the units in the potential contributing area are in the Clinton River basin or Rouge complex. High density nonsewered residences are projected to increase 16 percent between 1970 and 1990. Individual on-site disposal systems have been identified as causing water quality problems here [GLBC, 1976].

As the figures in Table 80 show, the estimated capital investment required to correct malfunctioning on-site systems is $47.1 million. Operation and maintenance costs would be $1.6 million per year. The average annual cost was thus estimated to be $6.8 million per year.

Extrapolation of these figures to all of Planning Subarea 4.1 indicates that capital costs would be $93.8 million, with annual operating costs of $3.3 million. The average annual cost of this program would thus be $13.6 million.

Other Problems

Seven sites in RBG 4.1 are dredged of 714,109 cubic meters (934,087 cubic yards) on an average annual basis. Ninety percent of the dredged material is polluted, thus requiring confined disposal.

Total annual maintenance dredge spoil is projected to increase 41 percent between 1970 and 1990; polluted spoil may increase 57 percent in the same period.

TABLE 80

ON-SITE WASTE DISPOSAL, RBG 4.1

COUNTY	TOTAL NUMBER OF SYSTEMS	PERCENT OF COUNTY IN PCA	ESTIMATED NUMBER OF SYSTEMS IN PCA	NUMBER FAILING	CAPITAL COST ($\$X10^6$)	OPERATING COST ($\$X10^3$)	AVERAGE ANNUAL ($\$X10^6$)
MICHIGAN							
Lenawee	10,730	66	7,080	1,770	3.27	113.8	0.47
Macomb	25,454	90	22,910	5,730	10.58	368.4	1.53
Monroe	20,069	45	9,030	2,260	4.17	145.3	0.60
Oakland	77,452	30	23,240	5,810	10.73	373.6	1.56
St. Clair	17,729	90	15,960	3,990	7.37	256.6	1.07
Sanilac	6,766	50	3,380	840	1.55	54.0	0.22
Washtenaw	11,269	33	3,720	930	1.72	59.8	0.25
Wayne	20,869	80	16,690	4,170	7.70	268.1	1.12
TOTAL	--	--	102,010	25,500	47.09	1,639.6	6.82

RIVER BASIN GROUP 4.2

DESCRIPTION

River Basin Group 4.2 is the southernmost part of the Great Lakes Basin. It drains an area of 26,851 square kilometers (10,367 square miles), almost all of which is in Ohio and Indiana. At the west end of Lake Erie, Planning Subarea 4.2 (Figure 33), includes 23 counties in Ohio and Indiana. Five hydrologic areas, the Ottawa, Maumee and Sandusky River basins, and the Toussaint-Portage and Huron-Vermilion complexes comprise this river basin group.

The land is flat to undulating, with very little local relief. Most of this RBG is in the Lake Erie plain, with the western and southern reaches rising into gently undulating glacial till plains. Bedrock is predominantly dolomites and limestone. The soils range from silty clay loams to clay, are poorly to moderately well drained and generally have a slow permeability. Figure 34 illustrates the region's predominant soil textures. Areas along the Lake Erie shore produce fruit and truck crops.

Minerals produced included clay, gypsum, peat, petroleum and natural gas, sand and gravel, and stone (limestone, dolomite, and sandstone).

Major rivers are: the Ottawa, Maumee (the largest tributary to the Great Lakes), Portage, Sandusky, Huron and Vermilion Rivers. Because this area has such poor natural drainage, extensive networks of ditches and subsurface tile drains have been constructed to remove water from much of the land.

Two-thirds of the region is in agricultural use. Seven percent is urbanized and 25 percent is forested. Table 81 shows the major land cover in the five hydrologic areas.

In 1970 the population exceeded 1.7 million, up from 1.2 million in 1940; two-thirds was urban in 1970. Highest population concentrations occur in the major urban centers of Toledo (pop.: 367,650), Lima (pop.: 51,372), Findlay (pop.: 36,362), Fremont (pop.: 19,528), and Sandusky (pop.: 32,023) in Ohio and Fort Wayne (pop.: 185,299) in Indiana (1975 population estimates). Small rural communities are found throughout the area.

Total employment in 1970 was 670,000, or about six percent of the Great Lakes total. The manufacturing sector employed 241,000 workers in 1970, or about 36 percent of the region's employment, with food products and primary metals among the major employers. Agriculture accounted for three percent, with mining employment insignificant.

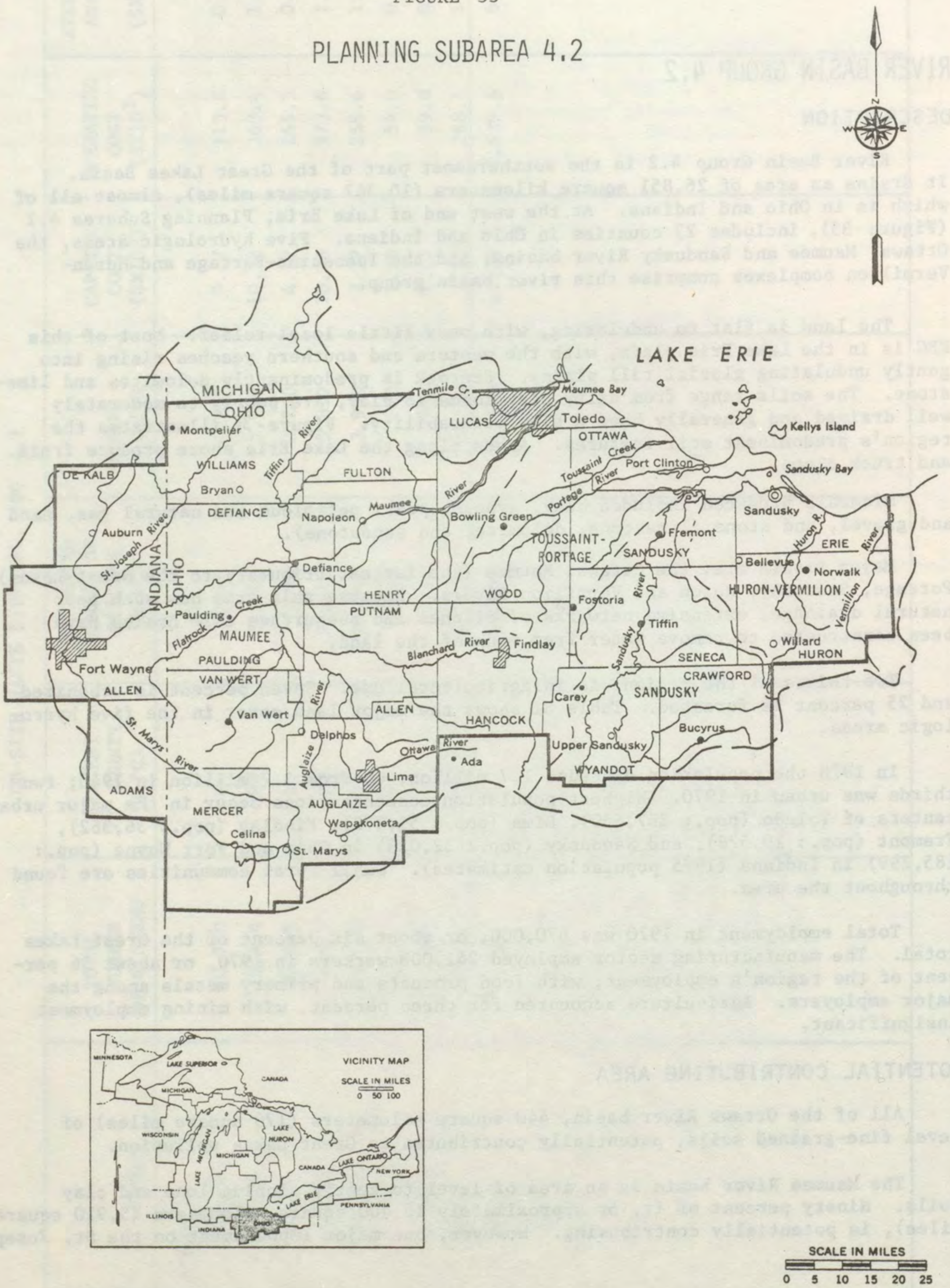
POTENTIAL CONTRIBUTING AREA

All of the Ottawa River basin, 440 square kilometers (170 square miles) of level fine-grained soils, potentially contributes to Great Lakes pollution.

The Maumee River basin is an area of level to gently sloping loam and clay soils. Ninety percent of it, or approximately 15,400 square kilometers (5,910 square miles), is potentially contributing. However, one major impoundment on the St. Joseph

FIGURE 33

PLANNING SUBAREA 4.2

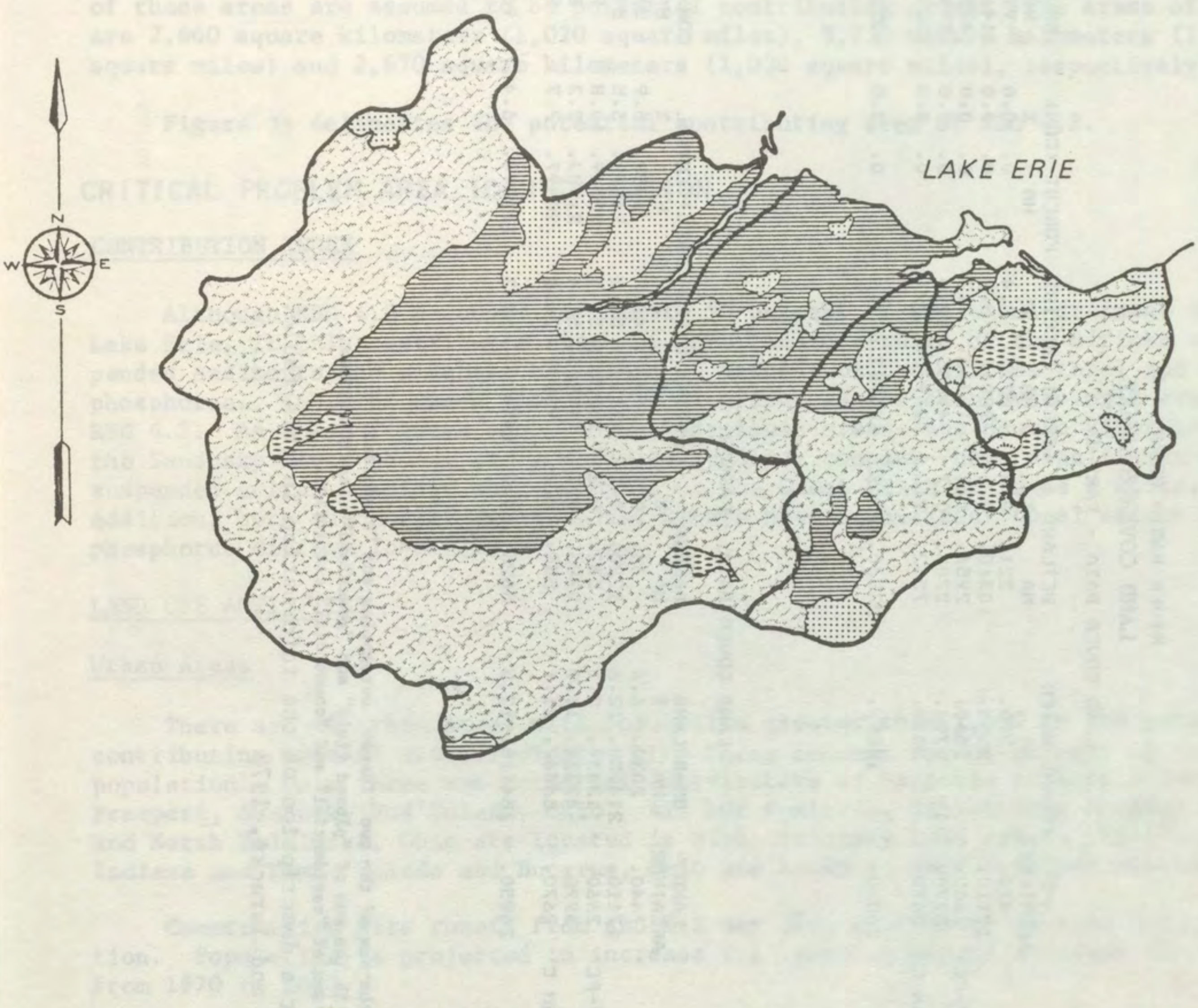


4.2

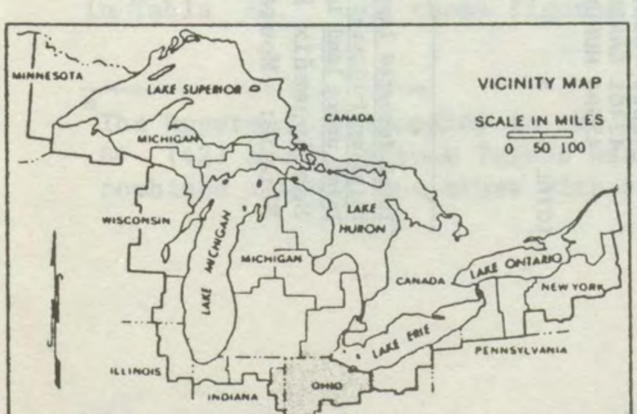
FIGURE 34

SOIL TEXTURE

River Basin Group 4.2



Source: Sonzogni, et al, 1978



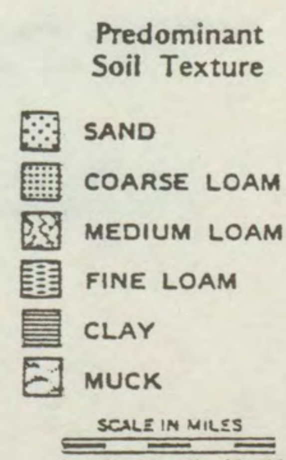


TABLE 81

RIVER BASIN GROUP 4.2

LAND COVER SUMMARY

LAND COVER DATA - PART 1

#	NAME	LAND AREA:KM2	INLAND WATER HA	WETLAND HA	%	FOREST (DECID) HA	%	FOREST (CON) HA	%	BRUSHLAND HA	%
42101	OTTAWA	440.	220.	221.	0.5	3715.	8.4	0.	0.0	9994.	22.7
42202	MAUMEE	17110.	8555.	10318.	0.6	98017.	5.7	0.	0.0	314686.	18.4
42300	TOUSSAINT-PC	2660.	2660.	2956.	1.1	19345.	7.3	0.	0.0	47289.	17.8
42401	SANDUSKY	3970.	794.	2785.	0.7	47735.	12.0	0.	0.0	54896.	13.8
42500	HURON-VERM C	2670.	2670.	7552.	2.8	26970.	10.1	0.	0.0	58255.	21.8
TOTAL	5	26850.	14899.	23830.	0.9	195782.	7.3	0.	0.0	485119.	18.1

LAND COVER DATA - PART 2

#	NAME	LAND AREA:KM2	GRASSLAND HA	%	BARREN HA	%	PLOWED FIELD HA	%	RESIDENTIAL HA	%	COMMERCIAL HA	%
42101	OTTAWA	440.	2830.	6.4	44.	0.1	17777.	40.4	6987.	15.9	2432.	5.5
42202	MAUMEE	17110.	214950.	12.6	1720.	0.1	971573.	56.8	94578.	5.5	5159.	0.3
42300	TOUSSAINT-PC	2660.	13434.	5.1	537.	0.2	152883.	57.5	28749.	10.8	806.	0.3
42401	SANDUSKY	3970.	47338.	11.9	2785.	0.7	219981.	55.4	21083.	5.3	398.	0.1
42500	HURON-VERM C	2670.	56367.	21.1	539.	0.2	96012.	36.0	20497.	7.7	809.	0.3
TOTAL	5	26850.	334918.	12.5	5625.	0.2	1458224.	54.3	171894.	6.4	9604.	0.4

---

*Total forested land is the sum of the two "forest" categories and "brushland."
Total agricultural land is the sum of "plowed field" and "grassland" classifications.
Total urban land is the sum of "residential" and "commercial" categories.

See Appendix 3 for a description of the information in this table.

Source: Monteith and Jarecki, 1978

above Fort Wayne, Indiana, estimated to have a high trap efficiency, is the reason ten percent of the basin is not in the PCA.

The Toussaint-Portage complex, Sandusky River, and Huron-Vermilion complex hydrologic areas are essentially similar to the Maumee River basin in soil and topographic characteristics. No major impoundments are present. Thus, 100 percent of these areas are assumed to be potential contributing areas. The areas of each are 2,660 square kilometers (1,020 square miles), 3,970 square kilometers (1,520 square miles) and 2,670 square kilometers (1,030 square miles), respectively.

Figure 35 delineates the potential contributing area of RBG 4.2.

CRITICAL PROBLEM AREA IDENTIFICATION

CONTRIBUTION INDEX

Although RBG 4.2 accounts for nearly 50 percent of the total drainage area of Lake Erie, it only contributes slightly more than one-third of the diffuse suspended sediments and slightly more than 40 percent of the diffuse total and orthophosphorus. Table 82 shows the contribution indices for each hydrologic area in RBG 4.2. As these figures show, three hydrologic areas--the Maumee River basin, the Sandusky River basin, and the Huron-Vermilion complex--have significant diffuse suspended solids loadings when compared to the Great Lakes Basin as a whole. In addition, both the Maumee and Sandusky Rivers have significant total and/or orthophosphorus diffuse loadings.

LAND USE ACTIVITIES

Urban Areas

There are 41 urban areas with population greater than 2,500 in the potential contributing area of RBG 4.2 (Table 83). These account for 61 percent of the region's population. Only three are potential contributors of bacteria to Lake Erie: Freeport, Sandusky and Toledo, Ohio. All but Fostoria, Gibsonburg, Bowling Green, and North Baltimore, Ohio are located in high tributary load areas. Fort Wayne, Indiana and Lima, Toledo and Bucyrus, Ohio are known to have combined sewers.

Construction site runoff from RBG 4.2 may also contribute to Lake Erie pollution. Population is projected to increase 1.1 percent annually during the period from 1970 to 2020.

Estimated costs for urban stormwater and combined sewer controls are summarized in Table 84.* As these figures show, the average annual cost ranges from $17.8

*The apparent discrepancy in the number of urban areas between Tables 83 (41) and 84 (42) arose because Toledo was treated in two parts, one served exclusively by combined sewers, the other with storm sewers.

FIGURE 35

POTENTIAL CONTRIBUTING AREA OF RBG 4.2

4.2

TABLE 32

CONTRIBUTION INDICES

RIVER BASIN GROUP 4.2

HYDROLOGIC AREA	LAND AREA (km^2)*	PCA AREA (km^2)*	SUSPENDED SOLIDS	TOTAL PHOSPHORUS	ORTHO PHOSPHORUS
Ottawa River	440	440	0.9	0.8	0.8
Maumee River	17,110	15,400	1.0	1.2	1.0
Toussaint-Portage Complex	2,660	2,660	0.5	0.6	0.8
Sandusky River	3,970	3,970	1.0	1.0	0.2
Huron-Vermillion Complex	2,670	2,670	1.2	0.8	0.4

*To convert square kilometers to square miles, multiply by 0.386

$$\text{CI} = \frac{\text{(\% of Great Lakes Diffuse Load) (from hydrologic area)}}{\text{(\% of Great Lakes PCA in) (hydrologic area)}}$$

Total Great Lakes PCA = 105,950 km^2

Total Great Lakes Diffuse Loads

Suspended Solids = 9,492,407 Mtonnes/yr.

Total P = 13,155 Mtonnes/yr.

Ortho P = 3,007 Mtonnes/yr.

NOTE: Loads are average of 1975 and 1976 values with Lake Erie values assured equal for both years

TABLE 83

URBAN AREAS IN THE POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 4.2

URBAN AREA	HYDROLOGIC AREA		POPULATION (1970)	AREA (ACRES*) (1970)
OHIO				
Archbold	Maumee River	4.2.2	3,047	961
Findlay	Maumee River	4.2.2	35,800	7,294
Fostoria	Toussaint-Portage Complex	4.2.3	16,037	3,520
Napoleon	Maumee River	4.2.2	7,791	3,774
Bellevue	Huron-Vermillion Complex	4.2.5	8,604	2,048
Norwalk	Huron-Vermillion Complex	4.2.5	13,386	3,710
Willard	Huron-Vermillion Complex	4.2.5	5,510	3,455
Waterville	Maumee River	4.2.2	2,940	1,087
Celina	Maumee River	4.2.2	8,072	1,472
Port Clinton	Toussaint-Portage Complex	4.2.3	7,202	1,151
Oak Harbor	Maumee River	4.2.2	2,807	704
Ada	Maumee River	4.2.2	5,309	640
Paulding	Maumee River	4.2.2	2,983	575
Ottawa	Maumee River	4.2.2	3,622	1,279
Fremont	Sandusky River	4.2.4	18,490	3,391
Clyde	Huron-Vermillion Complex	4.2.5	5,503	1,536
Gibsonburg	Toussaint-Portage Complex	4.2.3	2,585	640
Tiffen	Sandusky River	4.2.4	21,596	3,581
Lima	Maumee River	4.2.2	58,273	17,530
Toledo	Maumee River	4.2.2	453,634	101,460
Delphos	Maumee River	4.2.2	7,608	961
Wapakoneta	Maumee River	4.2.2	7,324	2,621

*To convert acres to hectares, multiply by 0.4047

TABLE 83 (continued)

URBAN AREA	HYDROLOGIC AREA		POPULATION (1970)	AREA (ACRES*) (1970)
St. Mary's	Maumee River	4.2.2	7,699	2,430
Bucyrus	Sandusky River	4.2.4	13,111	2,112
Crestline	Sandusky River	4.2.4	5,947	1,279
Defiance	Maumee River	4.2.2	16,281	3,903
Huron	Huron-Vermillion Complex	4.2.5	6,896	3,327
Sandusky	Huron-Vermillion Complex	4.2.5	32,674	5,822
Delta	Maumee River	4.2.2	2,544	961
Swanton	Maumee River	4.2.2	2,927	511
Wauseon	Maumee River	4.2.2	4,932	2,430
Van Wert	Maumee River	4.2.2	11,320	2,559
Bowling Green	Toussaint-Portage Complex	4.2.3	21,760	4,159
North Baltimore	Toussaint-Portage Complex	4.2.3	3,143	1,023
Upper Sandusky	Sandusky River	4.2.4	5,645	1,662
Carey	Sandusky River	4.2.4	3,523	832
INDIANA				
Auburn	Maumee River	4.2.2	7,388	1,919
Garrett	Maumee River	4.2.2	4,715	1,023
Berne	Maumee River	4.2.2	2,988	768
Decatur	Maumee River	4.2.2	8,445	1,791
Fort Wayne	Maumee River	4.2.2	190,866	44,141
TOTAL - PCA			1,050,927	246,042
Planning Subarea 4.2			1,724,868	6,319,400

*To convert acres to hectares, multiply by 0.4047

TABLE 84

URBAN CONTROL SUMMARY FOR RBG 42

NUMBER OF URBAN AREAS: 42

LOW LEVEL OF TREATMENT (<30% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.19

CAPITAL COST	: $	122182992.
ANNUAL OPERATING COST	: $	4366078.
AVERAGE ANNUAL COST*	: $	17826752.

MEDIUM LEVEL OF TREATMENT (30% TO 60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.56

CAPITAL COST	: $	266020560.
ANNUAL OPERATING COST	: $	6112310.
AVERAGE ANNUAL COST*	: $	35419296.

HIGH LEVEL OF TREATMENT (>60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.86

CAPITAL COST	: $	320802560.
ANNUAL OPERATING COST	: $	9068093.
AVERAGE ANNUAL COST*	: $	44410304.

CHLORINATION (MEDIUM AND HIGH LEVEL TREATMENT ONLY)

	COMBINED SEWER ONLY	COMBINED AND STORM SEWERS
CAPITAL:	896708.	8967245.
O&M :	61516.	205329.
ANNUAL*:	160305.	1193234.

*Average annual cost equals capital amortized over 25 years at 10 percent interest per year plus annual operation and maintenance cost.

million for low efficiency (19 percent solids removal) treatment to $44.4 million for the high efficiency (86 percent removal) alternative. The addition of chlorination to the medium and high efficiency treatment alternatives in those areas which may contribute bacteria to the lake would add from $160 thousand to $1.2 million per year to the cost.

Because the potential contributing area includes essentially all of the urban areas with more than 2,500 persons, costs in the potential contributing area would be identical to those of the planning subarea. Therefore, no extrapolation was necessary.

Construction sediment controls would cost an estimated $1.0 million per year. Detention ponds in new developments would cost $6.9 million per year to build plus an additional $137 thousand per year to maintain.

Agricultural Areas

There are 1,934 thousand hectares (4,779 thousand acres) of cropland within the potential contributing area of RBG 4.2 (see Table 85). Two-thirds of this cropland, or 1,293 thousand hectares (3,194 thousand acres) requires treatment. According to 1968 Conservation Needs Inventory data, 1,484 thousand hectares (3,667 thousand acres) out of a total 1,916 thousand hectares (4,735 thousand acres) of cropland in Planning Subarea 4.2 required erosion control treatment in 1968.

The potential contributing area accounts for 895 cattle, 326 swine, and 229 poultry feedlot operations (see Table 86). Only 43 percent of the cattle feedlots, 40 percent of the swine, and 31 percent of the poultry operations have waste controls.

Agricultural runoff and intensive livestock operations within this region have a significant impact on Lake Erie water quality.

The estimated costs of applying best management practices to reduce erosion in the potential contributing area are shown in Table 85. The one-time cost is $23.0 million, with annual recurring costs of $9.1 million. The average annual cost is thus $11.6 million. The estimated one-time cost of applying BMPs only to the fine-textured soils (1,086 thousand hectares) is $16.7 million, plus $6.2 million per year recurring costs. This reduces the average annual cost by 31 percent, to $8.0 million. Finally, the application of BMPs to all lands in Planning Subarea 4.2 identified in the Conservation Needs Inventory as requiring erosion controls would increase the annual cost to $13.4 million, with $26.4 million in one-time costs and $10.5 million per year recurring costs.

The estimated cost of providing animal waste control systems for those operations which require them is almost $6.8 million: $5.1 million for cattle, $1.2 million for swine, and almost $500 thousand for poultry. Estimates of costs for the entire planning subarea based on these results total $8.4 million. These costs in average annual terms are $750 thousand and $925 thousand, respectively.

TABLE 85

COSTS FOR INSTALLING AGRICULTURAL BEST MANAGEMENT PRACTICES IN THE POTENTIAL CONTRIBUTING AREA (PCA) OF RIVER BASIN GROUP 4.2

COUNTY	TOTAL ACRES* IN POTENTIAL CONTRIBUTING AREA	ACRES IN PCA NEEDING TREATMENT	COSTS FOR ALL SOILS ($ millions)		COSTS FOR FINE-TEXTURED SOILS ($ millions)	
			One-Time	Recurring	One-Time	Recurring
MICHIGAN						
Hillsdale	45,560	16,560	0.22	0.06	0.13	0.03
Lenawee	60,000	40,000	0.54	0.14	0.31	0.06
OHIO						
Allen	180,003	142,333	1.23	0.44	1.23	0.44
Ashland	757	527	**	**	**	**
Auglaize	195,713	112,671	0.89	0.31	0.89	0.31
Crawford	181,536	117,695	0.63	0.36	0.13	0.06
Defiance	139,952	74,466	0.24	0.07	0.24	0.07
Erie	81,038	64,183	0.21	0.14	0.21	0.14
Fulton	216,940	140,404	0.60	0.24	0.60	0.24
Hancock	279,755	188,805	1.58	0.55	1.58	0.55
Hardin	105,393	61,193	0.49	0.17	0.49	0.17
Henry	225,112	171,545	0.54	0.17	0.54	0.17
Huron	215,598	178,542	0.85	0.55	0.19	0.15
Lorain	26,810	16,810	0.06	0.06	0.06	0.06
Lucas	91,572	75,603	0.24	0.08	0.24	0.08
Marion	38,441	19,180	0.17	0.06	0.17	0.06

*To convert acres to hectares, multiply by 0.4047

**Cost is negligible

TABLE 85 (continued)

COUNTY	TOTAL ACRES* IN POTENTIAL CONTRIBUTING AREA	ACRES IN PCA NEEDING TREATMENT	COSTS FOR ALL SOILS ($ millions)		COSTS FOR FINE-TEXTURED SOILS ($ millions)	
			One-Time	Recurring	One-Time	Recurring
Mercer	229,282	158,857	1.35	0.47	1.35	0.47
Ottawa	118,863	81,846	0.26	0.08	0.26	0.08
Paulding	215,893	152,049	0.53	0.18	0.53	0.18
Putnam	255,471	178,110	0.79	0.26	0.79	0.26
Richland	14,195	8,695	0.04	0.03	**	**
Sandusky	206,916	135,572	0.47	0.15	0.47	0.15
Seneca	268,882	176,550	1.00	0.46	0.84	0.34
Shelby	16,730	8,770	0.07	0.02	0.07	0.02
Williams	40,200	32,700	0.22	0.08	0.22	0.08
Wood	361,791	288,860	1.00	0.37	0.87	0.28
Wyandot	246,624	167,321	3.11	1.09	3.11	1.09
INDIANA						
Adams	161,720	100,650	1.04	0.47	0.86	0.41
Allen	441,000	191,824	4.47	1.93	0.27	0.27
Dekalb	114,764	91,811	0.13	0.12	0.06	0.01
TOTAL	4,778,511	3,194,162	22.97	9.11	16.71	6.23

*To convert acres to hectares, multiply by 0.4047

**Cost is negligible

TABLE 86

COST FOR INSTALLING AGRICULTURAL WASTE MANAGEMENT SYSTEMS IN POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 4.2

COUNTY	TOTAL NUMBER OF FEEDLOT OPERATIONS >100 ANIMAL UNITS IN PCA			NUMBER OF FEEDLOT OPERATIONS IN PCA NEEDING TREATMENT			TOTAL COST ($ thousands)		
	CATTLE	SWINE	POULTRY	CATTLE	SWINE	POULTRY	CATTLE (at $10,000 per system)	SWINE (at $6,000 per system)	POULTRY (at $ 3,000 per system)
MICHIGAN									
Hillsdale	8	0	0	2	0	0	20	0	0
Lenawee	15	0	0	15	0	0	150	0	0
OHIO									
Allen	9	0	2	3	0	0	30	0	0
Auglaize	57	1	1	27	0	0	270	0	0
Crawford	21	4	0	8	1	0	80	6	0
Defiance	11	0	1	4	0	0	40	0	0
Erie	5	0	0	2	0	0	20	0	0
Fulton	80	8	10	34	3	2	340	18	6
Hancock	7	2	1	2	1	0	20	6	0
Hardin	6	0	0	3	0	0	30	0	0
Henry	45	2	10	18	1	0	180	6	0
Huron	25	1	0	12	0	0	120	0	0
Lorain	2	0	0	0	0	0	0	0	0
Lucas	17	0	1	9	0	0	90	0	0

TABLE 86 (continued)

COUNTY	TOTAL NUMBER OF FEEDLOT OPERATIONS >100 ANIMAL UNITS IN PCA			NUMBER OF FEEDLOT OPERATIONS IN PCA NEEDING TREATMENT			TOTAL COST ($ thousands)		
	CATTLE	SWINE	POULTRY	CATTLE	SWINE	POULTRY	CATTLE (at $10,000 per system)	SWINE (at $ 6,000 per system)	POULTRY (at $ 3,000 per system)
Marion	15	3	1	6	1	0	60	6	0
Mercer	68	0	20	37	0	3	370	0	9
Ottawa	5	0	0	2	0	0	20	0	0
Paulding	11	0	1	4	0	0	40	0	0
Putnam	38	2	12	23	1	0	230	6	0
Richland	2	0	0	0	0	0	0	0	0
Sandusky	18	1	0	6	0	0	60	0	0
Seneca	21	4	0	8	1	0	80	6	0
Shelby	5	0	0	2	0	0	20	0	0
Williams	31	0	1	17	0	0	170	0	0
Wood	25	0	0	10	0	0	100	0	0
Wyandot	20	3	0	8	1	0	80	6	0
INDIANA									
Adams	150	150	150	106	107	143	1,060	642	429
Allen	38	75	8	19	37	3	190	222	9
Dekalb	140	70	10	123	43	8	1,230	258	24
TOTAL	895	326	229	510	197	159	5,100	1,182	477

On-Site Waste Disposal

Nearly all of the 131,719 nonsewered nonfarm housing units in RBG 4.2 are located in the potential contributing area (Table 87). Three-quarters of the nonsewered households in RBG 4.2 are in rural areas. Almost half of those in the potential contributing area are found in the Maumee River basin. Low permeability of the soils throughout this region has resulted in septic tank failure problems [GLBC, 1976]. Nonsewered nonfarm housing units are projected to increase 24 percent between 1970 and 1990.

Individual on-site disposal systems in RBG 4.2 may contribute significantly to Lake Erie pollution.

The estimated capital cost of correcting problems related to malfunctioning on-site waste disposal systems is $54.7 million. An additional $1.7 million per year would be required for operation and maintenance. This results in an estimated average annual cost of $7.7 million. Extrapolation of these figures to the planning subarea indicates that the capital costs would rise to $58.1 million, with operating costs of $1.8 million. This increases the annual cost to $8.2 million.

Other Problems

There are four dredging operations which total almost 1.3 million cubic meters (1.68 million cubic yards) of dredge spoil. Nearly 98 percent, or 1.26 million cubic meters (1.64 cubic yards) are polluted. Less than one percent of the total dredge spoil in RBG 4.2 is disposed of in open lake areas while 99 percent is disposed of in diked locations. Both total and polluted spoil are projected to decrease five percent between 1970 and 1990 in annual maintenance volume.

There is a gypsum tailings deposit site along the north shore of Sandusky Bay which has resulted in dark, fine grain tailings materials extending 1,800 feet along the shore.

Polluted dredge spoil and tailings disposal in RBG 4.2 may contribute to pollution of Lake Erie.

TABLE 87

ON-SITE WASTE DISPOSAL, RBG 4.2

COUNTY	TOTAL NUMBER OF SYSTEMS	PERCENT OF COUNTY IN PCA	ESTIMATED NUMBER OF SYSTEMS IN PCA	NUMBER FAILING	CAPITAL COST ($X10^6)	OPERATING COST ($X10^3)	AVERAGE ANNUAL COST ($X10^6)
INDIANA							
Adams	22.65	90	2,040	510	0.90	27.6	0.13
Allen	15,025	70	10,520	2,630	4.64	142.2	0.65
DeKalb	2,391	80	1,910	480	0.85	26.0	0.12
OHIO							
Allen	8,186	100	8,190	2,050	3.62	110.8	0.51
Auglaize	3,440	95	3,270	820	1.45	44.3	0.20
Crawford	4,009	85	3,410	850	1.50	46.0	0.21
Defiance	3,473	90	3,130	780	1.38	42.2	0.19
Erie	7,317	100	7,320	1,830	3.23	98.9	0.45
Fulton	3,625	90	3,260	820	1.45	44.3	0.20
Hancock	4,261	100	4,260	1,060	1.87	57.3	0.26
Henry	3,704	100	3,700	920	1.62	49.7	0.23
Huron	5,667	100	5,670	1,420	2.51	76.8	0.35
Lucas	19,896	100	19,900	4,980	8.79	269.2	1.24
Mercer	2,909	55	1,600	400	0.71	21.6	0.10
Ottawa	5,994	100	5,990	1,500	2.65	81.1	0.37
Paulding	3,014	100	3,010	750	1.32	40.6	0.19
Sandusky	7,332	100	7,330	1,830	3.23	98.9	0.45
Putnam	4,059	100	4,060	1,020	1.80	55.1	0.25
Seneca	5,482	100	5,480	1,370	2.42	74.1	0.34
Van Wert	2,670	100	2,670	670	1.18	36.2	0.17

TABLE 87 (continued)

COUNTY	TOTAL NUMBER OF SYSTEMS	PERCENT OF COUNTY IN PCA	ESTIMATED NUMBER OF SYSTEMS IN PCA	NUMBER FAILING	CAPITAL COST ($X10^6)	OPERATING COST ($X10^3)	AVERAGE ANNUAL COST ($X10^6)
Williams	4,082	30	1,220	300	0.53	16.2	0.07
Wood	10,364	100	10,360	2,590	4.57	140.0	0.64
Wyandot	2,554	100	2,550	640	1.13	34.6	0.16
MICHIGAN							
Monroe	10,069	15	3,010	750	1.32	40.6	0.19
TOTAL	--	--	123,860	30,970	54.67	1,674.3	7.67

RIVER BASIN GROUP 4.3

DESCRIPTION

River Basin Group 4.3 drains 8,425 square kilometers (3,253 square miles) of northeastern Ohio into Lake Erie. The corresponding planning subarea, Figure 36, encompasses eight counties in Ohio. Five hydrologic areas make up RBG 4.2: Black-Rocky complex, Cuyahoga River, Chagrin complex, Grand River, and Ashtabula-Conneaut complex.

Paleozoic sedimentary bedrock, composed largely of limestone with overlying sandstone and shale make up the dominant geologic formations. Glacial till and outwash deposits cover the flat to rolling topography. Major land forms are lake plains and a glaciated plateau. Rimming Lake Erie are soils developed in the glacial Lake Erie sediments, predominantly medium-textured, but with some soils moderately fine and fine-textured (Figure 37). Coarse-textured lake beaches are also present. These soils are poorly drained, acid, and medium to high in natural fertility. To the south soils are formed in till, composed of sandstone, shale and some limestone. Topography is nearly level to gently rolling with some steep areas. Clay, shale, peat, petroleum, natural gas, salt, sand, gravel and stone (limestone and sandstone) are produced here.

The streams in RBG 4.3 are typically short, less than 160 kilometers (100 miles), with low average flows and gradients. Flooding occurs frequently in some streams and siltation is heavy. The major rivers are the Black, Rocky, Cuyahoga, Chagrin, Grand, and Ashtabula Rivers, and Conneaut Creek.

Agricultural use covers 42 percent of the region, while forests cover 41 percent and urban areas, 15 percent. Table 88 shows the major land cover in each of the five hydrologic areas.

In 1970 over 3.1 million people resided in Planning Subarea 4.3, an increase of more than one million from the 1940 Census figures. Ninety percent of the area residents were classified urban in 1970. Cleveland (pop.: 638,793) and Akron (pop.: 251,747) had the largest populations, while their satellite communities make up the bulk of the remaining total. Other population concentrations are found in Summit County and all the shoreline counties (1975 population estimates): Lorain (pop.: 84,907), Elyria (pop.: 52,474), Mentor (pop.: 39,523), Cuyahoga Falls (pop.: 46,804), Kent (pop.: 26,768), Sandusky (pop.: 32,023), Ashtabula (pop.: 24,264), and Parma (pop.: 98,883), are other important urban centers in this region.

Employment in 1970 was 1,240,000, almost 11 percent of the Great Lakes total. The manufacturing sector employed 451,000 workers or 37 percent of all employment. Primary metals alone accounted for over five percent of total employment. Agriculture and mining employment were relatively small, involving only one percent of the total work force in 1970. Professional and commercial services are concentrated in urban areas, employing approximately 40 percent of the total work force.

FIGURE 36

PLANNING SUBAREA 4.3

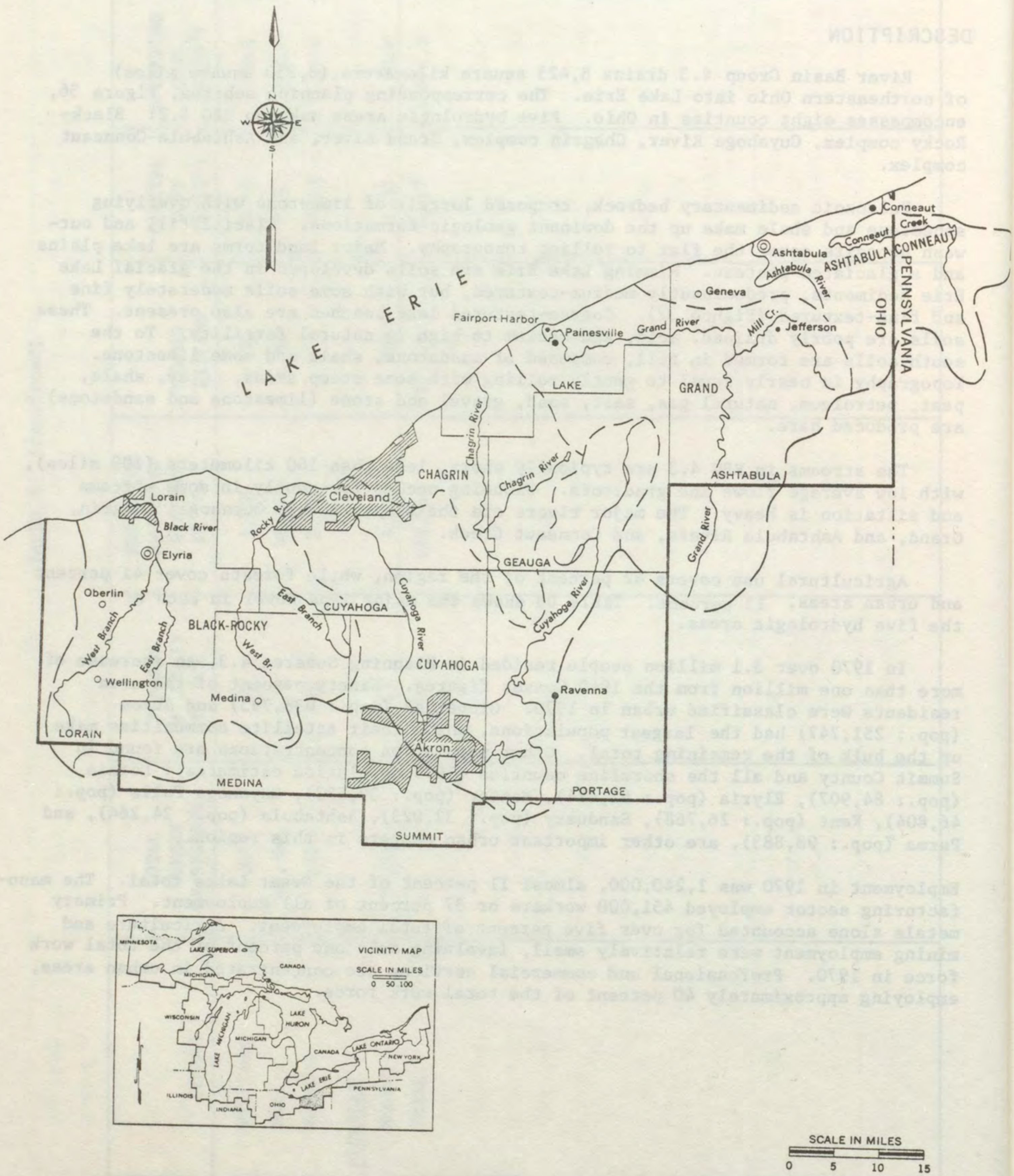
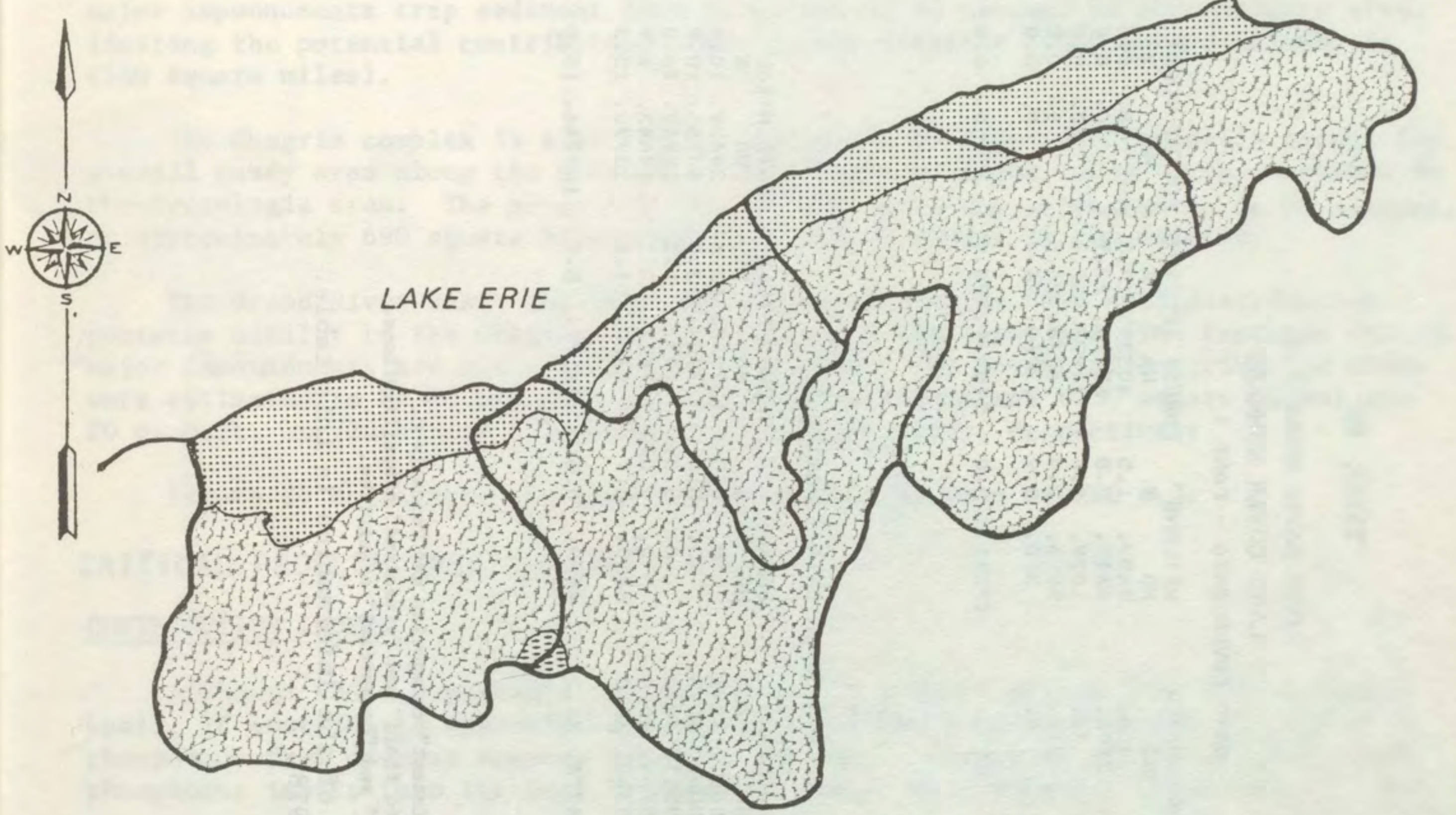


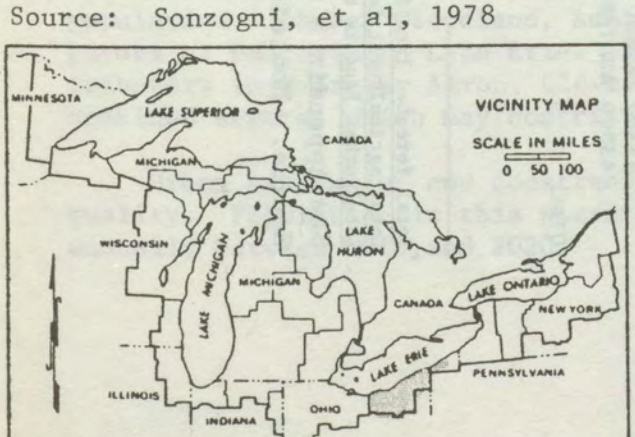
FIGURE 37

SOIL TEXTURE

River Basin Group 4.3



Source: Sonzogni, et al, 1978



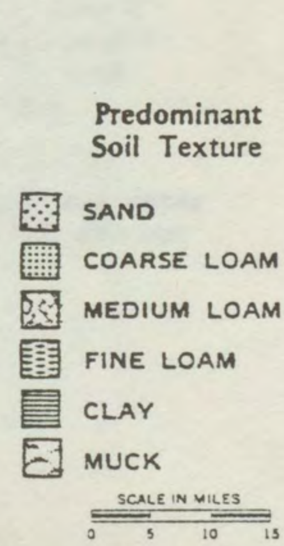


TABLE 88

RIVER BASIN GROUP 4.3

LAND COVER SUMMARY

LAND COVER DATA - PART 1

#	NAME	LAND AREA:KM2	INLAND WATER HA	WETLAND HA	WETLAND %	FOREST (DECID) HA	FOREST (DECID) %	FOREST (CON) HA	FOREST (CON) %	BRUSHLAND HA	BRUSHLAND %
43100	BLACK-ROCKYC	2300.	460.	3457.	1.5	40331.	17.5	0.	0.0	51162.	22.2
43201	CUYAHOGA	2340.	2106.	6612.	2.8	65171.	27.9	0.	0.0	26918.	11.5
43300	CHAGRIN COM	770.	77.	1079.	1.4	24973.	32.4	0.	0.0	3854.	5.0
43402	GRAND OH	2120.	212.	5093.	2.4	56236.	26.5	0.	0.0	42442.	20.0
43500	ASHTABULA-CC	900.	0.	810.	0.9	23760.	26.4	0.	0.0	10530.	11.7
TOTAL 5		8430.	2855.	17051.	2.0	210470.	25.0	0.	0.0	134907.	16.0

LAND COVER DATA - PART 2

#	NAME	LAND AREA:KM2	GRASSLAND HA	GRASSLAND %	BARREN HA	BARREN %	PLOWED FIELD HA	PLOWED FIELD %	RESIDENTIAL HA	RESIDENTIAL %	COMMERCIAL HA	COMMERCIAL %
43100	BLACK-ROCKYC	2300.	80661.	35.1	0.	0.0	29038.	12.6	24429.	10.6	922.	0.4
43201	CUYAHOGA	2340.	75560.	32.3	0.	0.0	7084.	3.0	44155.	18.9	8501.	3.6
43300	CHAGRIN COM	770.	29521.	38.3	0.	0.0	1002.	1.3	12949.	16.8	3623.	4.7
43402	GRAND OH	2120.	85734.	40.4	0.	0.0	7427.	3.5	14643.	6.9	424.	0.2
43500	ASHTABULA-CC	900.	33300.	37.0	4410.	4.9	1620.	1.8	13770.	15.3	1800.	2.0
TOTAL 5		8430.	304776.	36.2	4410.	0.5	46171.	5.5	109946.	13.0	15269.	1.8

*Total forested land is the sum of the two "forest" categories and "brushland."
Total agricultural land is the sum of "plowed field" and "grassland" classifications.
Total urban land is the sum of "residential" and "commercial" categories.

See Appendix 3 for a description of the information in this table.

Source: Monteith and Jarecki, 1978

POTENTIAL CONTRIBUTING AREA

An area of sandy soils along the shoreline in the Black-Rocky complex was the only portion eliminated from the potential contributing area. The remainder of the hydrologic area, approximately 1,840 square kilometers (710 square miles) in extent, comprises an estimated 80 percent of the complex.

The Cuyahoga River basin has predominantly fine-grained soils throughout. Two major impoundments trap sediment from an estimated 40 percent of the drainage area, limiting the potential contributing area to approximately 1,400 square kilometers (540 square miles).

The Chagrin complex is also largely underlain by fine-textured soils except for a small sandy area along the shoreline. There are no major lakes or impoundments in the hydrologic area. The potential contributing area was estimated to be 90 percent, or approximately 690 square kilometers (260 square miles) of the complex.

The Grand River basin and Ashtabula-Conneaut complex have soil distribution patterns similar to the Chagrin, with sands along the coast and fine textures inland. Major impoundments are not a factor in this area. The potential contributing areas were estimated to be 90 percent, or 1,910 square kilometers (730 square miles) and 80 percent, or 720 square kilometers (280 square miles), respectively.

Figure 38 delineates the potential contributing area of RBG 4.3.

CRITICAL PROBLEM AREA IDENTIFICATION

CONTRIBUTION INDEX

Although RBG 4.3 accounts for only about 15 percent of the Lake Erie drainage basin, it contributes approximately one-third of the suspended solids and ortho-phosphorus from diffuse sources entering the lake. Its share of the diffuse total phosphorus inputs into the lake is somewhat less, approximately 18 percent.

The contribution index values shown in Table 89 are among the highest in the Great Lakes Basin. All five of the hydrologic areas have been shown to be significant for each of the three parameters of interest.

Urban Areas

There are 10 urban areas with population greater than 2,500 in the potential contributing area of RBG 4.3 (Table 90), comprising 87 percent of the region's population. Akron, Cleveland, Ashtabula, and Lorain-Elyria are potential contributors of bacteria to Lake Erie. While all 10 communities are located in high tributary load areas, Akron, Cleveland and Lorain-Elyria are known to have combined sewers, which may contribute pollutants to the lake.

Urban stormwater and construction site runoff may also degrade Lake Erie water quality. Population in this planning subarea is projected to increase 0.6 percent annually between 1970 and 2020.

FIGURE 38

POTENTIAL CONTRIBUTING AREA
OF RBG 4.3

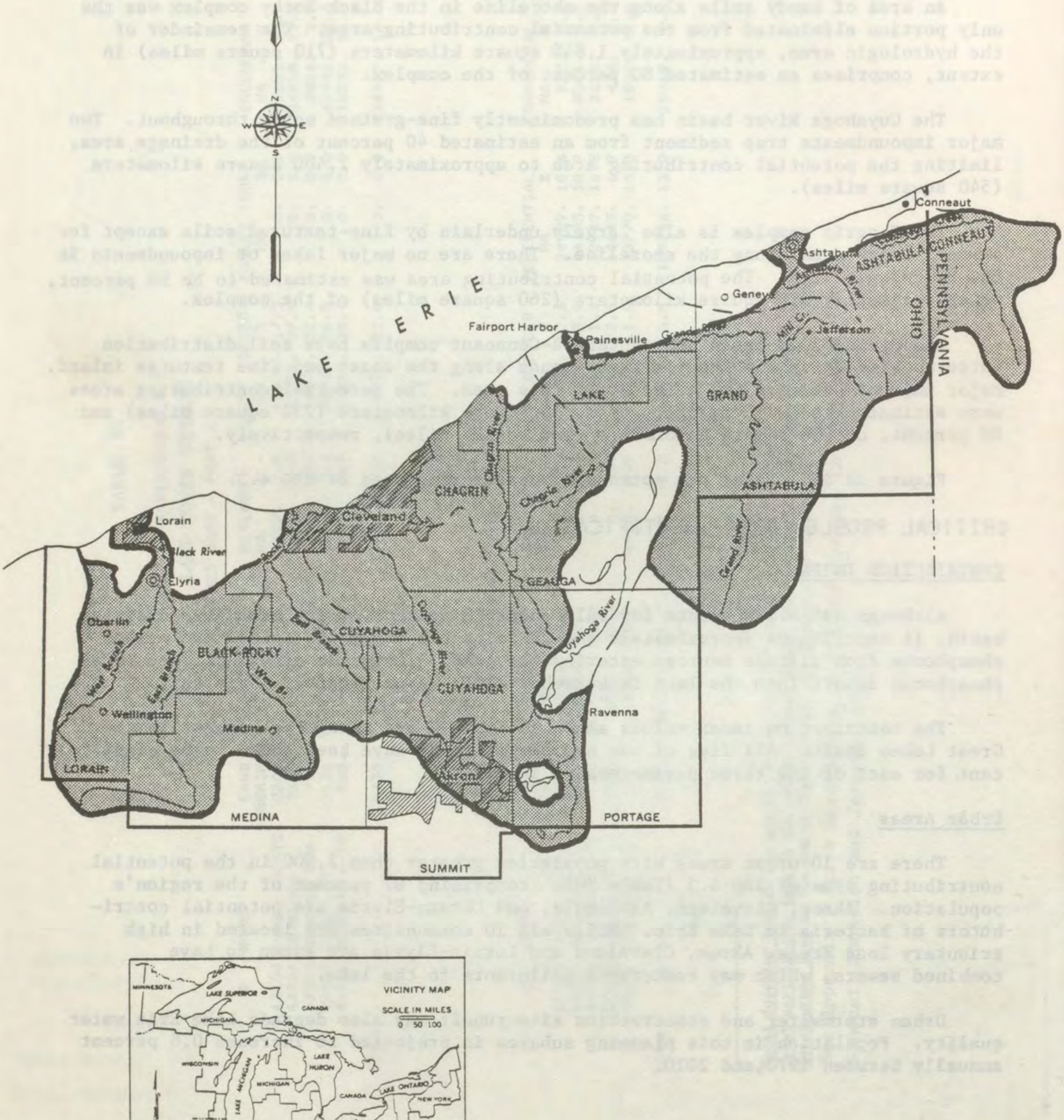


TABLE 89

CONTRIBUTION INDICES
RIVER BASIN GROUP 4.3

HYDROLOGIC AREA	LAND AREA (km^2)*	PCA AREA (km^2)*	SUSPENDED SOLIDS	TOTAL PHOSPHORUS	ORTHO PHOSPHORUS
Black-Rocky Complex	2,300	1,840	2.8	2.5	4.4
Cuyahoga River	2,340	1,400	5.0	3.0	1.4
Chagrin Complex	770	690	4.4	1.8	1.0
Grand River	2,120	1,910	3.3	1.6	1.0
Ashtabula-Conneaut Complex	900	720	3.7	2.1	1.2

*To convert square kilometers to square miles, multiply by 0.386

$$CI = \frac{(\text{\% of Great Lakes Diffuse Load})\ (\text{from hydrologic area})}{(\text{\% of Great Lakes PCA in})\ (\text{hydrologic area})}$$

Total Great Lakes PCA = 105,950 km^2

Total Great Lakes Diffuse Loads

Suspended Solids = 9,492,407 Mtonnes/yr.

Total P = 13,155 Mtonnes/yr.

Ortho P = 3,007 Mtonnes/yr.

NOTE: Loads are average of 1975 and 1976 values with Lake Erie values assured equal for both years

TABLE 90

URBAN AREAS IN THE POTENTIAL CONTRIBUTING AREA
OF RIVER BASIN GROUP 4.3

URBAN AREA	HYDROLOGIC AREA		POPULATION (1970)	AREA (ACRES*) (1970)
Akron, OH	Cuyahoga River	4.3.2	488,171	130,186
Cleveland, OH	Cuyahoga River	4.3.2	1,939,104	413,339
Lorain-Elyria, OH	Black-Rocky Complex	4.3.1	197,417	68,068
Ashtabula, OH	Ashtabula-Conneaut Complex	4.3.5	24,313	4,542
Oberlin, OH	Black-Rocky Complex	4.3.1	8,761	2,112
Wellington, OH	Black-Rocky Complex	4.3.1	4,137	2,559
Medina, OH	Black-Rocky Complex	4.3.1	10,913	4,671
Ravenna, OH	Cuyahoga River	4.3.2	11,780	3,200
Hudson, OH	Cuyahoga River	4.3.2	3,933	2,366
Chardon, OH	Grand River	4.3.4	3,991	2,495
TOTAL - PCA			2,692,520	633,538
Planning Subarea 4.3			3,098,048	2,308,600

*To convert acres to hectares, multiply by 0.4047

Cost estimates for implementing stormwater and combined sewer controls in the potential contributing area are shown in Table 91.* Average annual cost estimates range from $23.2 million for low efficiency (22 percent solids removal) controls to $94.2 million for high efficiency (85 percent) treatment. The cost of adding chlorination ranges from $300 thousand to $8.0 million per year.

Construction sediment controls would cost $1.5 million per year. The provision of detention ponds in new developments would require $12.0 million per year in construction costs plus $240 thousand per year maintenance.

Because the potential contributing area contains essentially all of the urban land of RBG 4.3, extrapolations were not done.

Agricultural Areas

There are 239 thousand hectares (589 thousand acres) of cropland within the potential contributing area of RBG 4.3 (see Table 92). Sixty-eight percent of this cropland, or 162 thousand hectares (401 thousand acres) requires treatment. According to Conservation Needs Inventory data, 212 thousand hectares (523 thousand acres) out of a total 300 thousand hectares (741 thousand acres) of cropland in Planning Subarea 4.3 required erosion control treatment in 1968.

The potential contributing area accounts for 144 cattle feedlots and three poultry operations. Almost half of the cattle feedlots and all three of the poultry operations have waste controls.

Agricultural runoff and intensive livestock operations within this region may have a significant impact on Lake Erie water quality.

The application of best management practices for erosion and sedimentation control in the potential contributing area would have installation costs of $1.5 million, with annual recurring costs of $1.4 million. Limiting their use to fine-textured soils (51 thousand hectares) would reduce the one-time cost to $450 thousand with $430 thousand per year recurring costs. The average annual costs of both approaches are $1.6 million and $480 thousand respectively. Applying these practices to all lands identified as needing treatment in the Conservation Needs Inventory results in one-time costs of $2.0 million and $1.9 million per year in recurring costs. The average annual cost is thus $2.1 million per year.

As Table 93 shows, it would cost an estimated $750 thousand, or $80 thousand per year, to fulfill animal waste management system needs in the potential contributing area. Data from the Inventory of Land Use for Lake Erie [IJC, 1976d] indicates that needs throughout the planning subarea are approximately equal to those within the potential contributing area so extrapolations were not made.

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*The apparent discrepancy in the number of urban areas included in Table 90 (10) and 91 (11) arises because Lorain-Elyria was treated as two areas in the cost assessment, one served by combined sewers, the other by separate sewers.

TABLE 91

URBAN CONTROL SUMMARY FOR RBG 43

NUMBER OF URBAN AREAS: 11

LOW LEVEL OF TREATMENT (<30% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.22

CAPITAL COST	: $	181416224.
ANNUAL OPERATING COST	: $	3268108.
AVERAGE ANNUAL COST*	: $	23254384.

MEDIUM LEVEL OF TREATMENT (30% TO 60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.56

CAPITAL COST	: $	398349568.
ANNUAL OPERATING COST	: $	11604494.
AVERAGE ANNUAL COST*	: $	55489920.

HIGH LEVEL OF TREATMENT (>60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.85

CAPITAL COST	: $	653665792.
ANNUAL OPERATING COST	: $	22759136.
AVERAGE ANNUAL COST*	: $	94772304.

CHLORINATION (MEDIUM AND HIGH LEVEL TREATMENT ONLY)

	COMBINED SEWER ONLY	COMBINED AND STORM SEWERS
CAPITAL:	1585629.	61459536.
O&M :	125497.	1278199.
ANNUAL*:	300183.	8049084.

* Average annual cost equals capital amortized over 25 years at 10 percent interest per year plus annual operation and maintenance cost.

TABLE 92

COSTS FOR INSTALLING AGRICULTURAL BEST MANAGEMENT PRACTICES IN THE POTENTIAL CONTRIBUTING AREA (PCA) OF RIVER BASIN GROUP 4.3

COUNTY	TOTAL ACRES* IN POTENTIAL CONTRIBUTING AREA	ACRES IN PCA NEEDING TREATMENT	COSTS FOR ALL SOILS ($ millions)		COSTS FOR FINE-TEXTURED SOILS ($ millions)	
			One-Time	Recurring	One-Time	Recurring
OHIO						
Ashtabula	118,954	64,569	0.17	0.20	0	0
Cuyahoga	11,445	10,448	0.02	0.02	0	0
Geauga	71,791	60,334	0.29	0.25	0	0
Lake	18,209	3,061	0.01	0.01	0	0
Lorain	133,609	86,609	0.31	0.30	0.31	0.30
Medina	120,758	96,358	0.46	0.41	0.12	0.11
Portage	35,806	15,506	0.08	0.07	0	0
Summit	36,700	32,388	0.14	0.13	0	0
Trumbull	18,600	12,550	0.04	0.05	0.02	0.02
PENNSYLVANIA						
Crawford	23,535	18,734	**	**	**	**
TOTAL	589,407	400,557	1.52	1.44	0.45	0.43

*To convert acres to hectares, multiply by 0.4047

**Costs included with RBG 4.4

TABLE 93

COST FOR INSTALLING AGRICULTURAL WASTE MANAGEMENT SYSTEMS IN POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 4.3

COUNTY	TOTAL NUMBER OF FEEDLOT OPERATIONS >100 ANIMAL UNITS IN PCA			NUMBER OF FEEDLOT OPERATIONS IN PCA NEEDING TREATMENT			TOTAL COST ($ thousands)		
	CATTLE	SWINE	POULTRY	CATTLE	SWINE	POULTRY	CATTLE (at $ 10,000 per system)	SWINE (at $ 6,000 per system)	POULTRY (at $ 3,000 per system)
OHIO									
Ashtabula	9	0	2	4	0	0	40	0	0
Cuyahoga	2	0	0	1	0	0	10	0	0
Geauga	21	0	0	13	0	0	130	0	0
Lake	2	0	0	2	0	0	20	0	0
Lorain	25	0	0	10	0	0	100	0	0
Medina	28	0	0	14	0	0	140	0	0
Portage	23	0	1	13	0	0	130	0	0
Summit	4	0	0	2	0	0	20	0	0
Trumbull	30	0	0	16	0	0	160	0	0
TOTAL	144	0	3	75	0	0	750	0	0

On-Site Waste Disposal

Of the nearly one million housing units in Planning Subarea 4.3, 14 percent were classified nonsewered in the 1970 Census. About 46 percent of the nonsewered units are in rural areas and about two-thirds, or 93,990, units may be located in the potential contributing area (Table 94). Forty-three percent of those in the PCA may be located in the Cuyahoga River basin; 32 percent in the Black-Rocky complex. Inadequate treatment of waste by private sewage treatment systems has been identified as a problem along Lake Erie and the Grand, Ashtabula, and Conneaut Rivers [GLBC, 1976]. High density nonsewered residential units in RBG 4.3 are projected to increase 11 percent between 1970 and 1990.

As Table 94 shows, the estimated capital cost of correcting on-site disposal problems in the potential contributing area is $47.0 million, with annual operating and maintenance costs of $1.7 million. The average annual cost is thus $7.2 million. Extrapolation to the entire planning subarea increases the capital cost to $71.1 million, with operation and maintenance costs of $2.5 million. Average annual costs in this case were estimated to be $10.3 million.

Other Problems

Streambank erosion has been cited as a significant problem in RBG 4.3, particularly along the Cuyahoga River. It is estimated that 28 percent of the sediment reaching Cleveland Harbor is from this source as opposed to 16 percent from sheet erosion [COE, 1977].

Six dredge disposal sites in the region account for 1,141 thousand cubic meters (1,494 thousand cubic yards) of average annual dredge spoil. More than 90 percent of this material is polluted. The sites are located near Lorain, Cleveland, Fairport Harbor, Ashtabula, and Conneaut. Both total and polluted spoil are projected to increase in annual maintenance volume by about six percent between 1970 and 1990.

TABLE 94

ON-SITE WASTE DISPOSAL, RBG 4.3

COUNTY	TOTAL NUMBER OF SYSTEMS	PERCENT OF COUNTY IN PCA	ESTIMATED NUMBER OF SYSTEMS IN PCA	NUMBER FAILING	CAPITAL COST ($\$X10^6$)	OPERATING COST ($\$X10^3$)	AVERAGE ANNUAL ($\$X10^6$)
OHIO							
Ashtabula	12,762	70	8,930	2,230	4.46	186.9	0.69
Cuyahoga	31,592	90	28,430	7,110	14.23	595.8	2.16
Geauga	12,926	60	7,760	1,940	3.88	162.6	0.59
Lake	11,468	50	5,730	1,430	2.86	119.8	0.43
Lorain	16,344	65	10,620	2,660	5.33	222.9	0.81
Medina	8,338	65	5,420	1,360	2.72	114.0	0.41
Portage	15,299	35	5,360	1,340	2.68	112.3	0.41
Summit	33,452	65	21,740	5,440	10.88	455.5	1.65
TOTAL	--	--	93,990	23,510	47.04	1,669.8	7.15

RIVER BASIN GROUP 4.4

DESCRIPTION

River Basin Group 4.4 is located at the northeastern end of the Lake Erie basin, and includes that part of the area draining into the Niagara River to approximately the lower end of Grand Island. The total drainage area is 6,838 square kilometers (2,640 square miles). Planning Subarea 4.4 includes four counties in western New York and one county in northwestern Pennsylvania as shown in Figure 39. Three hydrologic areas make up this river basin group: Erie-Chautauqua complex, Cattaraugus Creek and Tonawanda complex.

The entire area is underlain by formations of sedimentary rock: sandstone, shale, limestone, and dolomite, which range in age from the Cambrian to the Devonian systems of Paleozoic age. Overlying most of the bedrock formations are unconsolidated Quaternary sediments of glacial origin.

Soils in the area are divided into two major regions coinciding with the predominant land forms: the lake plain, which is relatively flat, except for rises up onto former beaches created by higher levels of Lake Erie; and the upland plateau which has relief up to several hundred feet with smoothly sloping hills that range from gently sloping to steep. The soils near the lake were formed from glacial lake sediments and are predominantly medium-textured with local areas of coarse- and fine-textured soils (Figure 40). Artificial drainage is often necessary, as well as lime fertilizer, to obtain maximum crop yields. Soils of the southern upland plateau are mostly medium-textured, with local areas of coarse to fine texture. Clay, shale, gypsum, peat, petroleum, natural gas, sand, gravel and stone (limestone and dolomite) are produced in this region.

The major tributaries of RBG 4.4 are Cattaraugus, Eighteen Mile, and Tonawanda Creeks, and the Buffalo River. The Erie-Chautauqua complex consists of a number of small streams but no major rivers. A total of more than 32,180 stream kilometers (20,000 stream miles) results in an average stream density of 4.7 kilometers of stream per square kilometer (7.6 miles per square mile).

Over one-third of the area is forested. Almost nine percent is urban and 24 percent agricultural. Table 95 shows major land cover in RBG 4.4. The number of orchards, groves and vineyards is second highest in the Basin, with grapes, pears and sweet cherries being the most significant crops.

The population of Planning Subarea 4.4 in 1970 was approximately 1,840,000, an increase of 500,000 since 1940. In 1970, 79 percent of the inhabitants were urban. The population is concentrated in and around the cities of (1975 population estimates): Buffalo (pop.: 407,160), Cheektowaga (pop.: 121,447), Town of Tonawanda (pop.: 101,384), North Tonawanda (pop.: 39,798), Tonawanda (pop.: 21,452), Kenmore (pop.: 22,149), Lockport (pop.: 26,319), Lackawanna (pop.: 25,374), DePew (pop.: 25,708) in New York and Erie (pop.: 127,895) Pennsylvania.

FIGURE 39

PLANNING SUBAREA 4.4

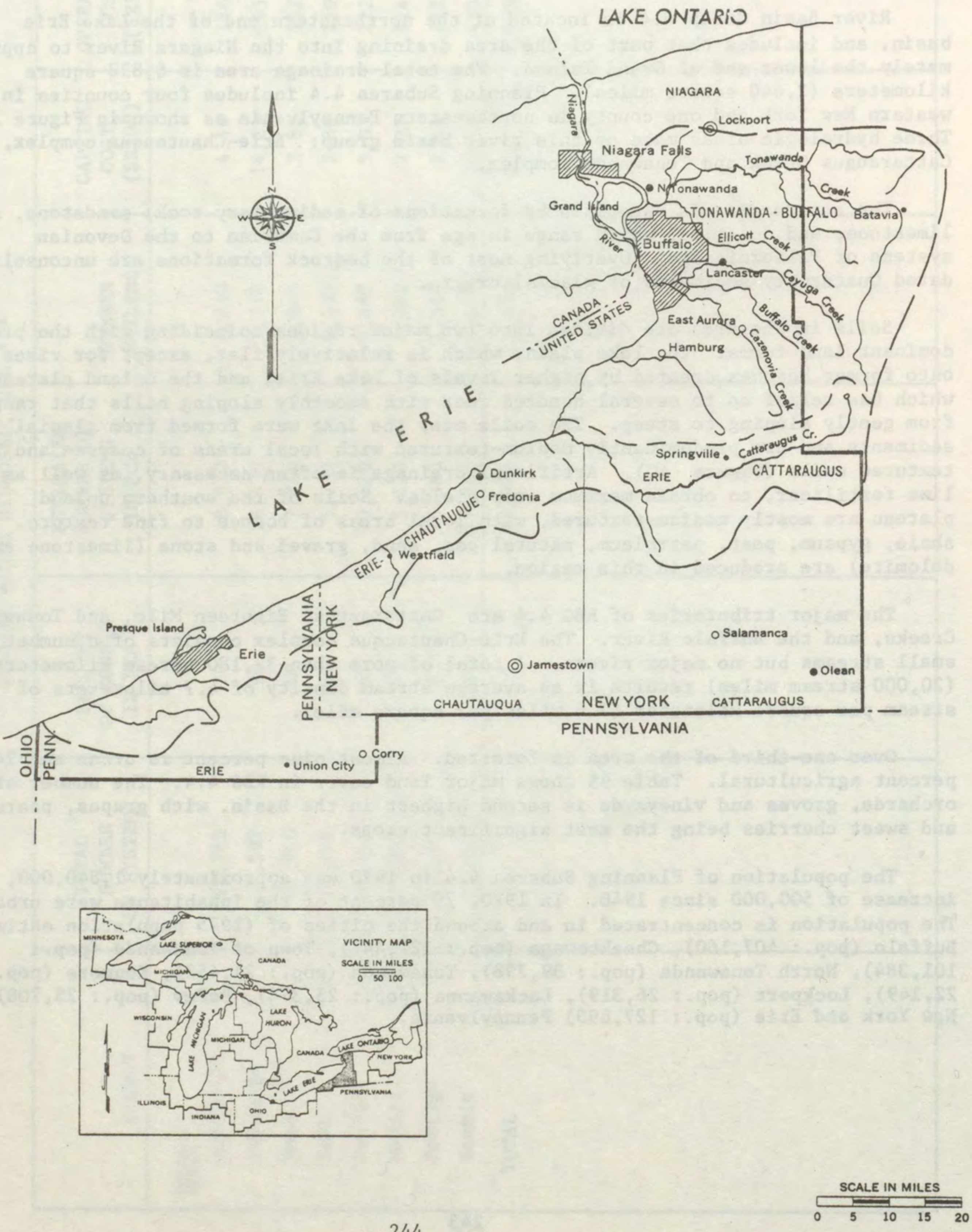
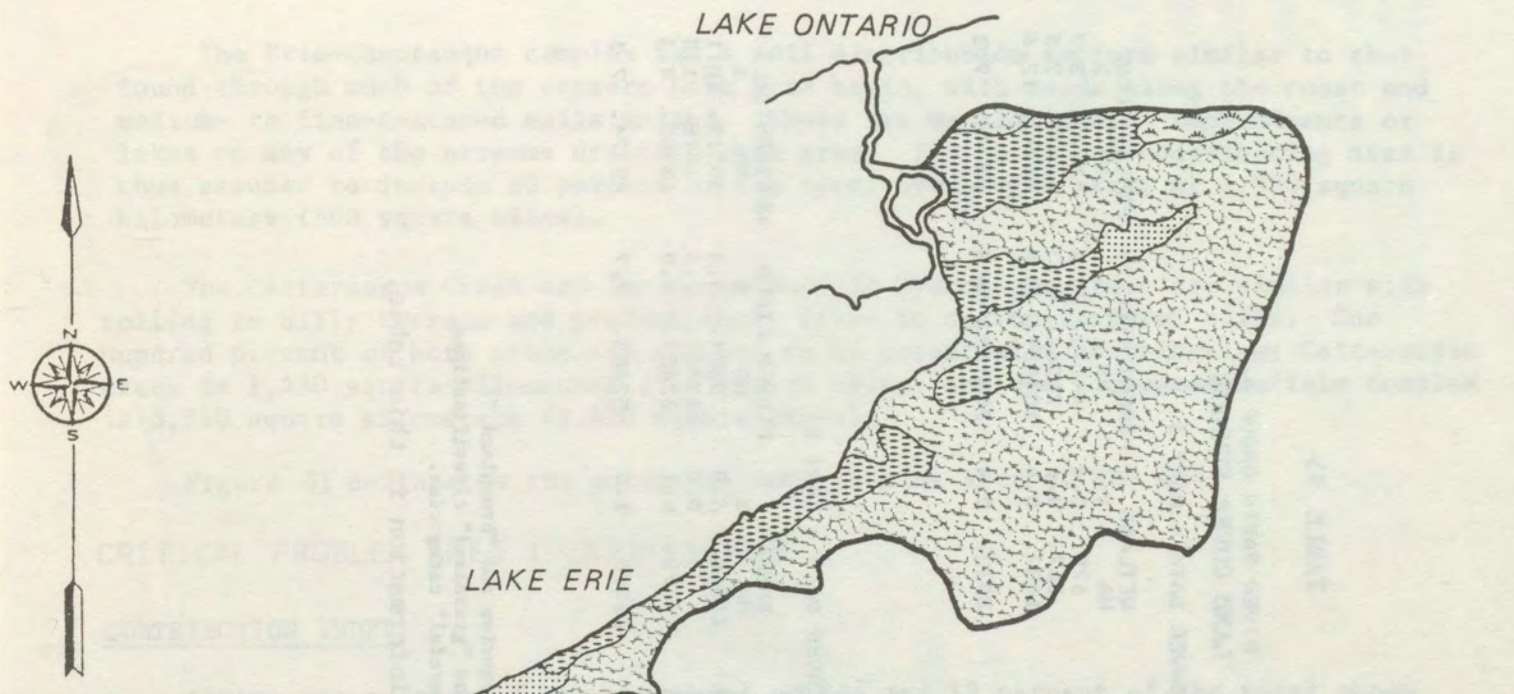


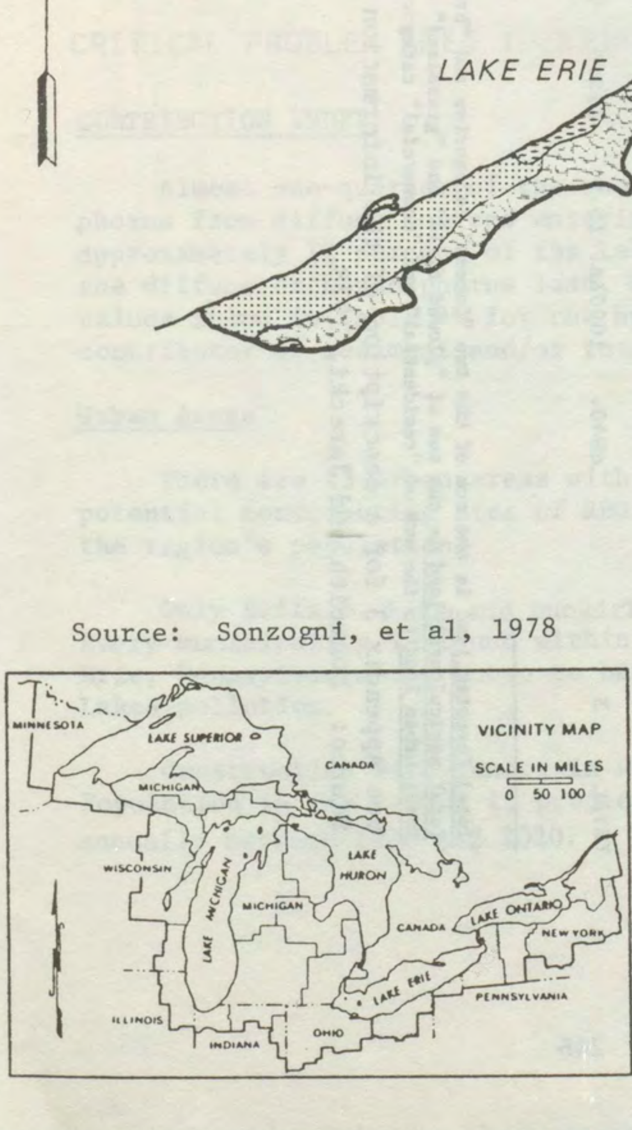
FIGURE 40

SOIL TEXTURE

River Basin Group 4.4



Source: Sonzogni, et al, 1978



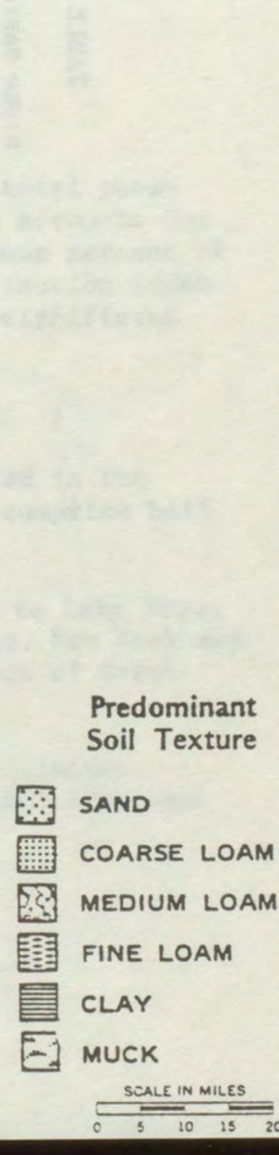


TABLE 95

RIVER BASIN GROUP 4.4
LAND COVER SUMMARY

LAND COVER DATA - PART 1

#	NAME	LAND AREA:KM2	INLAND WATER HA	WETLAND HA	%	FOREST (DECID) HA	%	FOREST (CON) HA	%	BRUSHLAND HA	%
44100	ERIE-CHAUT C	1690.	507.	678.	0.4	44072.	26.1	6272.	3.7	25935.	15.3
44201	CATTARAUGUS	1440.	432.	867.	0.6	71061.	49.3	10832.	7.5	16899.	11.7
44300	TONAWANDA CO	3710.	742.	1487.	0.4	181039.	48.8	46840.	12.6	46840.	12.6
TOTAL	3	6840.	1681.	3032.	0.4	296172.	43.3	63944.	9.3	89673.	13.1

LAND COVER DATA - PART 2

#	NAME	LAND AREA:KM2	GRASSLAND HA	%	BARREN HA	%	PLOWED FIELD HA	%	RESIDENTIAL HA	%	COMMERCIAL HA	%
44100	ERIE-CHAUT C	1690.	37800.	22.4	11018.	6.5	5594.	3.3	30512.	18.1	7119.	4.2
44201	CATTARAUGUS	1440.	28887.	20.1	0.	0.0	13432.	9.3	1878.	1.3	144.	0.1
44300	TONAWANDA CO	3710.	42379.	11.4	372.	0.1	33457.	9.0	15985.	4.3	2602.	0.7
TOTAL	3	6840.	109066.	15.9	11390.	1.7	52483.	7.7	48374.	7.1	9866.	1.4

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*Total forested land is the sum of the two "forest" categories and "brushland."
Total agricultural land is the sum of "plowed field" and "grassland" classifications.
Total urban land is the sum of "residential" and "commercial" categories.

See Appendix 3 for a description of the information in this table.
Source: Monteith and Jarecki, 1978.

Both population and employment (0.7 million in 1970) have been increasing less rapidly in this RBG than in the Great Lakes Basin as a whole. Manufacturing is important in both the Erie and Buffalo areas, and trades and services are also significant.

POTENTIAL CONTRIBUTING AREA

The Erie-Chautauqua complex has a soil distribution pattern similar to that found through much of the eastern Lake Erie basin, with sands along the coast and medium- to fine-textured soils inland. There are no significant impoundments or lakes on any of the streams draining this area. The potential contributing area is thus assumed to include 90 percent of the total hydrologic area, or 1,520 square kilometers (580 square miles).

The Cattaraugus Creek and Tonawanda-Buffalo hydrologic areas are similar with rolling to hilly terrain and predominantly fine- to medium-textured soils. One hundred percent of both areas are assumed to be potentially contributing; Cattaraugus Creek is 1,430 square kilometers (550 square miles) and the Tonawanda-Buffalo complex is 3,710 square kilometers (1,420 square miles).

Figure 41 delineates the potential contributing area of RBG 4.4.

CRITICAL PROBLEM AREA IDENTIFICATION

CONTRIBUTION INDEX

Almost one-quarter of the suspended solids and 18 percent of the total phosphorus from diffuse sources entering Lake Erie come from RBG 4.4 which accounts for approximately 12 percent of the Lake Erie drainage basin. Less than four percent of the diffuse orthophosphorus load, however, comes from this RBG. Contribution index values shown in Table 96 for the hydrologic areas show that each is a significant contributor of sediment and/or total phosphorus.

Urban Areas

There are 13 urban areas with population greater than 2,500 located in the potential contributing area of RBG 4.4 (Table 97). These communities comprise half the region's population.

Only Buffalo, Erie and Dunkirk are assumed to contribute bacteria to Lake Erie, Every municipality is found within a high tributary load area. Buffalo, New York and Erie, Pennsylvania are known to have combined sewers, which are a source of Great Lakes pollution.

Construction site runoff in RBG 4.4 may also contribute to lake pollution. Population in the region is projected to increase at an average rate of 0.3 percent annually between 1970 and 2020.

FIGURE 41

POTENTIAL CONTRIBUTING AREA
OF RBG 4.4

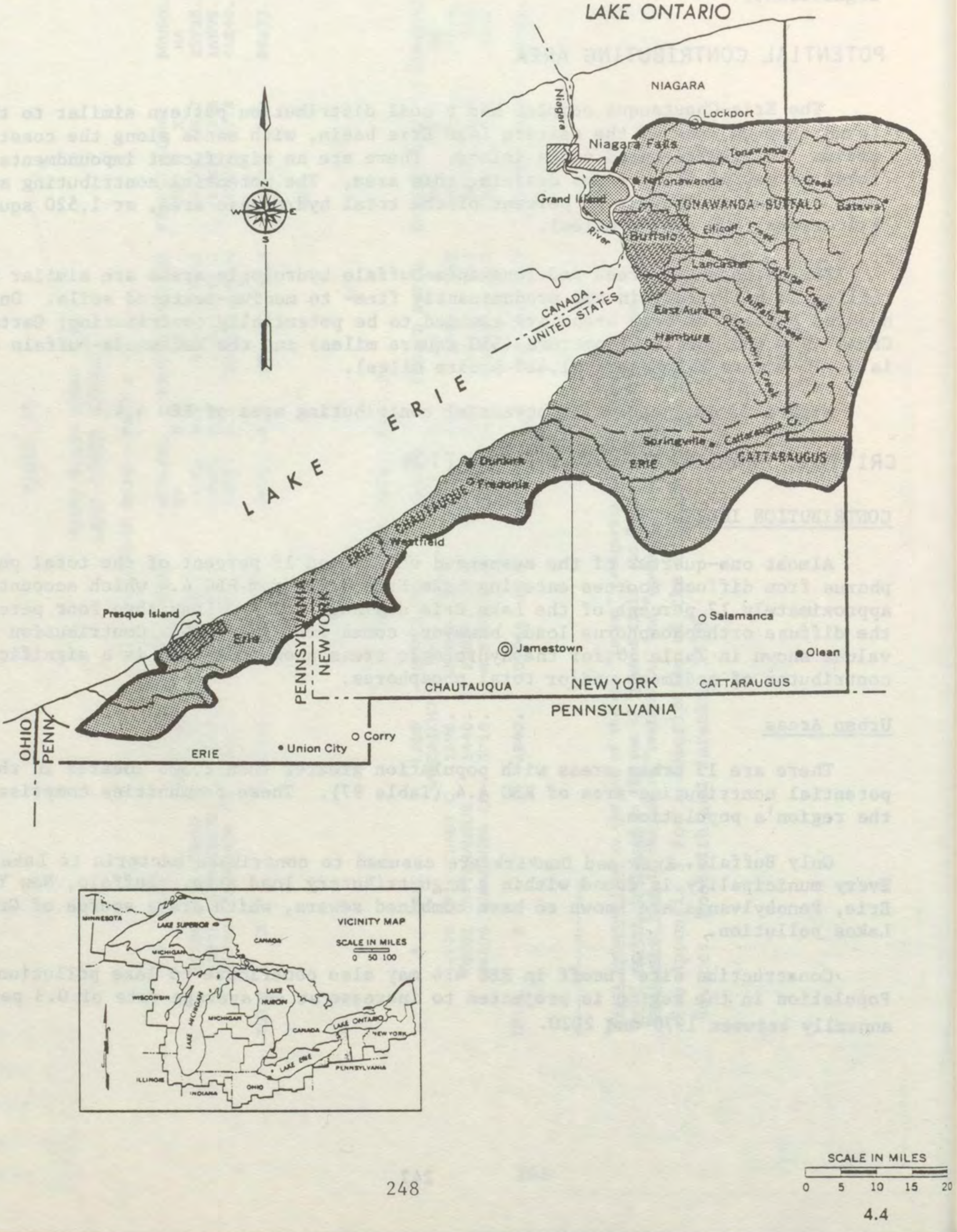

TABLE 96

CONTRIBUTION INDICES
RIVER BASIN GROUP 4.4

HYDROLOGIC AREA	LAND AREA (km^2)*	PCA AREA (km^2)*	SUSPENDED SOLIDS	TOTAL PHOSPHORUS	ORTHO PHOSPHORUS
Erie-Chautauqua Complex	1,690	1,520	3.3	1.5	0.6
Cattaraugus Creek	1,430	1,430	5.3	1.0	0.2
Tonawanda Complex	3,710	3,710	0.9	1.0	0.1

*To convert square kilometers to square miles, multiply by 0.386

$$CI = \frac{\text{(\% of Great Lakes Diffuse Load) (from hydrologic area)}}{\text{(\% of Great Lakes PCA in) (hydrologic area)}}$$

Total Great Lakes PCA = 105,950 km^2

Total Great Lakes Diffuse Loads

Suspended Solids = 9,492,407 Mtonnes/yr.

Total P = 13,155 Mtonnes/yr.

Ortho P = 3,007 Mtonnes/yr.

NOTE: Loads are average of 1975 and 1976 values with Lake Erie values assured equal for both years

TABLE 97

URBAN AREAS IN THE POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 4.4

URBAN AREA	HYDROLOGIC AREA	POPULATION (1970)	AREA (ACRES*) (1970)
Buffalo, NY	Tonawanda Complex 4.4.3	740,292	136,710
Erie, PA	Erie-Chautauqua Complex 4.4.1	133,185	28,020
Dunkirk, NY	Erie-Chautauqua Complex 4.4.1	16,855	2,948
Fredonia, NY	Erie-Chautauqua Complex 4.4.1	10,326	3,582
North East, PA	Erie-Chautauqua Complex 4.4.1	3,846	1,087
Girard, PA	Erie-Chautauqua Complex 4.4.1	2,613	1,536
Silver Creek, NY	Cattaraugus Creek 4.4.2	3,182	768
Westfield, NY	Erie-Chautauqua Complex 4.4.1	3,651	2,430
Alden, NY	Tonawanda Complex 4.4.3	2,651	1,726
East Aurora, NY	Tonawanda Complex 4.4.3	7,033	1,536
Springville, NY	Tonawanda Complex 4.4.3	4,350	1,855
Angola, NY	Tonawanda Complex 4.4.3	2,676	768
Akron, NY	Tonawanda Complex 4.4.3	2,863	1,151
TOTAL - PCA		933,523	184,117
Planning Subarea 4.4		1,841,836	3,069,900

*To convert acres to hectares, multiply by 0.4047

Urban stormwater and combined sewer overflow control costs are summarized in Table 98.* Estimates of the average annual cost range from $16.8 million for low efficiency (20 percent solids removal) treatment to $55.8 million for the high efficiency alternative (88 percent removal). The addition of chlorination for bacteria control would add from $350 thousand to $3.2 million per year.

The use of construction sediment control practices would cost an estimated $250 thousand per year. Capital costs of providing detention ponds in newly developed areas would be $1.8 million per year, with an additional $36 thousand per year for maintenance.

Because the potential contributing area included essentially all of the planning subarea, no cost extrapolations were made.

Agricultural Areas

There are 227 thousand hectares (560 thousand acres) of cropland within the potential contributing area of RBG 4.4 (see Table 99). Sixty-two percent of this cropland, or 138 thousand hectares (341 thousand acres), requires treatment. According to Conservation Needs Inventory data, 213 thousand hectares (527 thousand acres) out of a total 348 thousand hectares (859 thousand acres) of cropland in Planning Subarea 4.4 required erosion control treatment in 1968.

The potential contributing area has 275 cattle feedlots, two swine, and two poultry operations (see Table 100). Only six percent of the cattle feedlots, both of the swine operations and neither of the poultry operations have waste controls.

Agricultural runoff and intensive livestock operations within this region may have a significant impact on Lake Erie water quality.

As the cost estimates in Table 99 show, the one-time and recurring costs of applying best management practices in the potential contributing area of RBG 4.4 are $4.4 million and $1.9 million, respectively. The average annual cost of these practices is $2.4 million per year. Because of limitations in the information available, it was not possible to provide a reasonable estimate of costs for fine-textured soils only. Estimates based on land treatment needs identified in the Conservation Needs Inventory yield one-time and recurring costs of $6.7 million and $2.9 million. Average annual costs would be $3.6 million.

Animal waste controls would cost more than seven million dollars to install where needed in the potential contributing area. Extrapolating this to all intensive feedlot operations in the planning subarea increases the cost to $9.8 million. Average annual figures are $770 thousand and $1.1 million per year, respectively.

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*The apparent discrepancy between the number of urban areas in Table 97 (13) and 98 (14) arises because Buffalo was divided into two parts for the cost assessment, one served by combined sewers, the other by separate systems.

TABLE 98

URBAN CONTROL SUMMARY FOR RBG 44

NUMBER OF URBAN AREAS: 14

LOW LEVEL OF TREATMENT (<30% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.20

CAPITAL COST	: $	118642096.
ANNUAL OPERATING COST:	$	3759127.
AVERAGE ANNUAL COST*	: $	16829712.

MEDIUM LEVEL OF TREATMENT (30% TO 60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.56

CAPITAL COST	: $	338845184.
ANNUAL OPERATING COST:	$	8711598.
AVERAGE ANNUAL COST*	: $	46041536.

HIGH LEVEL OF TREATMENT (>60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.88

CAPITAL COST	: $	400964096.
ANNUAL OPERATING COST:	$	11671448.
AVERAGE ANNUAL COST*	: $	55844928.

CHLORINATION (MEDIUM AND HIGH LEVEL TREATMENT ONLY)

	COMBINED SEWER ONLY	COMBINED AND STORM SEWERS
CAPITAL:	1865523.	23703920.
O&M :	144206.	612474.
ANNUAL*:	349727.	3223891.

* Average annual cost equals capital amortized over 25 years at 10 percent interest per year plus annual operation and maintenance cost.

TABLE 99

COSTS FOR INSTALLING AGRICULTURAL BEST MANAGEMENT PRACTICES IN THE POTENTIAL CONTRIBUTING AREA (PCA) OF RIVER BASIN GROUP 4.4

COUNTY	TOTAL ACRES* IN POTENTIAL CONTRIBUTING AREA	ACRES IN PCA NEEDING TREATMENT	COSTS FOR ALL SOILS ($ millions)		COSTS FOR FINE-TEXTURED SOILS ($ millions)	
			One-Time	Recurring	One-Time	Recurring
PENNSYLVANIA						
Erie	71,489	58,321	2.44**	1.60**	†	†
NEW YORK						
Cattaraugus	34,000	19,300	0.19	0.02	††	††
Chatauqua	72,200	41,900	0.24	0.07	0	0
Erie	147,000	66,000	0.21	0.03	††	††
Genesee	110,800	81,200	0.82	0.10	0.01	0
Wyoming	80,500	41,200	0.46	0.06	††	††
Niagara	44,100	33,500	0	††	0	††
TOTAL	560,089	341,421	4.36	1.88	0.01	††

*To convert acres to hectares, multiply by 0.4047

**Includes costs for 18,734 acres in Crawford County in RBG 4.3

†Fine textured soils not differentiated

††Cost is negligible

TABLE 100

COST FOR INSTALLING AGRICULTURAL WASTE MANAGEMENT SYSTEMS
IN POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 4.4

COUNTY	TOTAL NUMBER OF FEEDLOT OPERATIONS ≥100 ANIMAL UNITS IN PCA			NUMBER OF FEEDLOT OPERATIONS IN PCA NEEDING TREATMENT			TOTAL COST ($ thousands)		
	CATTLE	SWINE	POULTRY	CATTLE	SWINE	POULTRY	CATTLE (at $27,000 per system)	SWINE (at $17,000 per system)	POULTRY (at $ 25,000 per system)
NEW YORK									
Cattaraugus	42	0	0	42	0	0	1,134	0	0
Chautauqua	30	0	0	27	0	0	729	0	0
Erie	53	0	2	51	0	2	1,377	0	50
Genesee	22	2	0	18	0	0	486	0	0
Wyoming	124	0	0	118	0	0	3,186	0	0
Niagara	4	0	0	2	0	0	54	0	0
TOTAL	275	2	2	258	0	2	6,966	0	50

On-Site Waste Disposal

Of the total 103,142 nonsewered, nonfarm residential units in Planning Subarea 4.4* in the 1970 Census, about 82 percent are in rural areas. About 68 percent are estimated to be located in the potential contributing area (Table 101). Of those in the potential contributing area, 65 percent are in the Tonawanda complex. Nonsewered housing units here are projected to increase only two percent between 1970 and 1990.

Impermeable soils and a high groundwater table have been cited as causing septic tank malfunctions and thereby degrading groundwater quality in the Erie-Chautauqua complex [GLBC, 1976]. High-density nonsewered residential areas in RBG 4.4 thus may have an impact on Lake Erie water quality.

Correction of on-site waste disposal problems in the potential contributing area would require an estimated capital investment of $32.7 million, with $1.2 million per year in operating costs thereafter. The average annual would be $4.8 million. Extrapolating these estimates to all on-site systems in the planning subarea increases capital costs to $48.4 million, with $1.8 million per year for operation and maintenance. The annual cost is $7.1 million in this case.

Other Problems

There are four dredge spoil disposal sites in RBG 4.4. The four locations have a total of 539,738 cubic meters (706,464 cubic yards) of annual average polluted dredge spoil. The disposal sites are located near Erie, Pennsylvania, and Dunkirk, and Buffalo, New York. The volume of total and polluted spoil is projected to increase about four percent between 1970 and 1990.

*Totals for Planning Subarea 4.4 do not truly reflect those for the river basin group because portions of Genesee and Wyoming Counties found in the hydrologic region are not located within the political boundaries. Thus, RBG totals would be higher.

TABLE 101

ON-SITE WASTE DISPOSAL, RBG 4.4

COUNTY	TOTAL NUMBER OF SYSTEMS	PERCENT OF COUNTY IN PCA	ESTIMATED NUMBER OF SYSTEMS IN PCA	NUMBER FAILING	CAPITAL COST ($X10^6)	OPERATING COST ($X10^3)	AVERAGE ANNUAL COST ($X10^6)
PENNSYLVANIA							
Erie	18,070	35	6,320	1,580	2.97	107.8	0.44
NEW YORK							
Cattauaugua	13,091	30	3,930	980	1.84	66.8	0.27
Chautauqua	17,447	30	5,230	1,310	2.46	89.3	0.36
Erie	37,635	100	37,640	9,410	17.67	641.8	2.59
Niagara	16,899	60	10,140	2,540	4.77	173.2	0.70
Genesee	8,558	55	4,710	1,180	2.22	80.5	0.32
Wyoming	5,751	30	1,720	430	0.81	29.3	0.12
TOTAL	--	--	69,690	17,430	32.74	1,188.7	4.80

7 LAKE ONTARIO BASIN

LAKE BASIN SUMMARY

BASIN DESCRIPTION

The United States portion of the Lake Ontario basin covers 43,500 square kilometers (16,800 square miles), and the St. Lawrence drainage area adds an additional 12,652 square kilometers (4,885 square miles), for a total of 56,152 square kilometers (21,685 square miles). Only 0.5 percent of the area is located in the State of Pennsylvania with the rest in the State of New York. The Lake Ontario basin is divided into three river basin groups: River Basin Group 5.1, which lies almost entirely in western New York except for a small portion in Pennsylvania, and River Basin Groups 5.2 and 5.3 which include much of central and northern New York. Figure 42 is a map of the U.S. Lake Ontario drainage basin.

This basin has a varied topography of deeply incised valleys, severely eroded mountains, and hilly uplands, with lowlands bordering the lake and the St. Lawrence River. Because glaciation in the Lake Ontario region involved less extensive deposition of material, a more rugged landscape than that of the other lake basins has evolved.

With the exception of the narrow Lake Plains area, soils are typically poor with high acidity, and composed of a mixture of sand, gravel, and stones. Wetlands are common in the headlands. Shoreline bluffs, which consist principally of clay and silt, are highly erodible.

Significant quantities of iron ore, lead, talc, marble, limestone and dolomite are produced. Sand and gravel, peat, marl and salt are also extracted.

The population density is approximately 57 people per square kilometer (148 per square mile). The estimated 1975 population was 2,579,000 people, a 32 percent increase from the 1940 population of 1,758,000.

The water quality of Lake Ontario is to a large extent dependent on the quality of the upstream lakes but the large volume of the lake is a factor in maintaining better water quality than Lake Erie. Primary problems of Lake Ontario reflect the influence of Lake Erie, and include the build-up of chemical constituents (sulfates and chlorides) and nutrients.

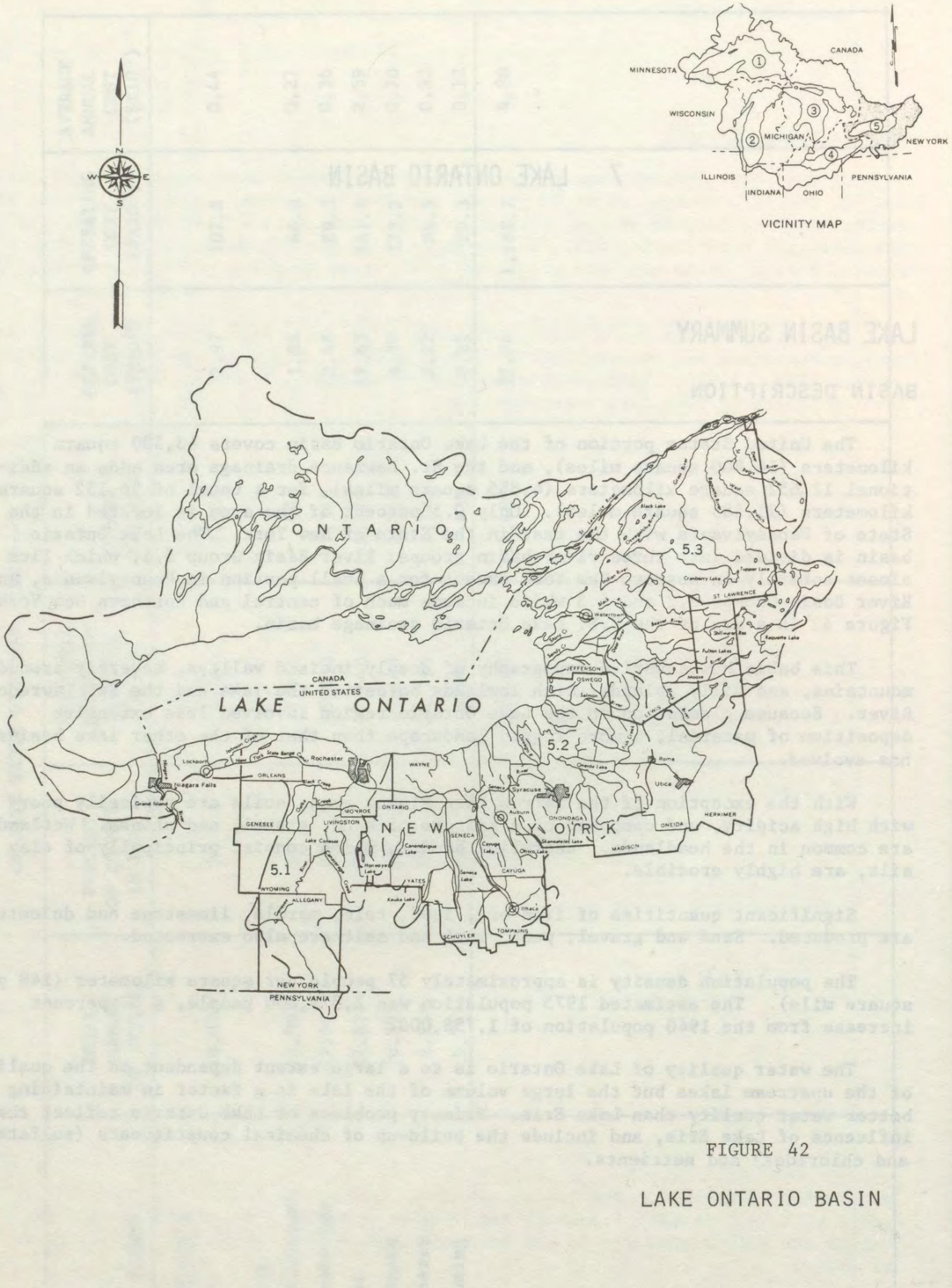


FIGURE 42

LAKE ONTARIO BASIN

The open waters of Lake Ontario generally exhibit a mesotrophic state. Portions of the U.S. nearshore waters are eutrophic, although the nearshore waters along the eastern end of the lake are generally mesotrophic.

PROBLEM AREA SUMMARY

The estimated potential contributing area totals 13,240 square kilometers (5,111 square miles), or nearly 30 percent of the basin. The largest share (44 percent) of the potential contributing area lies in RBG 5.1.

An assessment of the diffuse tributary sediment and phosphorus loadings to the lake has revealed the following hydrologic areas as having a significant input of one or both of these contaminants: Genesee River, Oswego River, Salmon complex, Black River, Oswegatchie River, and Grass-Raquette-St. Regis complex.

The following potential critical problem areas and associated remedial costs were identified on the basis of land use activities.

URBAN AREAS

Twenty-three urban areas with a total population of 582,568, covering 154,251 acres were identified in the Lake Ontario potential contributing area. The annual growth rate varied from 0.2 percent in RBG 5.3 to 0.8 percent in 5.2, to 1.6 percent in 5.1.

Stormwater and combined sewer control total costs for the basin's potential contributing area range from $14.0 million (low level treatment) to $32.1 million (high level). Chlorination for those areas contributing bacteria would add from $300 thousand to $1.4 million to the medium and high efficiency alternatives. Estimated annual control costs for all the basin's urban areas would range from $43.0 million for the low level alternative to $132.4 million for the high level. Chlorination was not inlcuded.

Construction sediment controls applied to those urban areas in the potential contributing area would cost $900 thousand annually. Detention ponds in new developments would cost $5.8 million in annual construction and $110 thousand in annual maintenance. Extrapolation to the entire lake basin yields the following results: construction sediment controls would cost $1.4 million annually; detention ponds $12.6 million in annual construction and $260 thousand in annual maintenance.

AGRICULTURAL AREAS

Of 501 thousand hectares (1,237 thousand acres) of cropland in Lake Ontario's potential contributing area, 68 percent, or 341 thousand hectares (842 thousand acres), requires erosion control. Application of best management practices to all moderate- and fine-textured soils here would cost $8.8 million one-time and $1.5 million recurring, for an average annual cost of $2.5 million. Limiting application to fine-textured soils would limit the expense to $200 thousand one-time and insignificant recurring costs, for an average annual cost of $20 thousand per year. Extrapolation to the lake basin resulted in the following estimates: $25.1 million for installation, and $4.6 million annual recurring expenses or $7.4 million per year in average annual terms.

Almost 300 intensive livestock operations are located in the potential contributing area of Lake Ontario. About 80 precent, or 265, need waste controls. Installation of waste management systems would cost $7.1 million. Installation throughout the lake basin would total $42.7 million. These figures in average annual terms are $780 thousand and $4.7 million, respectively.

ON-SITE WASTE DISPOSAL

Throughout the potential contributing area there are an estimated 53,420 malfunctioning septic systems. Remedial programs would cost $68.2 million capital, $2.7 million annual operation and maintenance, or $10.2 million per year average annual. Expanding to include all failing systems in the lake basin increases the costs to $353.9 million in capital, and $14.3 million in annual operating expenses, for an average annual cost of $53.3 million. On-site waste disposal is a significant problem in this basin.

The costs for urban, agricultural, and on-site waste disposal remedial measures in the Lake Ontario potential contributing area are displayed in Table 102.

OTHER PROBLEMS

Other problems identified in the Lake Ontario basin include the disposal of polluted dredge spoil and possible sewage disposal, and erosion problems related to recreational activities in the region.

TABLE 102

COST

SUMMARY FOR LAKE

ONTARIO

PRACTICE	CAPITAL COST ($ millions)	OPERATING, MAINTENANCE AND RECURRING COST ($ millions)	AVERAGE ANNUAL COST ($ millions)
Urban Areas			
Low Level Treatment	102.3	2.7	14.0
Medium Level Treatment	141.7	3.0	18.6
High Level Treatment	263.0	8.1	37.1
Chlorination -			
Combined only	1.8	0.1	0.3
Both	10.3	0.3	1.4
Sediment Controls	-	0.9	0.9
Detention Ponds	-	5.9	5.9
Agricultural Areas			
Best Management Practices:			
All Soils	8.8	1.5	2.5
Fine Soils	0.2	†	†
Animal Waste Controls	7.1	-	0.8
On-Site Waste Disposal	68.2	2.7	10.2

† <0.1

RIVER BASIN GROUP 5.1

DESCRIPTION

River Basin Group 5.1 is located in the northeastern portion of the Great Lakes Basin along the southern shore of Lake Ontario. It consists of two hydrologic areas, Niagara-Orleans complex and Genesee complex, which together drain 9,104 square kilometers (3,515 square miles). The corresponding planning subarea, as shown in Figure 43 includes six northwestern New York counties.

Bedrock formations in RBG 5.1 are composed of shales, limestones and sandstone. Glacial and lacustrine deposits of sand, clay, and gravel top the bedrock.

Figure 44 shows the region's predominant soil textures. The land here rises gradually from Lake Ontario, where there is a narrow lake plain, to the Allegheny Plateau. Immediately south of the lake plain is a rolling belt of medium-textured, permeable glacial drift. This belt is 20 to 30 miles wide and contains some of the best soils in New York State. Beyond this belt, the land rises into the Allegheny Plateau regions where elevations average 1,700 to 2,000 feet and the soils are developed in a heavy-textured glacial drift and in shale and limestone bedrock. Minerals produced include gypsum, salt, sand and gravel, petroleum, natural gas, and stone (limestone, dolomite, and sandstone).

Principal streams include the Genesee River, and the Canaseraga, Otatka, Black, Honeoye, Johnson, and Oak Orchard Creeks. The Genesee River varies from flashy and steep in its headwaters (slopes to 18 meters per kilometer, or 100 feet per mile) to sluggish and meandering as it flows over flat, alluvial plains. Streams in the Niagara-Orleans complex are not steep, and their flows are relatively stable. The Genesee River complex is a major sediment transporter. Winter and spring floods generally cause significant damage.

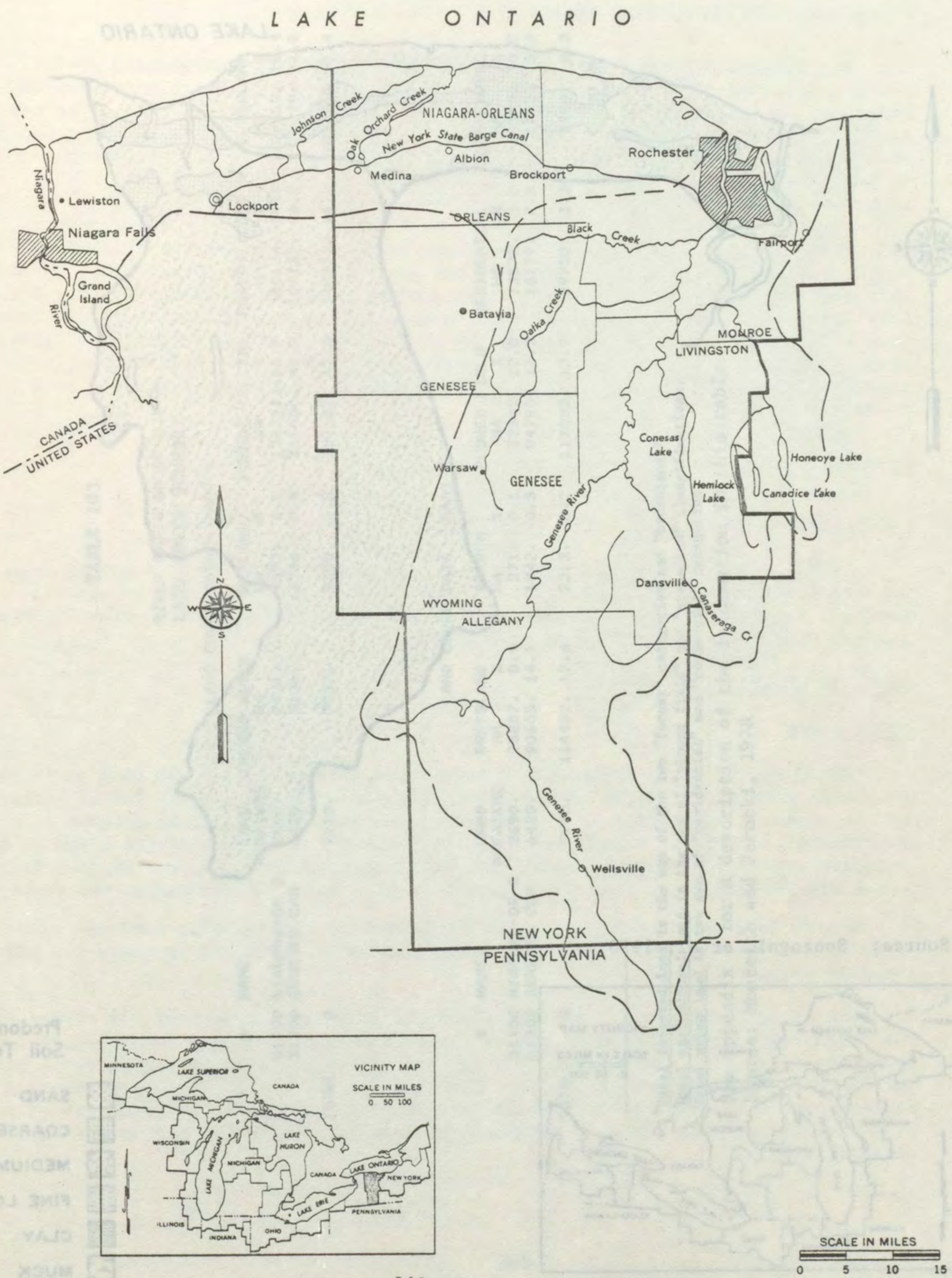
Forests cover about 70 percent of the region. Agriculture covers 25 percent, and urban uses cover only 3.6 percent. Table 103 shows the major land cover in each of the hydrologic areas.

With the exception of the Rochester metropolitan area, RBG 5.1 has a relatively sparse population, evenly distributed, with few significant urban centers. Approximately 25 percent of the 1970 total population was classified as rural. Population rose from 620,000 in 1940 to 946,000 in 1970, an increase of more than 30 percent.

The major urban centers (1975 population estimates) are: Rochester (pop.: 267,173), East Rochester (pop.: 11,755), Niagara Falls (pop.: 80,773), Fairport (pop.: 7,478), Batavia (pop.: 17,379), Genesee (pop.: 7,052), and Brockport (pop.: 11,755). Total employment in 1970 was 380,750, with 38 percent devoted to manufacturing activities, mostly located in Monroe County. The Rochester metropolitan area also serves as a center for trades and services in the region, which provides jobs for over 40 percent of the 1970 work force. In the rest of the region agriculture is a major economic factor.

FIGURE 43

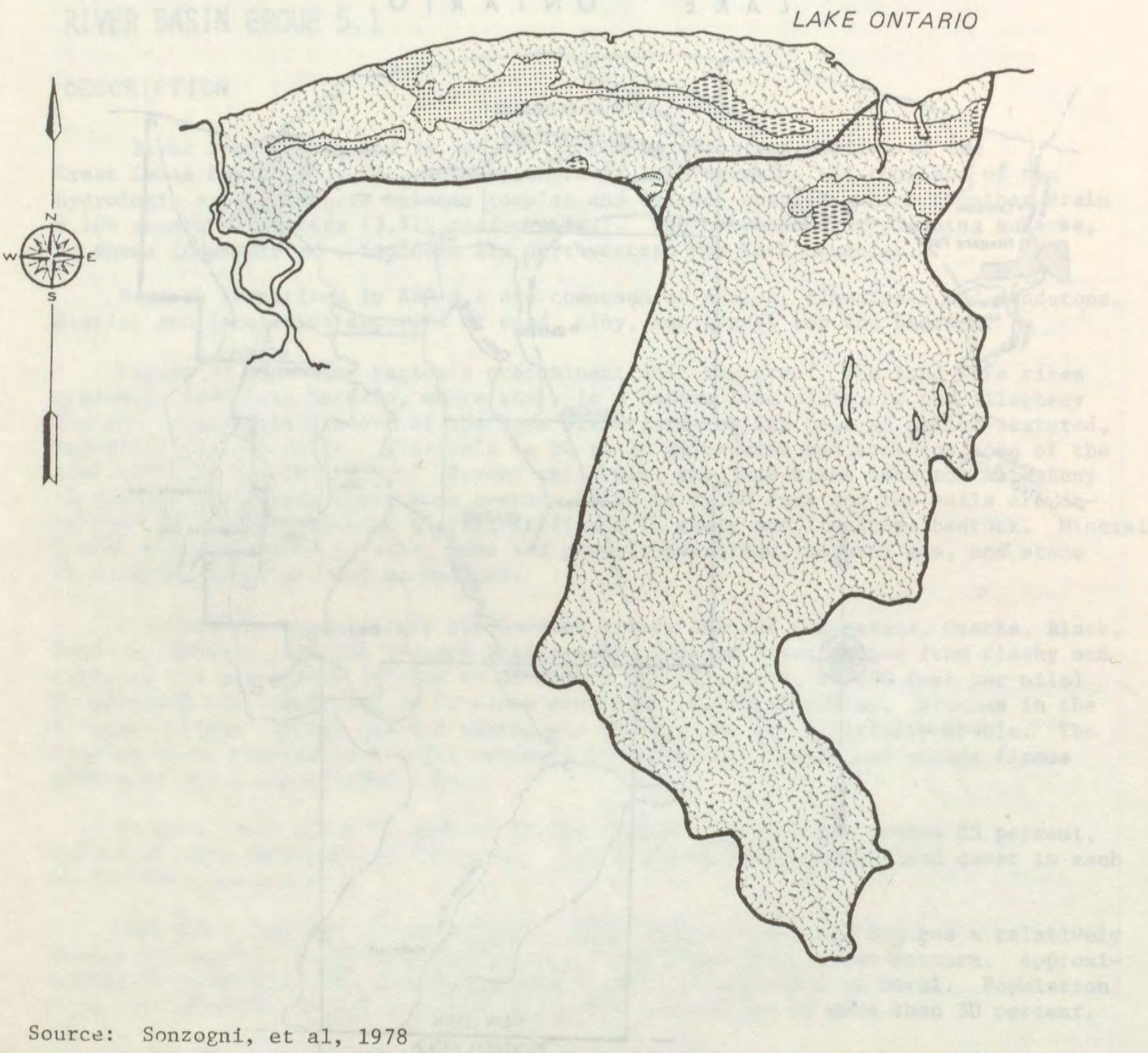
PLANNING SUBAREA 5.1



5.1

FIGURE 44

SOIL TEXTURE
River Basin Group 5.1



Source: Sonzogni, et al, 1978

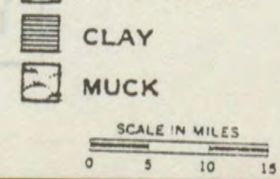


TABLE 103

RIVER BASIN GROUP 5.1

LAND COVER SUMMARY

LAND COVER DATA - PART 1

#	NAME	LAND AREA:KM2	INLAND WATER HA	WETLAND HA	%	FOREST (DECID) HA	%	FOREST (CON) HA	%	BRUSHLAND HA	%
51100	NIAGARA-OR C	2690.	2421.	4072.	1.5	126221.	46.9	40174.	14.9	27959.	10.4
51200	GENESEE COM	6420.	5136.	3236.	0.5	261460.	40.7	106137.	16.5	75720.	11.8
TOTAL	2	9110.	7557.	7308.	0.8	387681.	42.6	146311.	16.1	103678.	11.4

LAND COVER DATA - PART 2

#	NAME	LAND AREA:KM2	GRASSLAND HA	%	BARREN HA	%	PLOWED FIELD HA	%	RESIDENTIAL HA	%	COMMERCIAL HA	%
51100	NIAGARA-OR C	2690.	23887.	8.9	271.	0.1	32302.	12.0	13572.	5.0	543.	0.2
51200	GENESEE COM	6420.	90605.	14.1	1942.	0.3	84780.	13.2	16179.	2.5	1942.	0.3
TOTAL	2	9110.	114492.	12.6	2213.	0.2	117082.	12.9	29752.	3.3	2484.	0.3

---

*Total forested land is the sum of the two "forest" categories and "brushland."
Total agricultural land is the sum of "plowed field" and "grassland" classifications.
Total urban land is the sum of "residential" and "commercial" categories.

See Appendix 3 for a description of the information in this table.
Source: Monteith and Jarecki, 1978

POTENTIAL CONTRIBUTING AREA

The Niagara-Orleans complex has two small areas of coarse-grained soils; the remainder of the area has fine- to medium-textured soils. No major impoundments are present but the New York State Barge Canal bisects the area. The net effect of the canal on the delivery of pollutants to the lakes is unknown, but is assumed to be negligible. Thus, the potential contributing area was estimated to be 90 percent of the hydrologic area or about 2,420 square kilometers (930 square miles).

The upper portion of the Genesee River is impounded above the village of Mt. Morris. Also, several large lakes are present in the eastern portion of the watershed. Another impoundment is at Irondequoit Bay, which opens directly into Lake Ontario. These impoundments were assumed to act as efficient sediment traps, thus eliminating about 50 percent of the river basin from the potential contributing area. The remaining 50 percent is approximately 3,460 square kilometers (1,330 square miles). Figure 45 shows the extent of the potential contributing area in RBG 5.1.

CRITICAL PROBLEM AREA IDENTIFICATION

CONTRIBUTION INDEX

As Table 104 shows, both suspended solids and total phosphorus inputs from the Genesee River basin are significantly higher than those from areas in general. However, in no case are the inputs from the Niagara-Orleans complex significantly greater than for the Great Lakes as a whole.

LAND USE ACTIVITIES

Urban Areas

There are 14 urban areas with a population greater than 2,500 located in the potential contributing area of RBG 5.1 (Table 105). These account for 51 percent of the region's population. Only Rochester and Niagara Falls were assumed to contribute bacteria to Lake Ontario, while Rochester and Lockport are known to have combined sewers. Rochester and all the other municipalities in the Genesee River basin are located in an area which generates high loads of phosphorus and sediments.

Runoff from construction sites in the potential contributing area may also degrade Lake Ontario water quality. Population is projected to increase 1.6 percent annually between 1970 and 2020.

The estimated costs of combined sewer and stormwater treatment for cities in the potential contributing area are shown in Table 106. Average annual costs for treatment range from 11.1 million for the low efficiency alternative to $27.1 million for the high efficiency alternative. Chlorination for those cities contributing bacteria would add from $180 thousand per year for combined sewer treatment only, to $1.2 million per year for both combined and storm sewers to the medium and high load alternatives.

FIGURE 45

POTENTIAL CONTRIBUTING AREA OF

RBG 5.1

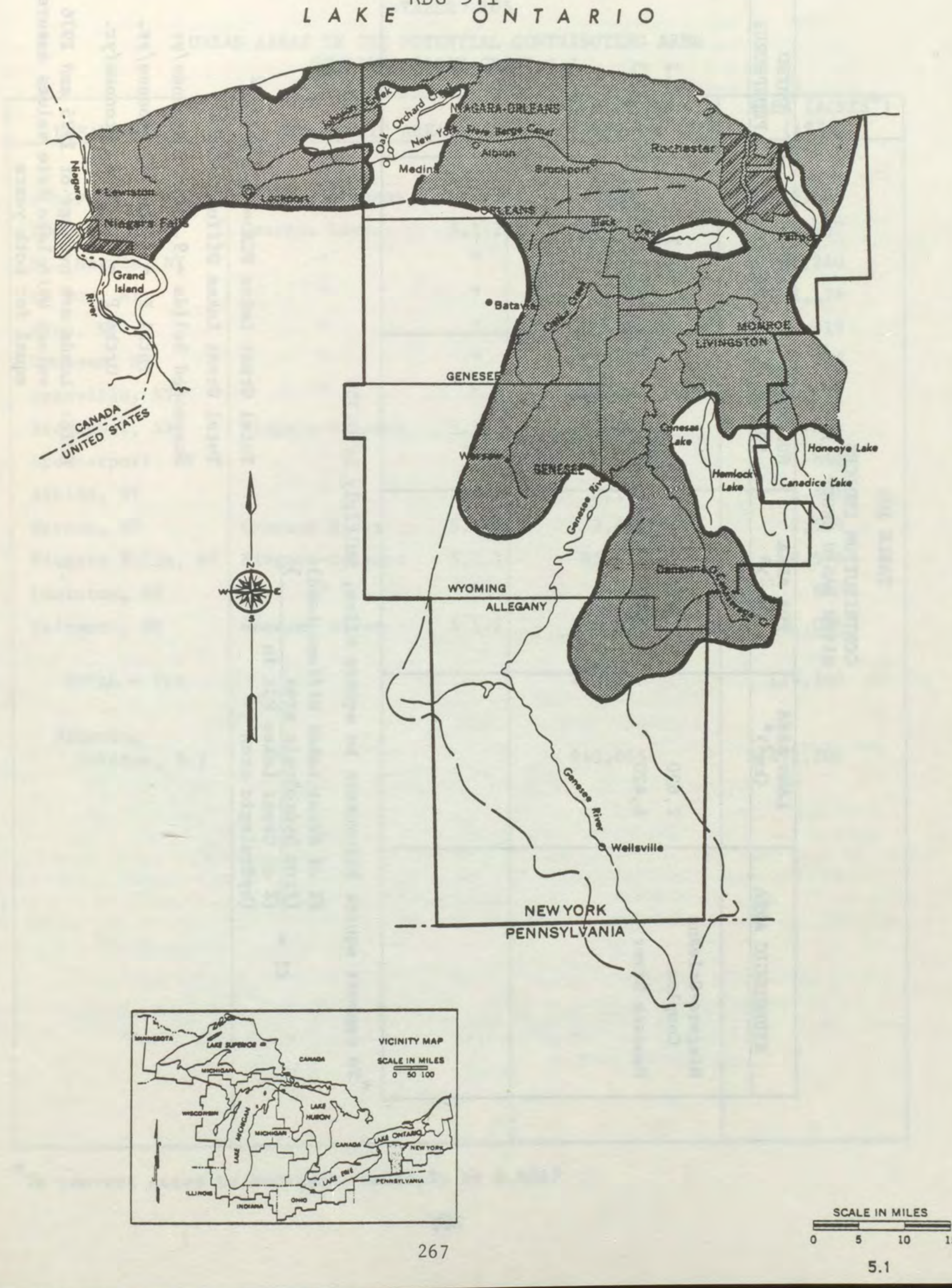


TABLE 104

CONTRIBUTION INDICES
RIVER BASIN GROUP 5.1

HYDROLOGIC AREA	LAND AREA (km^2)*	PCA AREA (km^2)*	SUSPENDED SOLIDS	TOTAL PHOSPHORUS	ORTHO PHOSPHORUS
Niagara-Orleans Complex	2,690	2,420	0.3	0.7	0.2
Genesee River	6,420	3,460	2.7	1.2	0.3

*To convert square kilometers to square miles, multiply by 0.386

$$CI = \frac{(\text{\% of Great Lakes Diffuse Load})\ (\text{from hydrologic area})}{(\text{\% of Great Lakes PCA in})\ (\text{hydrologic area})}$$

Total Great Lakes PCA = 105,950 km^2

Total Great Lakes Diffuse Loads

Suspended Solids = 9,492,407 Mtonnes/yr.

Total P = 13,155 Mtonnes/yr.

Ortho P = 3,007 Mtonnes/yr.

NOTE: Loads are average of 1975 and 1976 values with Lake Erie values assured equal for both years

TABLE 105

URBAN AREAS IN THE POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 5.1

URBAN AREA	HYDROLOGIC AREA		POPULATION (1970)	AREA (ACRES*) (1970)
Lockport, NY	Niagara-Orleans	5.1.1	25,399	5,244
Rochester, NY	Genesee River	5.1.2	316,155	93,207
Mt. Morris, NY	"	"	3,417	2,240
Le Roy, NY	"	"	5,118	2,176
Avon, NY	"	"	3,260	1,919
Geneseo, NY	"	"	5,714	1,726
Dansville, NY	"	"	5,436	1,472
Brockport, NY	Niagara-Orleans	5.1.1	7,878	1,344
Spencerport, NY	"	"	2,929	832
Albion, NY	"	"	5,122	1,601
Warsaw, NY	Genesee River	5.1.2	3,619	2,559
Niagara Falls, NY	Niagara-Orleans	5.1.1	85,615	8,576
Lewiston, NY	"	"	3,292	640
Fairport, NY	Genesee River	5.1.2	6,474	1,024
TOTAL - PCA			479,428	124,560
Planning Subarea 5.1			940,055	2,491,200

*To convert acres to hectares, multiply by 0.4047

TABLE 106

URBAN CONTROL SUMMARY FOR RBG 51

NUMBER OF URBAN AREAS: 14

LOW LEVEL OF TREATMENT (<30% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.25

CAPITAL COST	: $	84632704.
ANNUAL OPERATING COST	: $	1788268.
AVERAGE ANNUAL COST*	: $	11112099.

MEDIUM LEVEL OF TREATMENT (30% TO 60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.60

CAPITAL COST	: $	103071184.
ANNUAL OPERATING COST	: $	2057415.
AVERAGE ANNUAL COST*	: $	13412580.

HIGH LEVEL OF TREATMENT (>60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.88

CAPITAL COST	: $	193196880.
ANNUAL OPERATING COST	: $	5806069.
AVERAGE ANNUAL COST*	: $	27090208.

CHLORINATION (MEDIUM AND HIGH LEVEL TREATMENT ONLY)

	COMBINED SEWER ONLY	COMBINED AND STORM SEWERS
CAPITAL:	978946.	8491944.
O&M :	70165.	246378.
ANNUAL*:	178014.	1181920.

* Average annual cost equals capital amortized over 25 years at 10 percent interest per year plus annual operation and maintenance cost.

Construction sediment controls applied only to those urban areas in the potential contributing area would cost $800 thousand annually. Construction of detention ponds in new developments in the potential contributing area would add $5.5 million annually with $110 thousand in operating and maintenance costs each year.

The estimated capital costs for applying urban stormwater and combined sewer controls to all urban areas throughout RBG 5.1 range from $137.5 to $314.9 million, as shown in Table 107. Operating and maintenance costs vary from $3.1 to $9.2 million annually. The average annual costs for urban combined sewer and stormwater controls throughout RBG 5.1 would thus vary from $18.2 to $43.9 million. Chlorination was not included.

In similar fashion, construction sediment control costs throughout RBG 5.1 would be $830 thousand a year. Detention pond costs for newly developed areas would cost $8.9 million annually plus $180 thousand for maintenance each year.

Agricultural Areas

There are 335 thousand hectares (827 thousand acres) of cropland within the potential contributing area of RBG 5.1 (see Table 108). Sixty-eight percent of this cropland, or 226 thousand hectares (559 thousand acres), requires treatment. According to Conservation Needs Inventory data, 288 thousand hectares (712 thousand acres) out of a total 427 thousand hectares (1,055 thousand acres) of cropland in Planning Subarea 5.1 required erosion control treatment in 1968.

The potential contributing area of RBG 5.1 accounts for 219 cattle feedlot operations, six swine operations, and one poultry feedlot (see Table 109). Only 10 percent of the cattle feedlots have waste controls. None of the swine and poultry operations have waste controls. Based on information in Inventory of Land Use [IJC, 1976e], some 420 cattle, 18 swine, and 24 poultry operations in the planning area may be without waste management systems.

Agricultural runoff and intensive livestock operations within this region may have a significant impact on Lake Ontario water quality.

As the figures in Table 108 show, the application of best management practices to all lands needing erosion control treatment in the potential contributing area would have a one-time cost of $6.4 million and annual recurring costs of $1.0 million. The average annual cost would be $1.7 million. The application of best management practices to only fine-textured soils in the potential contributing area (28 thousand hectares) would cost $20 thousand in recurring expenses only; there are no one-time costs for fine-textured soils.

The cost of treating all those lands in the planning subarea identified in the 1968 Conservation Needs Inventory as needing erosion control was estimated to be $8.1 million, one-time, $1.3 million, recurring, for an annual cost of $2.2 million.

TABLE 107

ESTIMATED COST OF CONTROLS FOR ALL URBAN AREAS, RBG 5.1

TREATMENT LEVEL		COST IN PCA ($ millions)	ADJUSTED AREA IN PCA (ACRES*)	COST PER ACRE ($)	TOTAL URBAN ACREAGE	ADJUSTED** URBAN ACREAGE	RBG COST ($ millions)
LOW	Capital	84.6	47,180	1,790	130,185	76,809	137.5
	O&M	1.8	47,180	40	130,185	76,809	3.1
MEDIUM	Capital	103.1	47,180	2,200	130,185	76,809	169.0
	O&M	2.1	47,180	45	130,185	76,809	3.5
HIGH	Capital	193.2	47,180	4,100	130,185	76,809	314.9
	O&M	5.8	47,180	120	130,185	76,809	9.2

*To convert acres to hectares, multiply by 0.4047

**Urban area adjustment factor = 0.59

Average Annual Cost:

Low:	$18.2 million
Medium:	22.1 million
High:	43.9 million

TABLE 108

COSTS FOR INSTALLING AGRICULTURAL BEST MANAGEMENT PRACTICES IN THE POTENTIAL CONTRIBUTING AREA (PCA) OF RIVER BASIN GROUP 5.1

COUNTY	TOTAL ACRES* IN POTENTIAL CONTRIBUTING AREA	ACRES IN PCA NEEDING TREATMENT	COSTS FOR ALL SOILS ($ millions)		COSTS FOR FINE-TEXTURED SOILS ($ millions)	
			One-Time	Recurring	One-Time	Recurring
NEW YORK						
Allegany	19,600	12,800	0.21	0.01	0	0
Genesee	90,700	66,300	0.95	0.11	**	0
Livingston	159,500	106,800	1.06	0.12	0	**
Monroe	180,200	140,500	1.77	0.30	0	0.01
Niagara	115,800	88,100	0.60	0.19	0	0.01
Ontario	83,300	34,200	0.26	0.05	0	**
Orleans	98,200	69,700	1.01	0.15	0	0
Steuben	12,800	6,800	0.08	0.02	0	0
Wyoming	66,500	33,900	0.42	0.05	**	0
TOTAL	826,600	559,100	6.36	1.00	**	0.02

*To convert acres to hectares, multiply by 0.4047

**Cost is negligible

TABLE 109

COST FOR INSTALLING AGRICULTURAL WASTE MANAGEMENT SYSTEMS IN POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 5.1

COUNTY	TOTAL NUMBER OF FEEDLOT OPERATIONS ≥100 ANIMAL UNITS IN PCA			NUMBER OF FEEDLOT OPERATIONS IN PCA NEEDING TREATMENT			TOTAL COST ($ thousands)		
	CATTLE	SWINE	POULTRY	CATTLE	SWINE	POULTRY	CATTLE (at $27,000 per system)	SWINE (at $17,000 per system)	POULTRY (at $ 25,000 per system)
NEW YORK									
Alleghany	5	0	0	3	0	0	81	0	0
Genesee	32	0	0	24	0	0	648	0	0
Livingston	79	2	1	72	2	1	1,944	34	25
Monroe	36	0	0	36	0	0	972	0	0
Niagara	9	0	0	9	0	0	243	0	0
Ontario	3	0	0	3	0	0	81	0	0
Orleans	17	4	0	15	4	0	405	0	0
Steuben	2	0	0	2	0	0	54	0	0
Wyoming	36	0	0	33	0	0	891	0	0
TOTAL	219	6	1	197	6	1	5,319	34	25

Table 108 shows that providing waste controls for feedlots in the potential contributing area needing them would cost $5.4 million. The cost for these controls installed throughout the planning subarea was estimated at $12.3 million.

On-Site Waste Disposal

Nonsewered, nonfarm residences account for 18 percent of the total housing units in the region, or 53,560 units. Of this, over 79 percent are in rural areas. The number of nonsewered households is projected to increase 37 percent between 1970 and 1990.

Table 110 shows the approximate distribution of nonsewered units located within the potential contributing area of each county in Planning Subarea 5.1. Over half (55 percent) of the units in the potential contributing area are located in the Genesee River basin. Private sewage disposal systems are contributing to poor Lake Ontario water quality in nearshore areas [GLBC, 1976].

The estimated capital investment required to alleviate problems with failing systems within the potential contributing area is $31.9 million, with an additional $1.7 million in annual operating costs (Table 110). The average annual cost would be $5.2 million. To alleviate these problems throughout the planning subarea would cost $176.3 million, capital, $9.3 million, operating, for an average annual cost of $28.7 million.

Other Problems

On an average annual basis, there is one dredged site, Rochester Harbor, in RBG 5.1. An annual average of 204,010 cubic meters (267,029 cubic yards) of polluted spoil requiring diked confinement is disposed of in the harbor.

As of July 1974, there were no diked containment sites for polluted dredge spoil in RBG 5.1. Rochester has selected a site and construction was planned for 1976. It is thus assumed that dredge spoil disposal is not a problem in RBG 5.1.

No other land use activites in this RBG have been identified as having an impact on Great Lakes water quality.

TABLE 110

ON-SITE WASTE DISPOSAL, RBG 5.1

COUNTY	TOTAL NUMBER OF SYSTEMS	PERCENT OF COUNTY IN PCA	ESTIMATED NUMBER OF SYSTEMS IN PCA	NUMBER FAILING	CAPITAL COST ($\$X10^6$)	OPERATING COST ($\$X10^3$)	AVERAGE ANNUAL COST ($\$X10^6$)
NEW YORK							
Alleghany	9,766	20	1,950	1,170	1.16	61.0	0.19
Genesee	8,558	45	3,850	2,310	2.29	120.4	0.37
Livingston	8,019	80	6,420	3,850	3.82	200.6	0.62
Monroe	30,333	88	26,690	16,010	15.88	834.3	2.58
Orleans	5,723	70	4,010	2,410	2.39	125.6	0.39
Wyoming	5,751	30	1,720	1,030	1.02	53.7	0.17
Niagara	16,899	40	6,760	4,060	4.03	211.6	0.65
Ontario	10,821	20	2,160	1,300	1.29	67.8	0.21
TOTAL	--	--	53,560	32,140	31.88	1,675.0	5.18

RIVER BASIN GROUP 5.2

DESCRIPTION

River Basin Group 5.2, located in the eastern part of the Great Lakes Basin on the southeast shore of Lake Ontario, drains an area of 17,657 square kilometers (6,817 square miles). A twelve county region of north central New York State makes up the planning subarea, as shown in Figure 46. Three hydrologic areas comprise the RBG: Wayne-Cayuga complex, Oswego River and the Salmon complex.

Sedimentary rocks, ranging in age from Ordovician to Devonian and composed of limestone, dolomite, sandstone and shale locally interbedded with gypsum and salt layers, comprise the bedrock strata. Barriers of glacial debris left by the retreating ice form drainage divides. The glaciers also left a layer of soil composed of silt, clay, sand and gravel overlying the southern sloping bedrock formations. Predominant soil textures in the region are identified in Figure 47.

The lake plains, which occupy the northern portion of the area, are characterized by low relief and numerous marshes. The land is typically flat to gently rolling. Many waterfalls are found along streams in the western portion of the lake plains. In the western sector, half-oval shaped glacial features called drumlins make the region hilly. Deeply glaciated valleys, in a north-south orientation, characterize the Finger Lakes Hills in the southwest corner. Clay and shale, natural gas, peat, salt, sand and gravel, and stone (limestone, dolomite and sandstone) are produced in this RBG.

A wedge of hilly, sandy and stony glacial drift lies immediately southwest of Lake Ontario. South of this sandy zone is a wide band of rolling land lying on medium-textured, permeable glacial drift. On the southern fringes of 5.2, soils are developed in heavy-textured glacial till and shale rock.

The major rivers are the Oswego, Salmon, and Little Salmon Rivers and Sterling and Sandy Creeks. In addition, the Barge Canal makes use of the Oswego River and its two major tributaries, the Seneca and Oneida.

Almost 65 percent of the region is covered by forests. Twenty-eight percent is agricultural land; a much smaller 6.2 percent is urbanized. Table 111 shows major land cover by hydrologic area.

In 1970 over 1.3 million persons resided in RBG 5.2, an increase of 400,000 since 1940. Growth rates and population densities were highest in counties having major urban and industrial centers such as (1975 population estimates): Syracuse (pop.: 182,543); Utica (pop.: 82,443); Oswego (pop.: 22,062); and cities along the Barge Canal. Sixty percent of the region's 1970 population was classified as urban. Suburban growth continues to supplant agriculture in expanding counties like Onondaga, Seneca, Cayuga, Tomkins, and Oneida. Other urban places are (1975 population estimates): Auburn (pop.: 32,730), Oneida (pop.: 11,118), Rome (pop.: 49,014), Geneva (pop.: 16,559), Oswego (pop.: 22,062), Ithaca (pop.: 28,770), and Newark (pop.: 10,682).

FIGURE 46

PLANNING SUBAREA 5.2

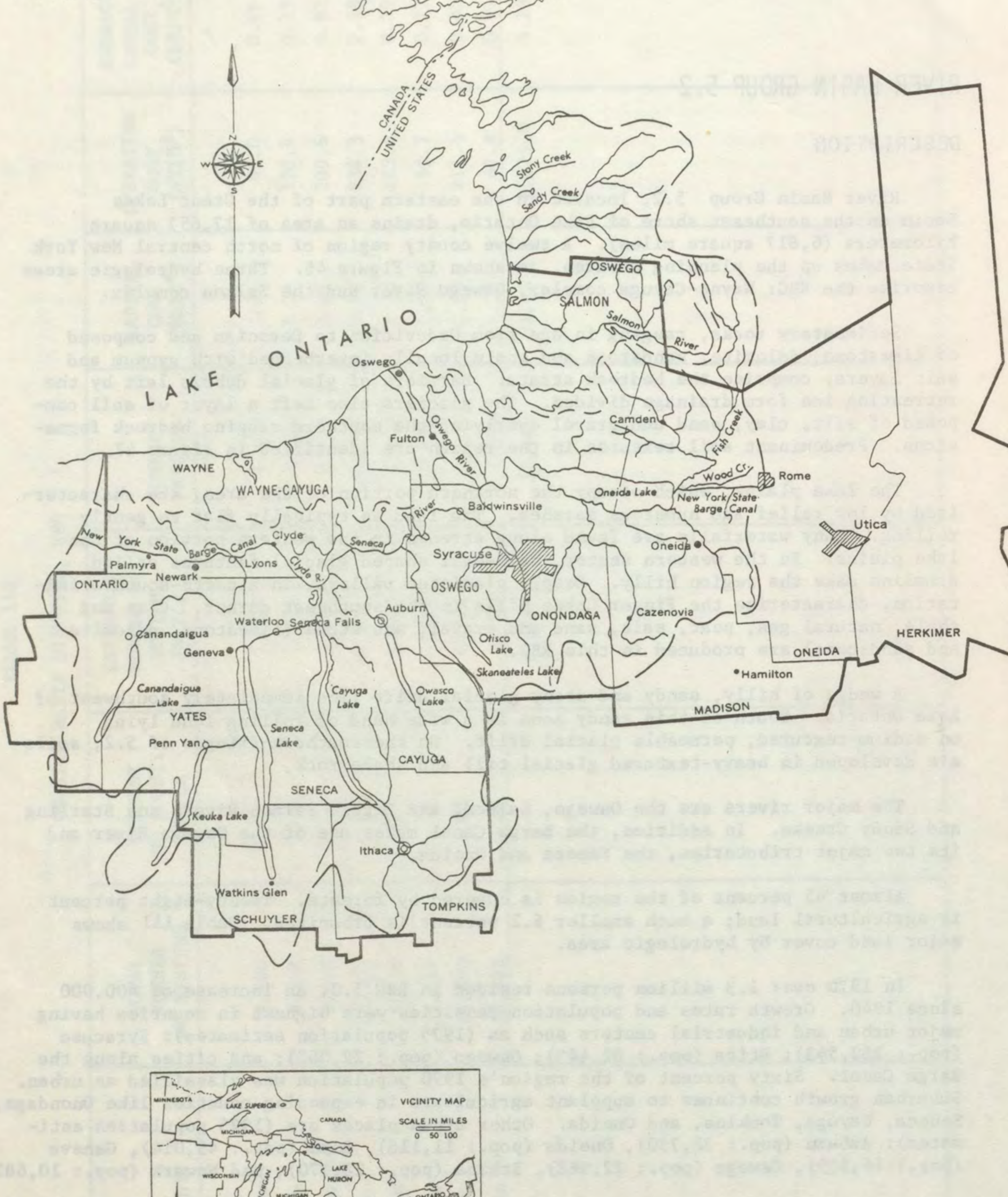
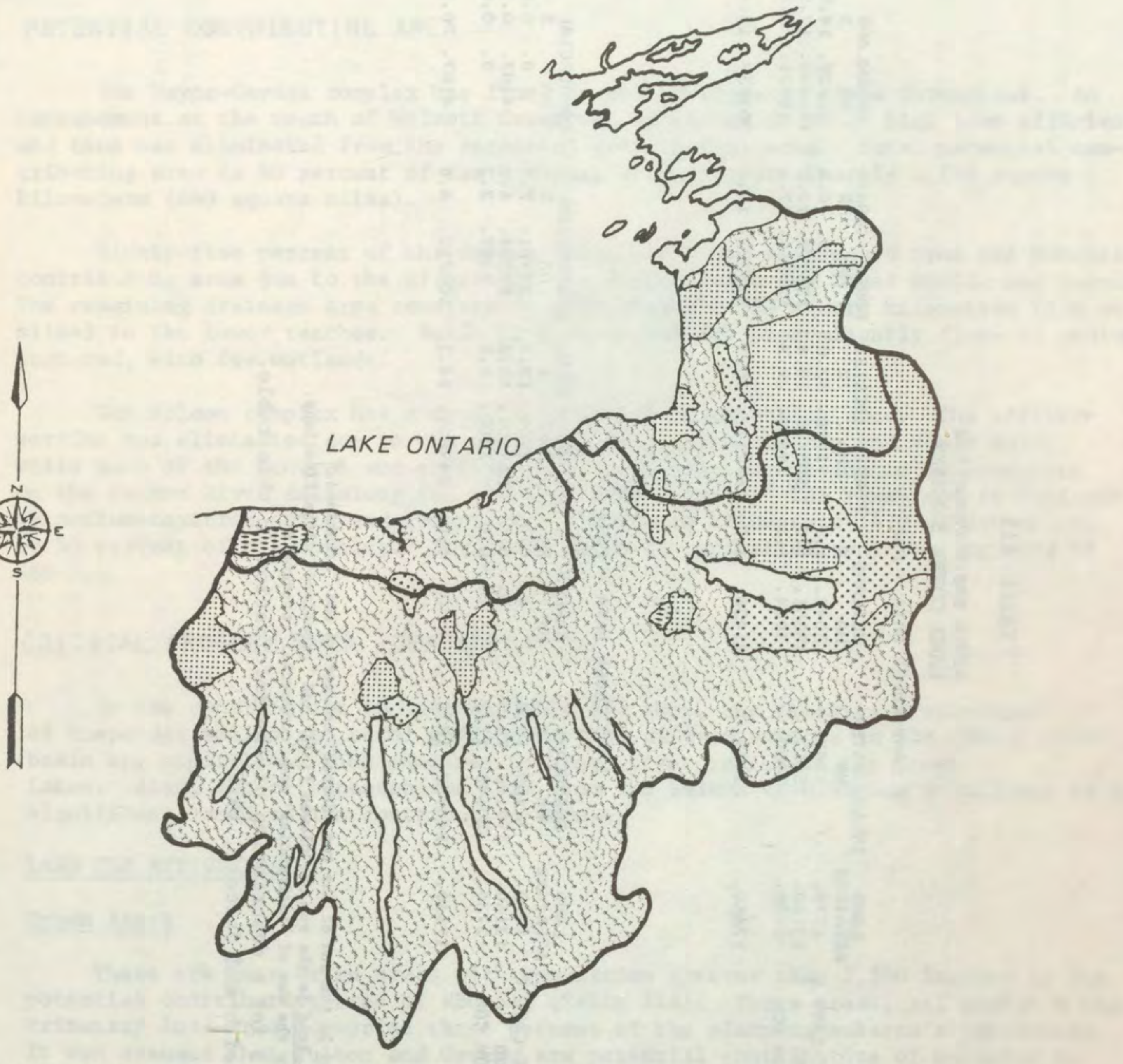


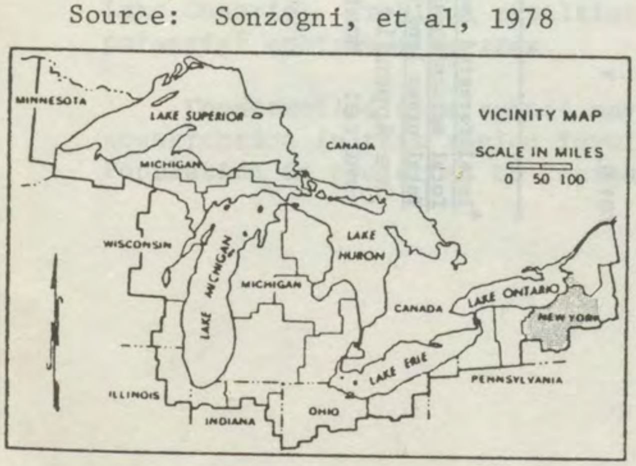
FIGURE 47

SOIL TEXTURE

River Basin Group 5.2



Source: Sonzogni, et al, 1978



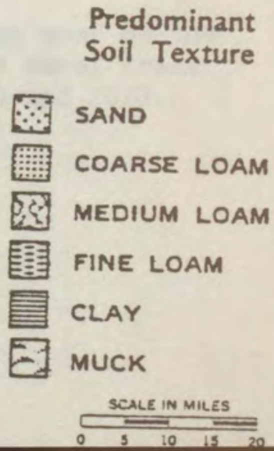


TABLE 111

RIVER BASIN GROUP 5.2
LAND COVER SUMMARY

LAND COVER DATA - PART 1

#	NAME	LAND AREA:KM2	INLAND WATER HA	WETLAND HA	WETLAND %	FOREST (DECID) HA	FOREST (DECID) %	FOREST (CON) HA	FOREST (CON) %	BRUSHLAND HA	BRUSHLAND %
52100	WAYNE-CAYU C	1770.	1947.	3042.	1.7	91990.	52.0	0.	0.0	26129.	14.8
52201	OSWEGO	13160.	75012.	15351.	1.2	505188.	38.4	133972.	10.2	160488.	12.2
52300	SALMON COM	2730.	5460.	3064.	1.1	79950.	29.3	129814.	47.6	15321.	5.6
TOTAL	3	17660.	82419.	21458.	1.2	677127.	38.3	263787.	14.9	201939.	11.4

LAND COVER DATA - PART 2

#	NAME	LAND AREA:KM2	GRASSLAND HA	GRASSLAND %	BARREN HA	BARREN %	PLOWED FIELD HA	PLOWED FIELD %	RESIDENTIAL HA	RESIDENTIAL %	COMMERCIAL HA	COMMERCIAL %
52100	WAYNE-CAYU C	1770.	19150.	10.8	0.	0.0	22908.	12.9	13781.	7.8	0.	0.0
52201	OSWEGO	13160.	191190.	14.5	0.	0.0	219101.	16.6	86524.	6.6	4187.	0.3
52300	SALMON COM	2730.	30643.	11.2	0.	0.0	7800.	2.9	6407.	2.3	0.	0.0
TOTAL	3	17660.	240982.	13.6	0.	0.0	249809.	14.1	106712.	6.0	4187.	0.2

---

*Total forested land is the sum of the two "forest" categories and "brushland."
Total agricultural land is the sum of "plowed field" and "grassland" classifications.
Total urban land is the sum of "residential" and "commercial" categories.

See Appendix 3 for a description of the information in this table.

Source: Monteith and Jarecki, 1978

Industry is highly developed and diversified, with the rapidly growing industrial city of Syracuse as the economic center of the region. Manufacturing employed over 29 percent of the work force in 1970.

POTENTIAL CONTRIBUTING AREA

The Wayne-Cayuga complex has fine- to medium-textured soils throughout. An impoundment at the mouth of Wolcott Creek was estimated to be of high trap efficiency and thus was eliminated from the potential contributing area. Total potential contributing area is 90 percent of the drainage area or approximately 1,140 square kilometers (440 square miles).

Ninety-five percent of the Oswego River basin was eliminated from the potential contributing area due to the effects of the Finger Lakes and Lakes Oneida and Onondaga. The remaining drainage area consists of approximately 700 square kilometers (270 square miles) in the lower reaches. Soils in this region are predominantly fine- to medium-textured, with few wetlands.

The Salmon complex has a complex potential contributing area. The northern portion was eliminated due to the predominance of rock outcrop and sandy soils, while much of the central and eastern parts were dropped out due to impoundments on the Salmon River and along the shore of Lake Ontario. The remainder is dominated by medium-textured soils and comprises 1,210 square kilometers (470 square miles), or 50 percent of the complex. Figure 48 shows the potential contributing area of RBG 5.2.

CRITICAL PROBLEM AREA IDENTIFICATION

As the contribution indices in Table 112 show, the relative proportions of suspended solids and total phosphorus from diffuse sources in the Oswego River basin are significant when compared to other river basins in the Great Lakes. Also, the orthophosphorus load from the Salmon complex was considered to be significant based on its contribution index.

LAND USE ACTIVITIES

Urban Areas

There are four urban areas with population greater than 2,500 located in the potential contributing area of RBG 5.2 (Table 113). These areas, all within a high tributary load area, comprise three percent of the planning subarea's population. It was assumed that Fulton and Oswego are potential contributors of bacteria to Lake Ontario. Problems resulting from combined sewer systems are not common in the potential contributing area.

Construction site runoff may degrade lake water quality, although most of the construction in this region involves seasonal vacation homes built in rural areas. Population is projected to increase 0.8 percent annually between 1970 and 2020.

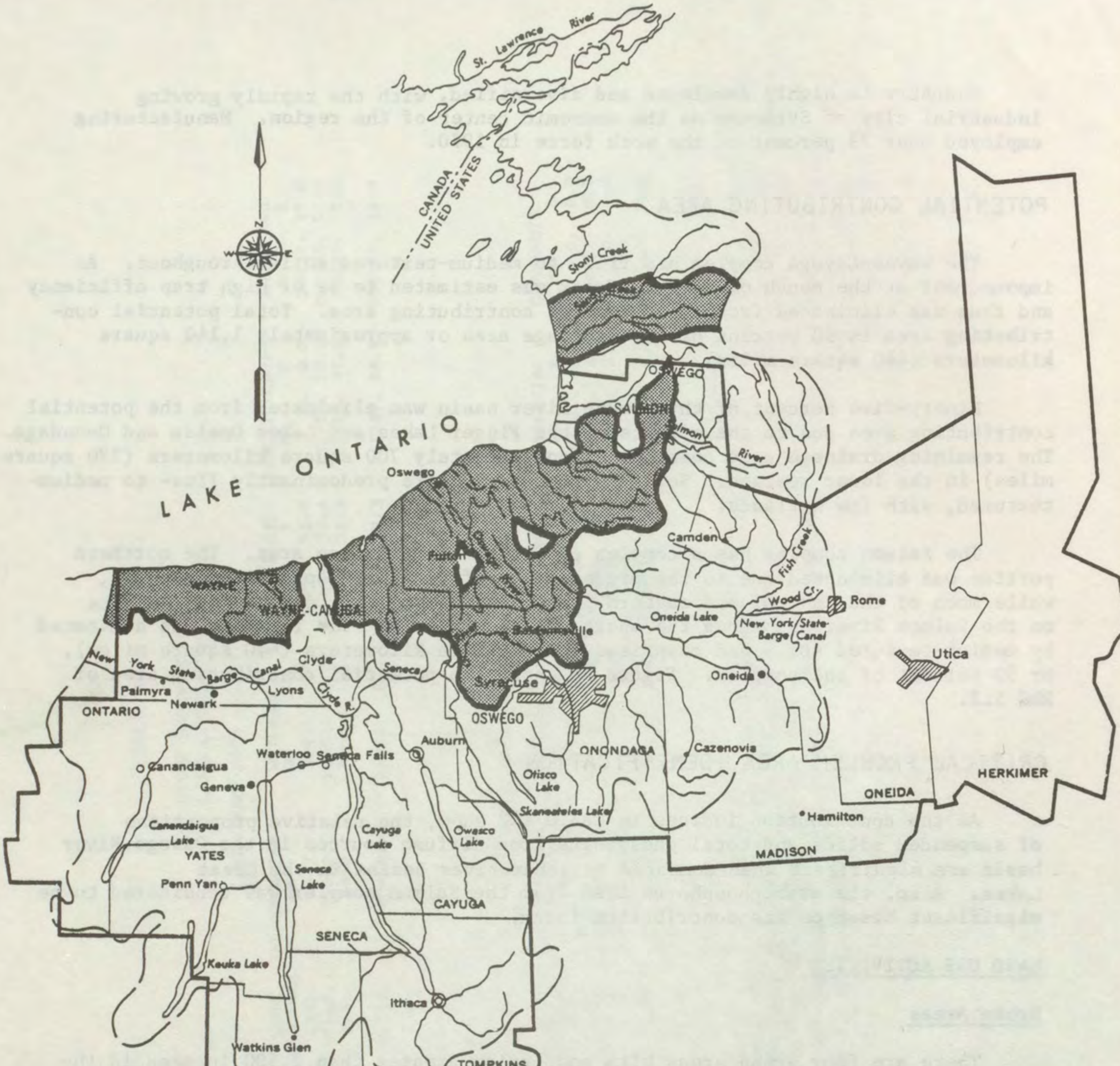


FIGURE 48

POTENTIAL CONTRIBUTING AREA OF
RBG 5.2

TABLE 112

CONTRIBUTION INDICES

RIVER BASIN GROUP 5.2

HYDROLOGIC AREA	LAND AREA (km^2)*	PCA AREA (km^2)*	SUSPENDED SOLIDS	TOTAL PHOSPHORUS	ORTHO PHOSPHORUS
Wayne-Cayuga Complex	1,770	1,140	0.3	0.7	0.2
Oswego River	13,160	660	1.6	4.4†	-
Salmon Complex	2,730	1,210	0.8	0.8	1.0

*To convert square kilometers to square miles, multiply by 0.386

$$CI = \frac{\text{(\% of Great Lakes Diffuse Load from hydrologic area)}}{\text{(\% of Great Lakes PCA in hydrologic area)}}$$

Total Great Lakes PCA = 105,950 km^2

Total Great Lakes Diffuse Loads

Suspended Solids = 9,492,407 Mtonnes/yr.

Total P = 13,155 Mtonnes/yr.

Ortho P = 3,007 Mtonnes/yr.

NOTE: Loads are average of 1975 and 1976 values with Lake Erie values assured equal for both years

† Based on one year of data (1976). 1975 diffuse load was estimated as 0.

TABLE 113

URBAN AREAS IN THE POTENTIAL CONTRIBUTING AREA
OF RIVER BASIN GROUP 5.2

URBAN AREA	HYDROLOGIC AREA		POPULATION (1970)	AREA (ACRES*) (1970)
Baldwinsville, NY	Oswego River	5.2.2	6,298	1,472
Fulton, NY	Oswego River	5.2.2	14,003	2,366
Oswego, NY	Oswego River	5.2.2	20,923	4,989
Phoenix, NY	Oswego River	5.2.2	2,617	640
TOTAL - PCA			43,841	9,467
Planning Subarea 5.2			1,361,673	5,427,400

*To convert acres to hectares, multiply by 0.4047

The estimated costs of combined sewer and stormwater treatment for cities in the potential contributing area are shown in Table 114. Average annual treatment costs range from $1.2 million for the low efficiency alternative (18 percent solids removal) to $4.3 million for the high efficiency alternative (87 percent solids removal). Chlorination for those cities contributing bacteria would add from $60 to $220 thousand per year to the cost of the medium and high level alternatives.

Construction sediment controls applied to only those urban areas in the potential contributing area would cost $30 thousand annually. Construction of detention ponds in new developments in the potential contributing area would add $200 thousand in annual construction and $4 thousand in annual operating and maintenance costs.

The estimated capital costs for applying urban stormwater and combined sewer controls to all urban areas in RBG 5.2 range from $141.3 to $554.7 million, as shown in Table 115. Operating and maintenance costs vary from $6.8 to $18.7 million annually. Thus, the average annual cost for urban stormwater controls throughout RBG 5.2 would vary from $22.4 to $79.8 million. Chlorination costs were not included.

In similar fashion, construction sediment control costs for the RBG would be $563 thousand a year. Detention pond construction in newly developed areas would cost $3.6 million annually plus $74 thousand for operation and maintenance each year.

Agricultural Areas

There are 77 thousand hectares (190 thousand acres) of cropland within the potential contributing area of RBG 5.2 (see Table 116). Seventy-three percent of this cropland, or 57 thousand hectares (140 thousand acres) requires treatment. According to Conservation Needs Inventory data, 470 thousand hectares (1,160 thousand acres) out of a total 712 thousand hectares (1,759 thousand acres) of cropland in Planning Subarea 5.2 required erosion control treatment in 1968.

The potential contributing area accounts for 19 cattle feedlots and two poultry operations (see Table 117). Only three of the cattle feedlots and neither of the poultry operations have waste controls. Based on information in Inventory of Land Use [IJC, 1976e], some 816 cattle, 24 swine and 65 poultry operations in the planning subarea may be without waste management systems.

Agricultural runoff and intensive livestock operations within this region may have significant impact on Lake Ontario water quality.

As the figures in Table 116 show, the application of best management practices to all lands needing treatment in the potential contributing area would have a

TABLE 114

URBAN CONTROL SUMMARY FOR RBG 52

NUMBER OF URBAN AREAS: 4

LOW LEVEL OF TREATMENT (<30% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.18

CAPITAL COST	: $	7620328.
ANNUAL OPERATING COST:	$	361337.
AVERAGE ANNUAL COST*	: $	1200854.

MEDIUM LEVEL OF TREATMENT (30% TO 60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.59

CAPITAL COST	: $	16551055.
ANNUAL OPERATING COST:	$	431629.
AVERAGE ANNUAL COST*	: $	2255028.

HIGH LEVEL OF TREATMENT (>60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.87

CAPITAL COST	: $	29867152.
ANNUAL OPERATING COST:	$	1003381.
AVERAGE ANNUAL COST*	: $	4293791.

CHLORINATION (MEDIUM AND HIGH LEVEL TREATMENT ONLY)

	COMBINED SEWER ONLY	COMBINED AND STORM SEWERS
CAPITAL:	396659.	1640367.
O&M :	17497.	44438.
ANNUAL*:	61196.	225154.

*Average annual cost equals capital amortized over 25 years at 10 percent interest per year plus annual operation and maintenance cost.

TABLE 115

ESTIMATED COST OF CONTROLS FOR ALL URBAN AREAS, RBG 5.2

TREATMENT LEVEL		COST IN PCA ($ millions)	ADJUSTED AREA IN PCA (ACRES*)	COST PER ACRE ($)	TOTAL URBAN ACREAGE	ADJUSTED** URBAN ACREAGE	RBG COST ($ millions)
LOW	Capital	7.6	5,590	1,360	176,054	103,872	141.3
	O&M	0.4	5,590	65	176,054	103,872	6.8
MEDIUM	Capital	16.6	5,590	2,960	176,054	103,872	307.5
	O&M	0.4	5,590	75	176,054	103,872	7.8
HIGH	Capital	29.9	5,590	5,340	176,054	103,872	554.7
	O&M	1.0	5,590	180	176,054	103,872	18.7

*To convert acres to hectares, multiply by 0.4047

**Urban area adjustment factor = 0.59

Average Annual Cost:

Low:	$22.4	million
Medium:	41.7	million
High:	79.8	million

TABLE 116

COSTS FOR INSTALLING AGRICULTURAL BEST MANAGEMENT PRACTICES
IN THE POTENTIAL CONTRIBUTING AREA (PCA) OF RIVER BASIN GROUP 5.2

COUNTY	TOTAL ACRES* IN POTENTIAL CONTRIBUTING AREA	ACRES IN PCA NEEDING TREATMENT	COSTS FOR ALL SOILS ($ millions)		COSTS FOR FINE-TEXTURED SOILS ($ millions)	
			One-Time	Recurring	One-Time	Recurring
NEW YORK						
Cayuga	16,600	11,100	0.10	0.02	0	0
Jefferson	13,000	8,800	0.03	0.01	0	0
Onondaga	27,900	16,200	0.14	0.04	0	0
Oswego	57,300	45,300	0.85	0.15	0	0
Wayne	75,400	58,100	0.70	0.15	0	**
TOTAL	190,200	139,500	1.82	0.37	0	**

*To convert acres to hectares, multiply by 0.4047

**Cost is negligible

TABLE 117

COST FOR INSTALLING AGRICULTURAL WASTE MANAGEMENT SYSTEMS
IN POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 5.2

COUNTY	TOTAL NUMBER OF FEEDLOT OPERATIONS ≥100 ANIMAL UNITS IN PCA			NUMBER OF FEEDLOT OPERATIONS IN PCA NEEDING TREATMENT			TOTAL COST ($ thousands)		
	CATTLE	SWINE	POULTRY	CATTLE	SWINE	POULTRY	CATTLE (at $ 27,000 per system)	SWINE (at $ 17,000 per system)	POULTRY (at $ 25,000 per system)
NEW YORK									
Cayuga	1	0	0	1	0	0	27	0	0
Jefferson	9	0	0	8	0	0	216	0	0
Onondaga	7	0	1	6	0	1	162	0	25
Oswego	2	0	1	1	0	1	27	0	25
Wayne	0	0	0	0	0	0	0	0	0
TOTAL	19	0	2	16	0	2	432	0	50

one-time cost of $1.8 million and annual recurring costs of $370 thousand. The average annual cost would be $570 thousand. Costs for fine-textured soils are negligible because of their infrequent occurrence in this potential contributing area.

The cost of applying best management practices to all RBG soils identified as requiring in the 1968 Conservation Needs Inventory was estimated to be $15.1 million one-time and $3.0 million, recurring, or $4.7 million per year on an average annual basis.

Table 117 shows that the installation of animal waste controls for all identified feedlots needing them in thepotential contributing area would cost $480 thousand. The cost of these controls installed throughout the planning subarea was estimated to be $20.5 million. Equivalent average annual costs are $50 thousand and $2.3 million, respectively.

On-Site Waste Disposal

Nonsewered, nonfarm residences account for one-third of the total housing units in the region, or 143,597 units. Of this, 86 percent are in rural areas. The number of nonsewered households is projected to increase 57 percent from 1970 to 1990. The potential contributing area accounts for approximately 17 percent of the nonsewered units in the region. Table 118 shows the approximate distribution of nonsewered units found within the potential contributing area of each county. Thirty-three percent are located in Wayne-Cayuga complex; 37 percent are in the Oswego River basin; and 40 percent are in the Salmon complex. On-lot disposal systems have been designated a high priority problem by the Central New York Regional Planning and Development Board.

The estimated capital investment required to alleviate problems with failing systems within the potential contributing area is $25.9 million, with an additional $733 thousand in annual operating costs (Table 118). The average annual cost would thus be $3.6 million. To alleviate these problems throughout the planning subarea would cost $148.5 million, capital, $4.2 million, operating, or $20.6 million per year in average annual terms.

Other Problems

There are three dredge disposal sites in the RBG. As of July 1974, none were confined operations. At Oswego, with 100 percent polluted spoil, or 41,777 cubic meters (56,683 cubic yards) on an average annual basis, construction of a confined disposal area was planned for 1975. Dredge spoil disposal was not considered to be a problem in RBG 5.2.

Although the impact of recreation activities on Great Lakes water quality is generally considered to be slight, the Central New York Regional Planning and Development Board has identified such problems to be of high priority concern. Important problems include sewage disposal and erosion.

TABLE 118

ON-SITE WASTE DISPOSAL, RBG 5.2

COUNTY	TOTAL NUMBER OF SYSTEMS	PERCENT OF COUNTY IN PCA	ESTIMATED NUMBER OF SYSTEMS IN PCA	NUMBER FAILING	CAPITAL COST ($\$X10^6$)	OPERATING COST ($\$X10^3$)	AVERAGE ANNUAL COST ($\$X10^6$)
NEW YORK							
Cayuga	9,040	20	1,810	1,090	1.88	53.1	0.26
Onondaga	28,763	20	5,750	3,450	5.94	168.0	0.82
Oswego	10,821	66	7,140	4,280	7.37	208.4	1.02
Wayne	14,473	45	6,510	3,910	6.74	190.4	0.93
Jefferson	11,097	35	3,880	2,330	4.01	113.5	0.55
TOTAL	--	--	24,090	15,060	25.94	733.4	3.58

RIVER BASIN GROUP 5.3

DESCRIPTION

The extreme eastern portion of the Great Lakes Basin, including the U.S. drainage into the St. Lawrence River, is included in River Basin Group 5.3, which drains an area of 19,004 square kilometers (7,338 square miles). Three New York counties comprise the corresponding planning subarea (see Figure 49). There are four hydrologic areas in the RBG: Black River, Perch complex, Oswegatchie River, and Grass-Raquette-St. Regis complex.

Millions of years of geologic and glacial action have shaped several distinctive land forms here. The St. Lawrence Marine Plain is a flat to gently rolling strip composed of marine clays, underlain by limestone and sandstone bedrock deposits. The St. Lawrence Hills, encompassing much of the northern portion of the RBG, is gently rolling, covered with glacial drift and underlain largely with sandstone. South of these two regions are the western Adirondack Hills, underlain largely by igneous and metamorphic rock. Here streams typically cut deep valleys in their flow across the land. The Tug Hill Plateau, an outlying area of the Appalachian Uplands, is underlain by Palezoic sandstones, limestones and shales. The eastern Ontario hills rise quickly from Lake Ontario to low hills, composed of glacial drift, at the foot of Tug Hill. Lying between Tug Hill and the Adirondacks, the Black River Valley forms a lowland, underlain largely by sandstones and shales, with many lacustrine deposits.

The back slopes of the Tug Hill Plateau have very rolling, sandy and stoney glacial drift. The northern part of the RBG lies in the nearly level to undulating St. Lawrence lowland, which has mixed glacial drift, lake-laid silts and clays, and extensive bedrock outcrops. The eastern part of the RBG lies in the steep Adirondack highland with extensive crystalline rock outcrops, stoney areas, and variable soil conditions. Figure 50 shows the region's predominant soil textures. Iron ore, lead, sand and gravel, silver, stone (marble, limestone, and dolomite), talc and zinc are produced here.

Major rivers are the Black, Perch, Oswegatchie, Grass, Raquette, and St. Regis Rivers.

About 86 percent of the land in RBG 5.3 is covered by forest. Urban uses cover one percent, and agriculture, concentrated in the lowland, covers 11 percent of the area. Table 119 shows the major land cover by hydrologic area. In general, the Adirondack Hills and the Tug Hill Plateau are unsuitable for any type of farming. Dairying is the principal farming activity in all RBG counties, with some mixed general farming in the Black River Valley and the eastern Lake Ontario region. There are some orchards and poultry farms.

Population has risen slowly from 1940 when it was 198,000, to 224,000 in 1970. Thirty-nine percent lived in urban areas in 1970. Principal urban centers include (1975 population estimates): Watertown (pop.: 29,103), Ogdensburg (pop.: 13,431), Massena (pop.: 13,442), Canton (pop.: 7,561), and Potsdam (pop.: 10,962).

FIGURE 49

PLANNING SUBAREA 5.3

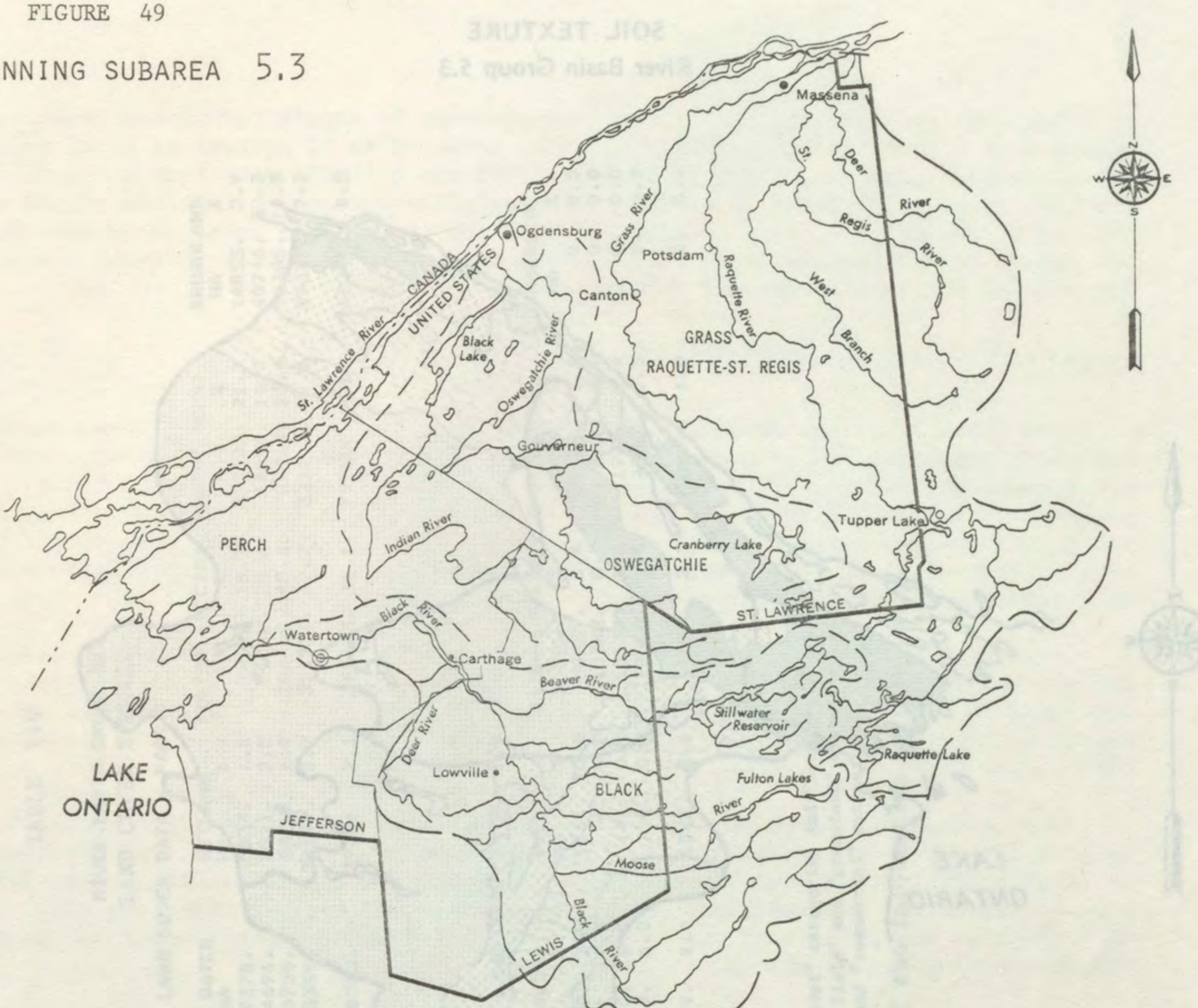
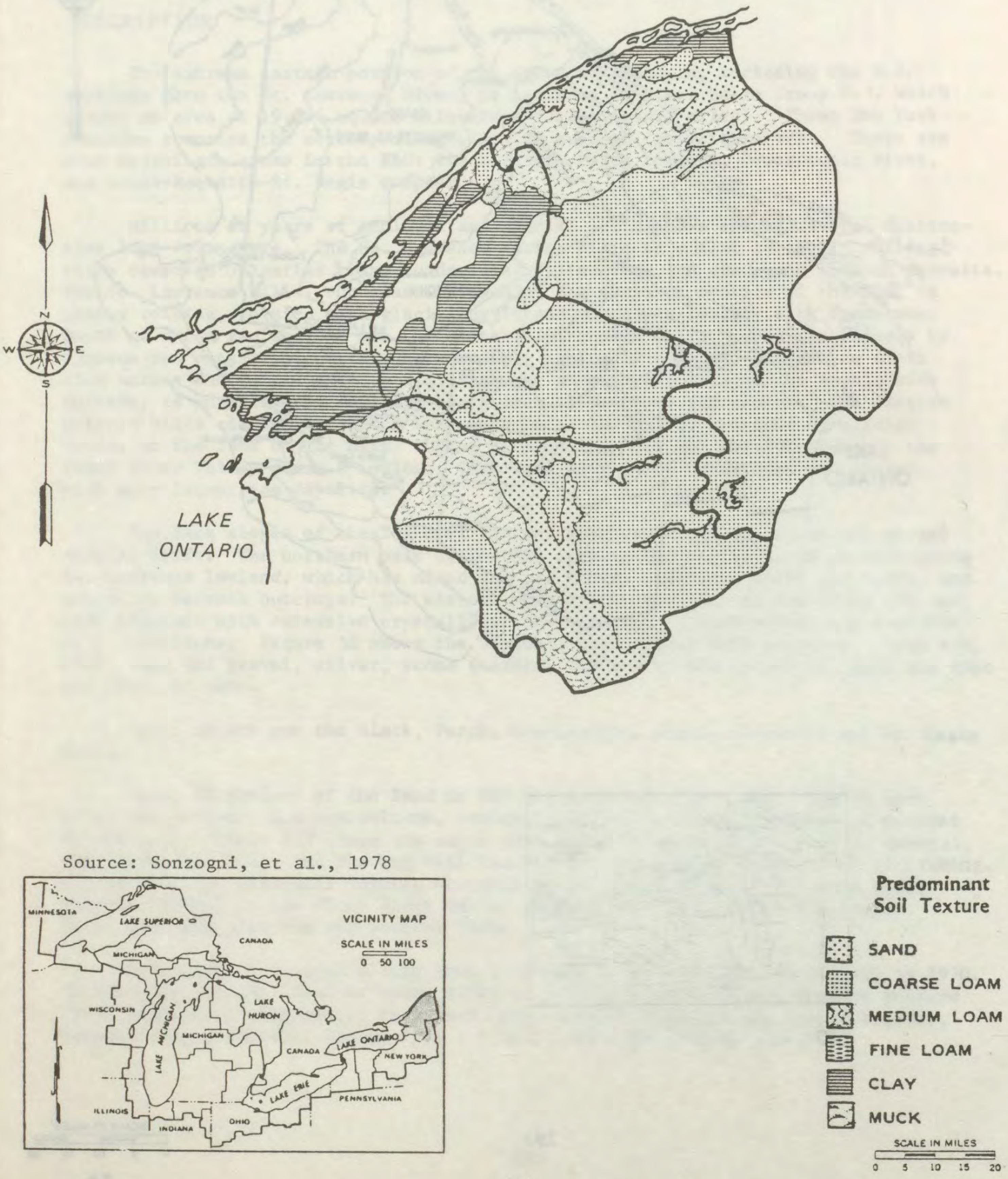


FIGURE 50

SOIL TEXTURE

River Basin Group 5.3



Source: Sonzogni, et al., 1978

TABLE 119

RIVER BASIN GROUP 5.3

LAND COVER SUMMARY

LAND COVER DATA - PART 1

#	NAME	LAND AREA:KM2	INLAND WATER HA	WETLAND HA	%	FOREST (DECID) HA	%	FOREST (CON) HA	%	BRUSHLAND HA	%
53101	BLACK	5210.	9378.	5836.	1.1	78521.	15.1	373507.	71.7	14855.	2.9
53200	PERCH COM	1260.	24696.	2821.	2.2	31030.	24.6	14104.	11.2	40746.	32.3
53301	OSWEGATCHIE	4300.	10750.	8379.	1.9	206400.	48.0	87764.	20.4	46308.	10.8
53400	GRASS-RA-SRC	8230.	35389.	22359.	2.7	351731.	42.7	324212.	39.4	59339.	7.2
TOTAL	4	19000.	80213.	39396.	2.1	667683.	35.1	799588.	42.1	161248.	8.5

LAND COVER DATA - PART 2

#	NAME	LAND AREA:KM2	GRASSLAND HA	%	BARREN HA	%	PLOWED FIELD HA	%	RESIDENTIAL HA	%	COMMERCIAL HA	%
53101	BLACK	5210.	28650.	5.5	1061.	0.2	8489.	1.6	10080.	1.9	0.	0.0
53200	PERCH COM	1260.	24291.	19.3	0.	0.0	10343.	8.2	2664.	2.1	0.	0.0
53301	OSWEGATCHIE	4300.	68800.	16.0	441.	0.1	10144.	2.4	1764.	0.4	0.	0.0
53400	GRASS-RA-SRC	8230.	49019.	6.0	0.	0.0	12040.	1.5	4300.	0.5	0.	0.0
TOTAL	4	19000.	170759.	9.0	1502.	0.1	41015.	2.2	18809.	1.0	0.	0.0

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*Total forested land is the sum of the two "forest" categories and "brushland."
Total agricultural land is the sum of "plowed field" and "grassland" classifications.
Total urban land is the sum of "residential" and "commercial" categories.

See Appendix 3 for a description of the information in this table.
Source: Monteith and Jarecki, 1978

Regional employment totals 75,840. Employment in manufacturing has remained constant at 17,000 since 1950. In 1970 this amounted to 22 percent of total employment. Agricultural employment of 6,100 in 1970 was a little more than a third of its 1940 level. Increases in employment in service-type industries from 43,400 in 1960 to 51,100 in 1970, have been responsible for the rise in total employment in the area. Recreationists swell both the summer and winter populations and account for much of the area's economic activity.

POTENTIAL CONTRIBUTING AREA

The Black River has several hydroelectric dams located along its lower reaches, but these are estimated to have relatively low trap efficiencies. However, impoundments along the upper portions of the river are assumed to significantly limit pollutant transport to the Great Lakes. In addition, much of the headwaters region has coarse-grained soils and extensive granite outcrops. The potential contributing area is thus confined to the western lowland which makes up 1,560 square kilometers (600 square miles), or 30 percent of the total.

The Perch complex is low-lying with predominantly fine-textured marine clay soils. The only significant impoundment is Perch Lake on the Upper Perch River, estimated to eliminate ten percent of the hydrologic area from the potential contributing area. The remainder has an area of approximately 1,100 square kilometers (420 square miles).

The Oswegatchie River basin has its headwaters in the Adirondack Mountains, an area of many lakes and wetlands. Soils are generally coarse-textured or absent in these upper reaches, but become loamy-textured along the lower Oswegatchie River. Many hydroelectric installations are present. The potential contributing area is limited to ten percent of the total hydrologic area, or approximately 430 square kilometers (170 square miles).

The Grass-Raquette-St. Regis complex is very similar to the Oswegatchie, though it has a broad belt of marine clay soils along the St. Lawrence River. Impoundments for hydroelectric power are present throughout the rivers' upper and middle reaches. The potential contributing area is limited to those lower reaches with clay soils, an area of approximately 1,230 square kilometers (470 square miles) comprising 15 percent of the hydrologic area. Figure 51 shows the potential contributing area of RBG 5.3.

CRITICAL PROBLEM AREA IDENTIFICATION

CONTRIBUTION INDEX

As the contribution indices in Table 120 show, two hydrologic areas - the Black River and Oswegatchie River basins - contribute significant portions of total and orthophosphorus to Lake Ontario. In addition, the Grass-Raquette-St. Regis complex contributes a significant amount of diffuse source total phosphorus.

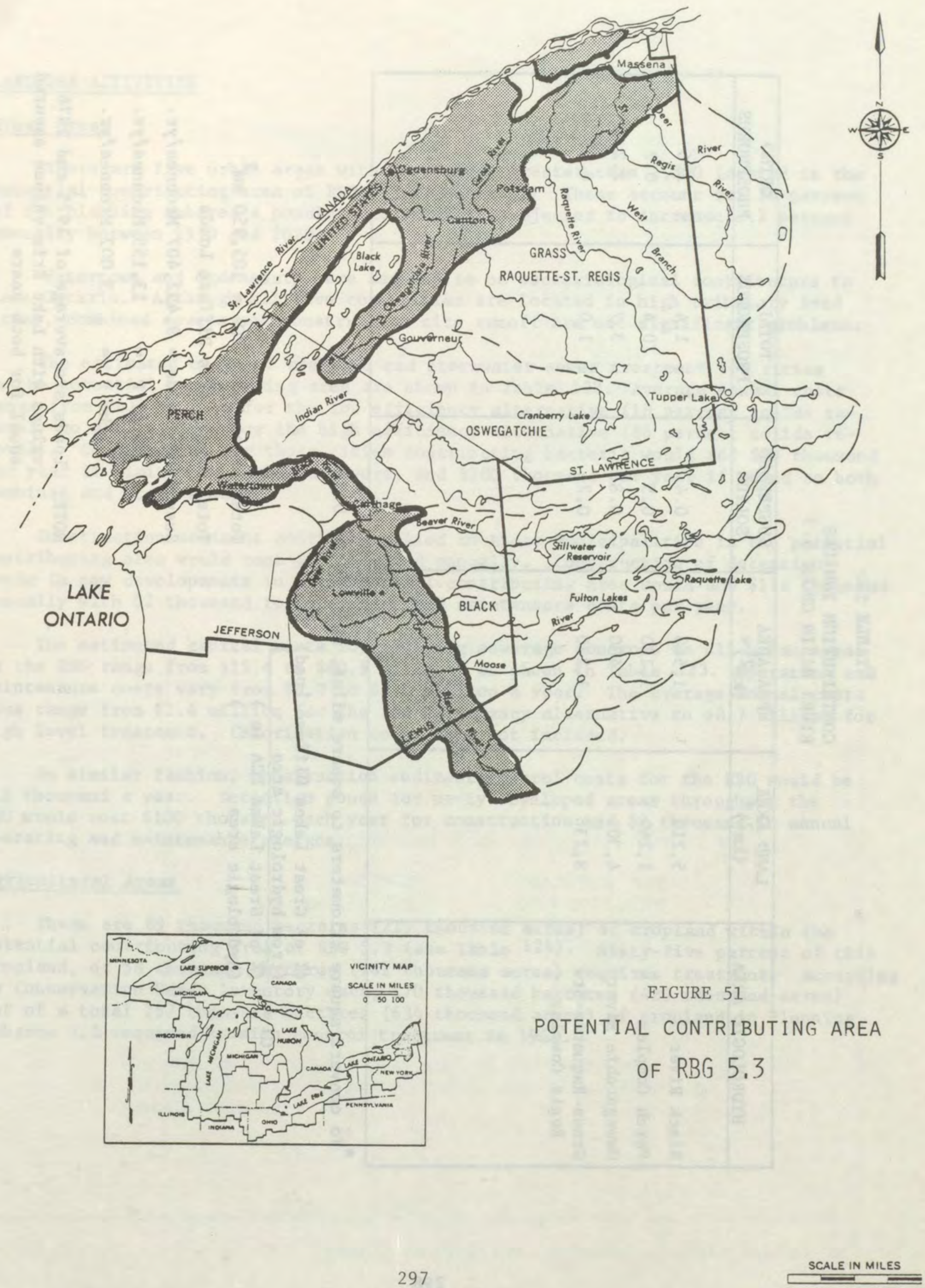


FIGURE 51

POTENTIAL CONTRIBUTING AREA

OF RBG 5.3

TABLE 120

CONTRIBUTION INDICES
RIVER BASIN GROUP 5.3

HYDROLOGIC AREA	LAND AREA (km^2)*	PCA AREA (km^2)*	SUSPENDED SOLIDS	TOTAL PHOSPHORUS	ORTHO PHOSPHORUS
Black River	5,210	1,560	0.4	1.4	1.6
Perch Complex	1,260	1,130	0.5	0.4	0.2
Oswegatchie River	4,301	430	0.8	3.7	2.2
Grass-Raquette-St. Regis Complex	8,238	1,230	0.2	1.0	0.5

*To convert square kilometers to square miles, multiply by 0.386

$$CI = \frac{\text{(\% of Great Lakes Diffuse Load) (from hydrologic area)}}{\text{(\% of Great Lakes PCA in) (hydrologic area)}}$$

Total Great Lakes PCA = 105,950 km^2

Total Great Lakes Diffuse Loads

Suspended Solids = 9,492,407 Mtonnes/yr.

Total P = 13,155 Mtonnes/yr.

Ortho P = 3,007 Mtonnes/yr.

NOTE: Loads are average of 1975 and 1976 values with Lake Erie values assured equal for both years

LAND USE ACTIVITIES

Urban Areas

There are five urban areas with population greater than 2,500 located in the potential contributing area of RBG 5.3 (Table 121). These account for 26 percent of the planning subarea's population, which is projected to increase 0.2 percent annually between 1970 and 2020.

Watertown and Ogdensburg were assumed to be bacteriological contributors to Lake Ontario. Although all five communities are located in high tributary load areas, combined sewers and construction site runoff are not significant problems.

The estimated costs of combined and stormwater sewer treatment for cities in the potential contributing area are shown in Table 122. Average annual costs range from $1.6 million for the low efficiency alternative (18 percent solids removal) to $5.7 million for the high efficiency alternative (86 percent solids removal). Chlorination for those cities contributing bacteria would add $70 thousand per year if limited to combined sewers, and $280 thousand per year if added to both combined and storm sewers.

Construction sediment controls applied to those municipalities in the potential contributing area would cost $16 thousand annually. Construction of detention ponds in new developments in the potential contributing area would add $114 thousand annually with $2 thousand for operation and maintenance costs per year.

The estimated capital costs for applying sewerage controls to all urban areas in the RBG range from $15.4 to $60.9 million, as shown in Table 123. Operating and maintenance costs vary from $0.7 to $2.0 million a year. The average annual costs thus range from $2.4 million for the low efficiency alternative to $8.7 million for high level treatment. Chlorination costs were not included.

In similar fashion, construction sediment control costs for the RBG would be $15 thousand a year. Detention ponds for newly developed areas throughout the RBG would cost $100 thousand each year for construction and $2 thousand in annual operating and maintenance charges.

Agricultural Areas

There are 89 thousand hectares (219 thousand acres) of cropland within the potential contributing area of RBG 5.3 (see Table 124). Sixty-five percent of this cropland, or 58 thousand hectares (142 thousand acres) requires treatment. According to Conservation Needs Inventory data, 170 thousand hectares (420 thousand acres) out of a total 257 thousand hectares (634 thousand acres) of cropland in Planning Subarea 5.3 required erosion control treatment in 1968.

TABLE 121

URBAN AREAS IN THE POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 5.3

URBAN AREA	HYDROLOGIC AREA		POPULATION (1970)	AREA (ACRES*) (1970)
Watertown, NY	Black River	5.3.1	30,787	5,886
Carthage, NY	Black River	5.3.1	3,889	1,279
Lowville, NY	Black River	5.3.1	3,671	1,087
Canton, NY	Oswegatchie River	5.3.3	6,398	8,966
Ogdensburg, NY	Grass-Raquette-St. Regis	5.3.4	14,554	3,006
TOTAL - PCA			59,299	20,224
Planning Subarea 5.3			224,143	3,385,600

*To convert acres to hectares, multiply by 0.4047

TABLE 122

URBAN CONTROL SUMMARY FOR RBG 53

NUMBER OF URBAN AREAS: 5

LOW LEVEL OF TREATMENT (<30% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.18

CAPITAL COST	: $	10119231.
ANNUAL OPERATING COST	: $	464809.
AVERAGE ANNUAL COST*	: $	1579626.

MEDIUM LEVEL OF TREATMENT (30% TO 60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.59

CAPITAL COST	: $	22004480.
ANNUAL OPERATING COST	: $	541583.
AVERAGE ANNUAL COST*	: $	2965776.

HIGH LEVEL OF TREATMENT (>60% REMOVAL)

OVERALL CONTROL EFFICIENCY: 0.86

CAPITAL COST	: $	39850912.
ANNUAL OPERATING COST	: $	1269414.
AVERAGE ANNUAL COST*	: $	5659716.

CHLORINATION (MEDIUM AND HIGH LEVEL TREATMENT ONLY)

	COMBINED SEWER ONLY	COMBINED AND STORM SEWERS
CAPITAL:	418783.	2004463.
O&M :	20828.	55695.
ANNUAL*:	66965.	276523.

*Average annual cost equals capital amortized over 25 years at 10 percent interest per year plus annual operation and maintenance cost.

TABLE 123

ESTIMATED COST OF CONTROLS FOR ALL URBAN AREAS, RBG 5.3

TREATMENT LEVEL		COST IN PCA ($ millions)	ADJUSTED AREA IN PCA (ACRES*)	COST PER ACRE ($)	TOTAL URBAN ACREAGE	ADJUSTED** URBAN ACREAGE	RBG COST ($ millions)
LOW	Capital	10.1	7,170	1,410	18,552	10,946	15.4
	O&M	0.5	7,170	65	18,552	10,946	0.7
MEDIUM	Capital	22.0	7,170	3,070	18,552	10,946	33.6
	O&M	0.5	7,170	75	18,552	10,946	0.8
HIGH	Capital	39.9	7,170	5,560	18,552	10,946	60.9
	O&M	1.3	7,170	180	18,552	10,946	2.0

*To convert acres to hectares, multiply by 0.4047

**Urban area adjustment factor = 0.59

Average Annual Cost:

Low: $2.4 million
Medium: 4.5 million
High: 8.7 million

TABLE 124

COSTS FOR INSTALLING AGRICULTURAL BEST MANAGEMENT PRACTICES IN THE POTENTIAL CONTRIBUTING AREA (PCA) OF RIVER BASIN GROUP 5.3

COUNTY	TOTAL ACRES* IN POTENTIAL CONTRIBUTING AREA	ACRES IN PCA NEEDING TREATMENT	COSTS FOR ALL SOILS ($ millions)		COSTS FOR FINE-TEXTURED SOILS ($ millions)	
			One-Time	Recurring	One-Time	Recurring
NEW YORK						
Jefferson	97,000	64,300	0.23	0.06	0.14	0.03
Lewis	42,000	23,500	0.17	0.02	0	0
Oneida	13,500	9,100	0.05	**	0	0
St. Lawrence	66,800	45,300	0.18	0.01	0.07	**
TOTAL	219,300	142,200	0.63	0.09	0.21	0.03

*To convert acres to hectares, multiply by 0.4047

**Cost is negligible

The potential contributing area has 50 cattle feedlot operations (Table 125). There are no swine or poultry operations. Based on information in Inventory of Land Use [IJC, 1976e], some 357 cattle, two swine, and nine poultry operations in the planning subarea may be without waste management systems.

Agricultural runoff and intensive livestock operations within this region may have an impact on Lake Ontario water quality.

As the figures in Table 124 show, the application of best management practices to all lands needing treatment in the potential contributing area would have a one-time cost of $630 thousand and annual recurring costs of $90 thousand, for an average annual cost of $160 thousand. The treatment of only fine-textured soils (34.3 thousand hectares) would cost $210 thousand one-time, and $30 thousand recurring, for an average annual figure of $50 thousand.

The cost of applying best management practices to all soils in the planning subarea identified by the 1968 Conservation Needs Inventory would be $1.9 million one-time, and $250 thousand recurring, for an average annual cost of $460 thousand.

Table 125 shows that the installation of animal waste controls for all intensive livestock operations in the potential contributing area needing them would cost $1.2 million. The cost for these controls installed throughout the planning subarea was estimated at $9.9 million. In average annual terms these costs are $130 thousand and $1.1 million per year, respectively.

On-Site Waste Disposal

Nonsewered, nonfarm residences account for 42 percent of the total housing units in the region or 29,022 units. Of this, 99 percent are in rural areas. The number of nonsewered households is projected to increase by four percent between 1970 and 1990.

Table 126 shows the approximate distribution of nonsewered units by county within the potential contributing area. These units total 10,370. Three-quarters are located in the Black River basin. Water quality problems from inadequate septic waste treatment have been reported [GLBC, 1976].

The estimated capital investment required to alleviate problems with failing septic systems within the potential contributing area is $10.4 million, with an additional $264 thousand in annual operating costs (Table 126). The average annual cost is $1.6 million. To remedy these problems throughout the planning subarea would cost $29.1 million in capital and $738 thousand in annual operation, for an annual cost of $3.9 million per year.

Other Problems

There are no dredge spoil disposal sites at the present time and no other land-related problems were identified in this RBG.

TABLE 125

COST FOR INSTALLING AGRICULTURAL WASTE MANAGEMENT SYSTEMS IN POTENTIAL CONTRIBUTING AREA OF RIVER BASIN GROUP 5.3

COUNTY	TOTAL NUMBER OF FEEDLOT OPERATIONS ≥100 ANIMAL UNITS IN PCA			NUMBER OF FEEDLOT OPERATIONS IN PCA NEEDING TREATMENT			TOTAL COST ($ thousands)		
	CATTLE	SWINE	POULTRY	CATTLE	SWINE	POULTRY	CATTLE (at $27,000 per system)	SWINE (at $17,000 per system)	POULTRY (at $ 25,000 per system)
NEW YORK									
Jefferson	11	0	0	9	0	0	243	0	0
Lewis	19	0	0	16	0	0	432	0	0
Oneida	1	0	0	1	0	0	27	0	0
St. Lawrence	19	0	0	17	0	0	459	0	0
TOTAL	50	0	0	43	0	0	1,161	0	0

TABLE 126

ON-SITE WASTE DISPOSAL, RBG 5.3

COUNTY	TOTAL NUMBER OF SYSTEMS	PERCENT OF COUNTY IN PCA	ESTIMATED NUMBER OF SYSTEMS IN PCA	NUMBER FAILING	CAPITAL COST ($\$X10^6$)	OPERATING COST ($\$X10^3$)	AVERAGE ANNUAL COST ($\$X10^6$)
NEW YORK							
Jefferson	11,097	33	3,660	2,200	3.68	93.2	0.50
Lewis	4,428	45	1,990	1,190	1.99	50.41	0.27
St. Lawrence	13,497	35	4,720	2,830	4.73	119.9	0.78
TOTAL	--	--	10,370	6,220	10.40	263.5	1.55

8 ALTERNATIVE REMEDIAL STRATEGIES FOR THE U.S. GREAT LAKES BASIN

The preceding chapters have presented nonpoint source problems and the estimated costs for a variety of remedial program components for their control. This chapter presents a range of cost estimates for remedial strategies developed for the U.S. portion of the Great Lakes Basin based on different combinations of program components. Described in Chapter 2, the four alternative strategies represent different approaches to implementing remedial programs for the land use activities of concern. The average annual costs for each strategy are summarized in Table 127.

ALTERNATIVE I: BASINWIDE REMEDIAL MEASURES

The first alternative strategy includes cost estimates for urban, agricultural, and on-site waste disposal controls applied throughout the U.S. Great Lakes Basin. Developed by extrapolating results from the potential contributing area, it represents a cost ceiling for implementing nonpoint source controls to reduce basin problems. Because it is an across-the-board program, neither the quality of receiving waters nor the estimated diffuse source loads were considered.

As the figures in Table 127 show, the estimated costs for basinwide controls range from \$530 million to \$970 million per year, depending primarily on the level of urban stormwater and combined sewer control used.

ALTERNATIVE II: REMEDIAL MEASURES APPLIED THROUGHOUT THE POTENTIAL CONTRIBUTING AREA

Limiting the application of nonpoint source controls to the potential contributing area reduces estimated costs to a range of \$330 million to \$670 million per year.

Table 128 shows the costs of remedial measures limited to the potential contributing area as a percent of those costs for the basin as a whole.

TABLE 128

COSTS OF REMEDIAL MEASURES LIMITED TO THE PCA
AS A PERCENT OF THOSE FOR THE BASIN AS A WHOLE

Urban							Agriculture			On-Site	Total		
Low	Med	High	Clr 1	Clr 2	Sed.	Ponds	All	Fine	Feed	Waste	A	B	C
77	81	75	-	-	94	88	37	-	36	38	62	70	68

TABLE 127

ALTERNATIVE REMEDIAL STRATEGY

AVERAGE ANNUAL COSTS

		URBAN							AGRICULTURE					ONSITE		TOTAL
									CROPLAND			FEEDLOTS				
		LOW	MED	HIGH	CLR 1	CLR 2	SED	POND	BASIN	PCA	FINE	BASIN	PCA	BASIN	PCA	
I. Basin Treatment	A	203.8					10.6	88.9	101.2*			13.4		115.1		533.0
	B		462.8		3.1		10.6	88.9	101.2*			13.4		115.1		795.1
	C			618.6		24.6	10.6	88.9	101.2*			13.4		115.1		972.4
II. Treatment Only in the PCA	A	156.5					10.0	78.3		37.7			4.8		44.0	331.3
	B		375.6		3.1		10.0	78.3		37.7			4.8		44.0	553.5
	C			466.4		24.6	10.0	78.3		37.7			4.8		44.0	665.8
III. Treatment Priorities Based on Contribution Index	High	23.3					1.5	12.2		1.6			0.1		6.9	45.6
	Medium						3.4	24.1		30.1						57.6
	Low						5.0				2.6					7.6
															Total	110.8
IV. Treatment Priorities Based on Local Nearshore Water Quality	Eutrophic	34.0					2.3	16.1		17.7			1.8		14.9	86.8
	Mesotrophic						3.9	30.8		14.4						49.1
	Oligotrophic						3.8				2.0					5.8
															Total	141.7

NOTE: Costs are in millions of dollars

*Costs for PSA 2.2 were not included because most of the area is outside of the Basin. Instead, costs for the PCA were used. PSA costs were:

BMPs = $13.8 million/year
Animal Waste = 1.1 million/year
On-Site Waste = 11.2 million/year

As Table 128 shows, limiting the application of urban remedial measures to the potential contributing area reduced the average annual cost by 20 to 25 percent in the case of runoff and combined sewer overflows, and about 10 percent in new development control costs. In contrast, the cost of agricultural controls was reduced by two-thirds. This apparent discrepancy was due to the high concentration of urban areas near the lakeshore and the fact that the presence of urban development was used as a criterion for delineating the potential contributing area. As a result, the average annual cost for the three alternative strategies, A, B, and C, in the potential contributing area fall within 60 to 70 percent of the corresponding basinwide figures.

ALTERNATIVE III: TREATMENT PRIORITIES BASED ON THE CONTRIBUTION INDEX

As was discussed in Chapter 2, each hydrologic area in the basin was evaluated in terms of its relative diffuse source loads. Contribution indices for sediment and total and orthophosphorus were calculated and each area classified as a high, medium, or low contributor based on their values. In this alternative, the level of control selected for a particular river basin group was based on a consideration of the contribution ratings of its component hydrologic areas. Figure 52 shows each river basin group classified by contribution index. Only RBG 4.3 was considered to be a high index value area. The remainder of Lake Erie, all of Lake Ontario and portions of the remaining lakes were considered to be medium value areas. Only Michigan's upper peninsula, the northern half of the lower peninsula and the Chicago-Milwaukee area had low index values.

This alternative had the lowest average annual cost of the four strategies evaluated, $110.8 million per year. Of that, more than 40 percent would be incurred in River Basin Group 4.3, where low level stormwater and combined sewer overflow controls and on-site waste disposal controls are included. Controls throughout the remainder of the basin are limited to construction sediment and in some areas detention ponds, and the use of best management practices for agricultural operations.

ALTERNATIVE IV: TREATMENT PRIORITIES BASED ON LOCAL NEARSHORE WATER QUALITY

In this strategy, the selection of control techniques for each river basin group was based on an assessment of nearshore water quality, represented by the trophic status, defined by chlorophyll a and total phosphorus concentration, and Secchi depth. Nearshore waters, classified by trophic status, are shown in Figure 53. A map of the basin with each river basin group classified as eutrophic, mesotrophic, or oligotrophic, based on that information, is shown in Figure 54. It should be kept in mind that this classification was based on limited data pertaining to the nearshore waters only. Also, water quality conditions within the nearshore area of a given RBG could vary; the classification was based on the dominant condition.

The average annual cost for this strategy is $141.7 million, 61 percent of which would be spent in those areas classified as eutrophic. Of that, almost 40 percent would be used to implement low-level treatment in the urban areas. Seventeen percent would be used for correcting failing on-site waste disposal systems, while $17.7 million, or 20 percent would be used to implement agricultural best management practices.

FIGURE 52

RIVER BASIN GROUPS CLASSIFIED BY CONTRIBUTION INDEX

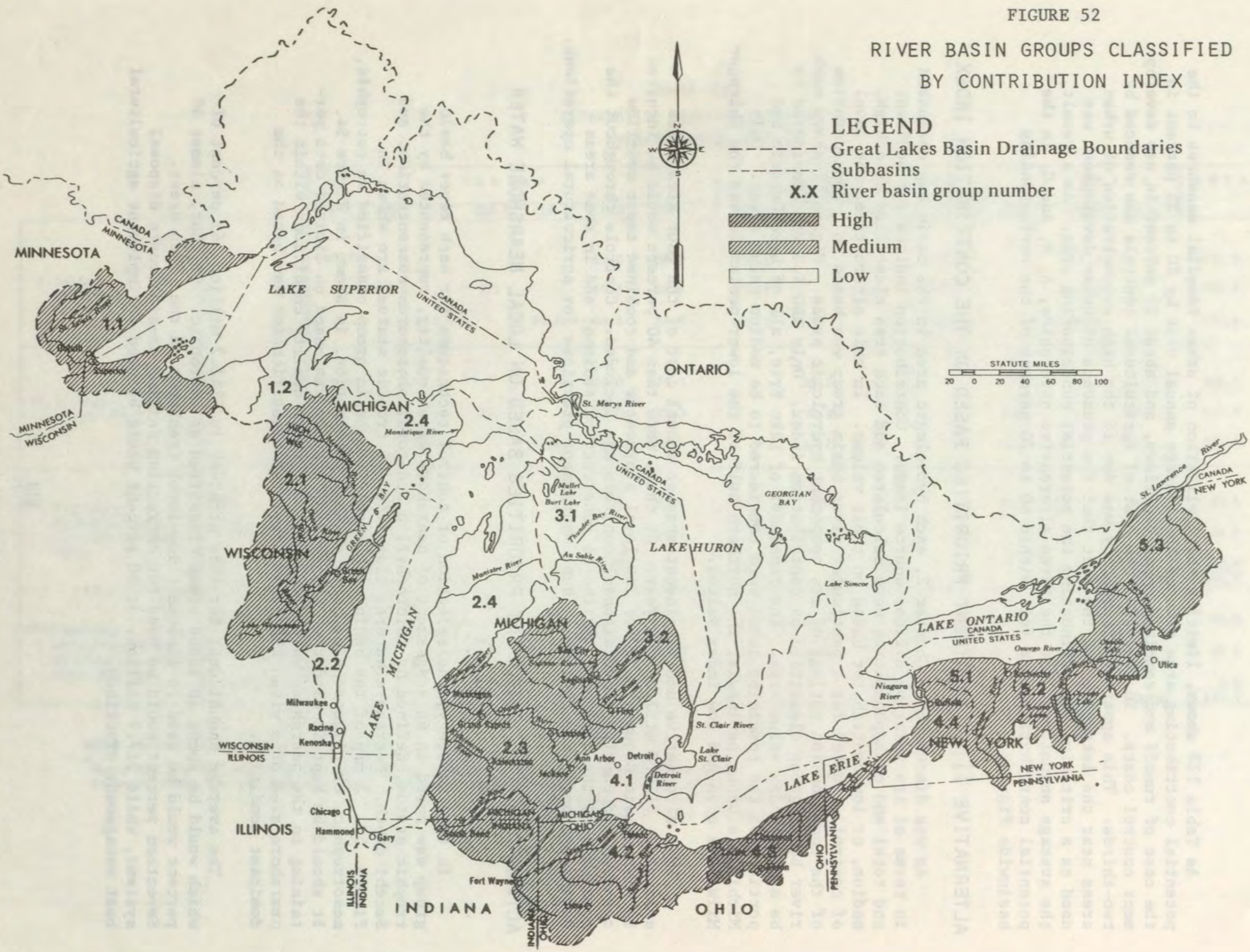
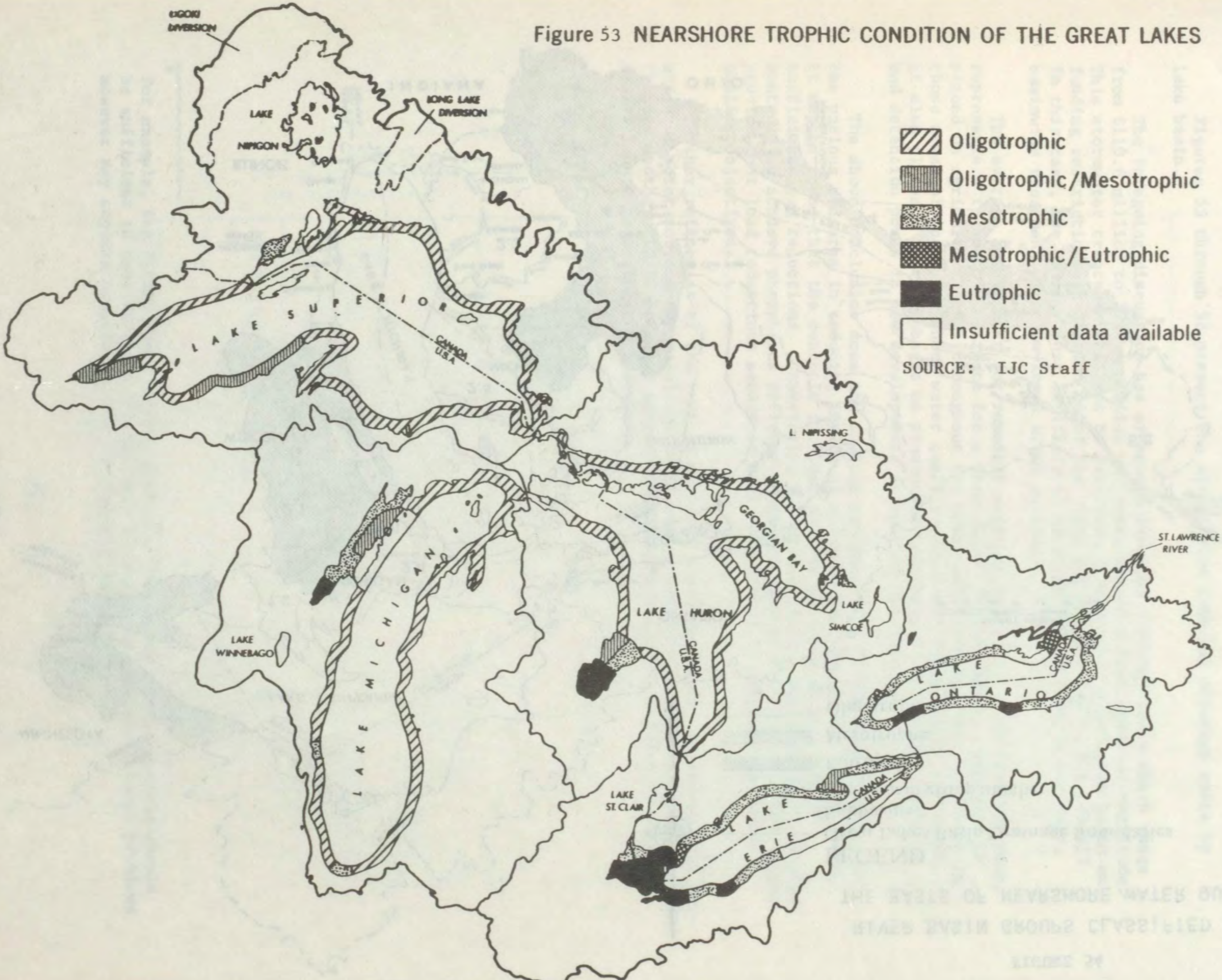


Figure 53 NEARSHORE TROPHIC CONDITION OF THE GREAT LAKES



Oligotrophic
Oligotrophic/Mesotrophic
Mesotrophic
Mesotrophic/Eutrophic
Eutrophic
Insufficient data available

SOURCE: IJC Staff

FIGURE 54

RIVER BASIN GROUPS CLASSIFIED ON THE BASIS OF NEARSHORE WATER QUALITY

Figures 55 through 58 present the alternative remedial strategy costs by lake basin.

The foregoing discussion has presented remedial strategy costs which range from $110.8 million to $976.4 million per year, almost a full order of magnitude. This stormwater treatment will not be provided, a reasonable conclusion based on funding restrictions in Section 36 of the Clean Water Act of 1977, P.L. 95-217. In this case, the maximum cost is likely to be about $533.0 million per year, basinwide treatment with low-level urban controls.

The average annual cost for remedial strategy four, $141.7 million per year, represents a reasonable estimate for a Great Lakes Basin program. Emphasis is placed on agricultural BMPs throughout the basin and low-level urban controls in those areas of the basin where water quality conditions appear to be the worst. It also places a heavy emphasis on preventive measures, with sediment controls and detention ponds in new developments in much of the Basin.

The above conclusion does not include consideration of the effectiveness of the various measures in reducing inputs of sediment and phosphorus to the lakes. It may be found that the controls included in that approach do not provide sufficient load reductions. Conversely, the application of municipal point source controls to achieve phosphorus effluent concentrations of 1.0 mg/l, or less, might provide that load reductions needed to meet established or contemplated water quality objectives.*

Further refinement of the cost of nonpoint source controls, including consideration of point sources and resultant lake loading reductions has been carried out through another PLUARG activity termed "overview modelling." Results of this activity have been reported elsewhere.

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* For example, the PLUARG Final Report concludes that point source controls should be sufficient to meet target loads in Lakes Michigan and Superior. Local problems however may require nonpoint source controls in some areas.

FIGURE 55

AVERAGE ANNUAL COST, ALTERNATIVE STRATEGY I: BASINWIDE CONTROLS

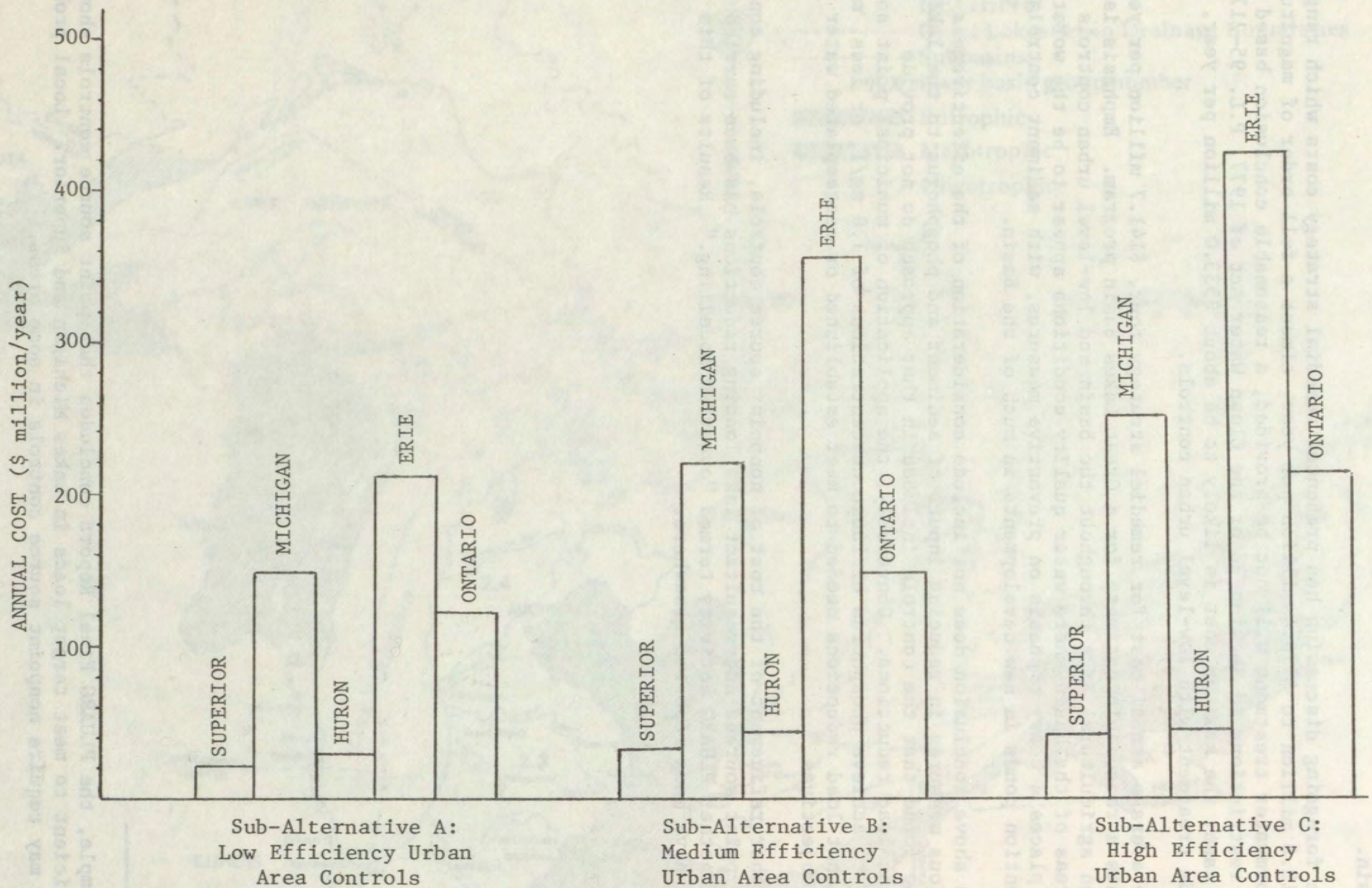


FIGURE 56

AVERAGE ANNUAL COST, ALTERNATIVE STRATEGY II: CONTROLS ONLY IN PCA

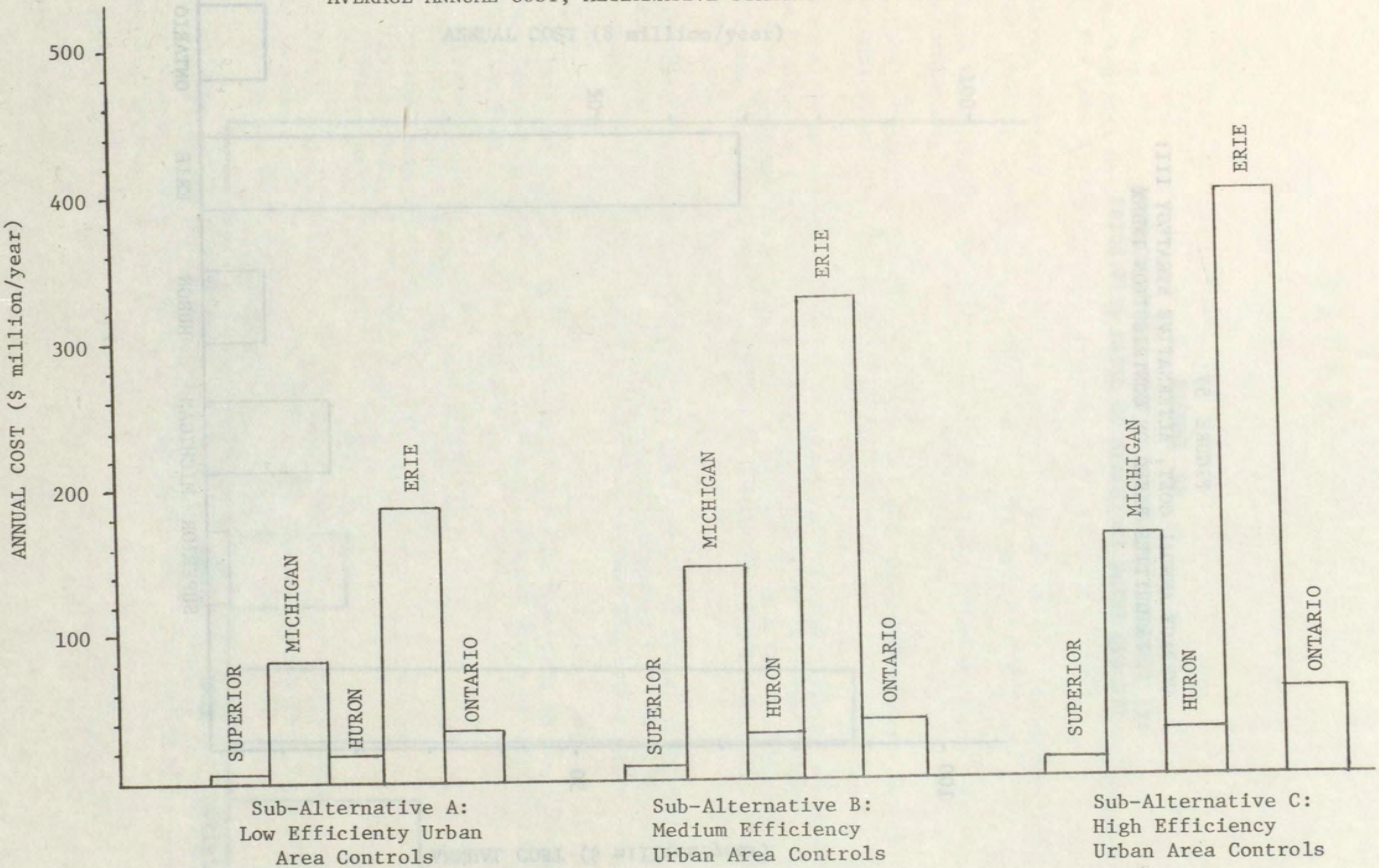


FIGURE 57

AVERAGE ANNUAL COST, ALTERNATIVE STRATEGY III: PRIORITIES BASED ON CONTRIBUTION INDEX

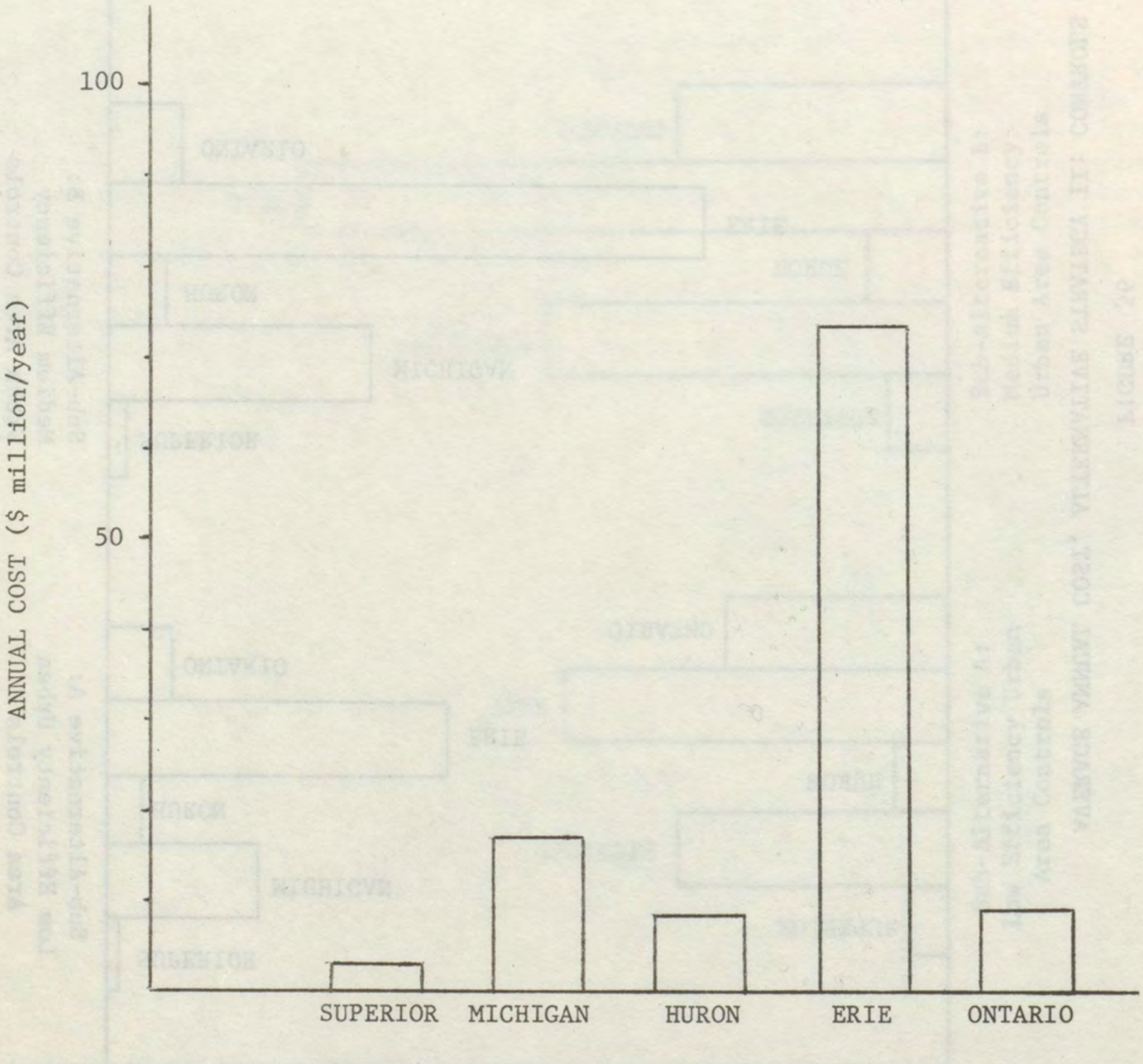
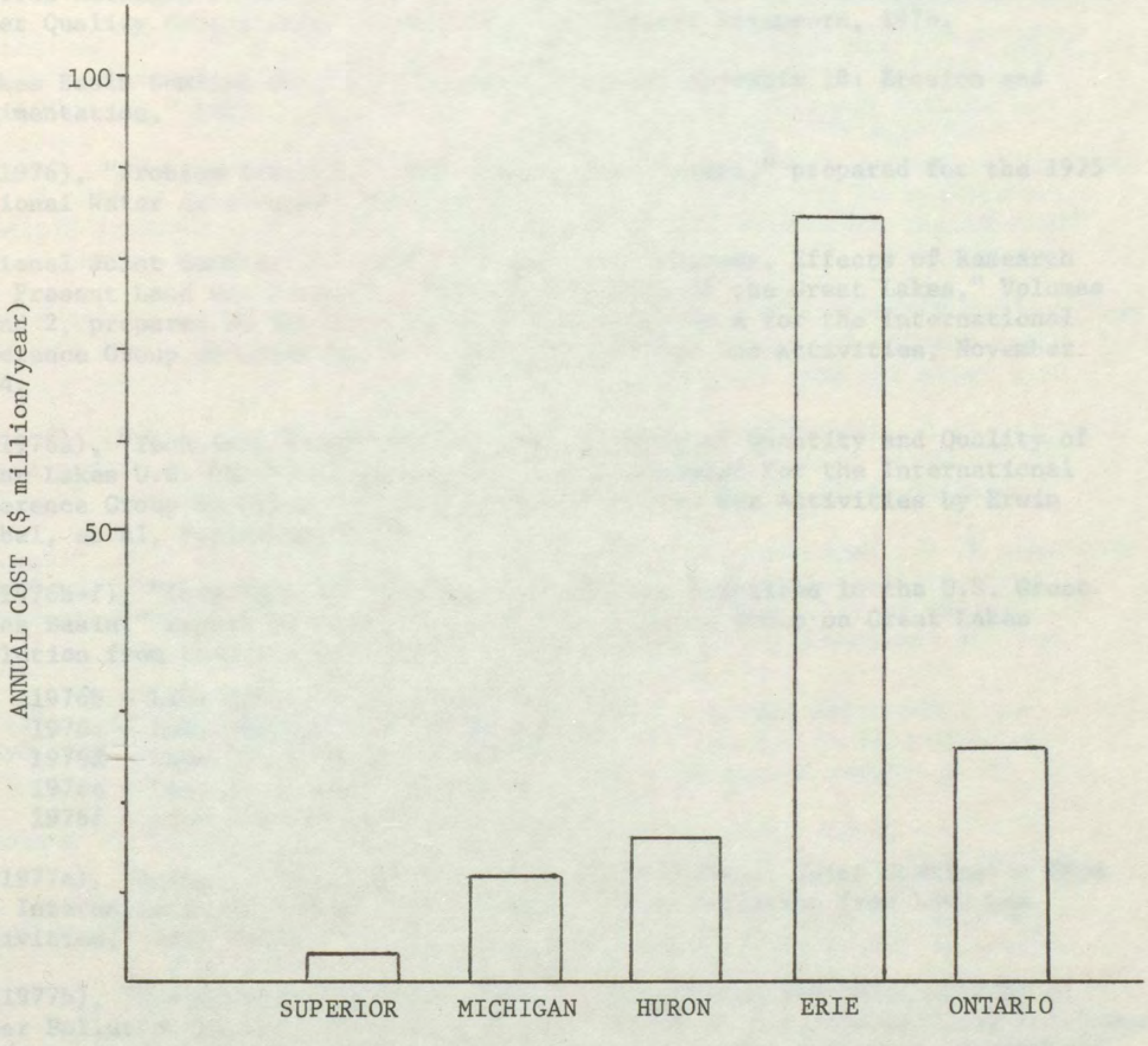


FIGURE 58

AVERAGE ANNUAL COST, ALTERNATIVE STRATEGY IV: PRIORITIES BASED ON NEARSHORE WATER QUALITY



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APPENDIX 1

URBAN STORMWATER AND COMBINED SEWER OVERFLOW CONTROL PROGRAM

The following program was used to estimate the costs of urban stormwater and combined sewer overflow control alternatives and to select three control combinations, one each of low, medium, and high solids removal efficiency, based on the cost-per-pound of solids removed. The program was run on the Michigan Terminal System (MTS) at the University of Michigan. Because MTS is a highly interactive system with a sophisticated file structure, the program was designed for use in a conversational mode utilizing files to store output products.

As it is presented, the program does not produce output of the form shown in this report (see, for example, Table 91). A second program was used to aggregate information by river basin group and produce the summary tables used in the report.

Input data (adjusted urban area and population, average annual precipitation, etc.) are read as real numbers. Thus, decimal points are necessary in each case (e.g., enter population as 50000., not 50000).

```
C**************************************************************************
C*                                                                        *
C*                                                                        *
C*                         URBAN STORMWATER AND                           *
C*                      COMBINED SEWER OVERFLOW                           *
C*                           CONTROL PROGRAM                              *
C*                                                                        *
C*                        Program Developed by                            *
C*                           William Skimin                               *
C*                    Great Lakes Basin Commission                        *
C*                           Ann Arbor, MI                                *
C*                                                                        *
C*                             July, 1978                                 *
C*                                                                        *
C*                                                                        *
C*                                                                        *
C*       This program was developed using procedures outlined in 'Cost    *
C* Estimates for Construction of Publicly-Owned Wastewater Treatment      *
C* Facilities: 1976 Needs Survey Summaries of Technical Data for Com-     *
C* bined Sewers and Stormwater Discharges', published February, 1977.     *
C* Although similar cost estimating functions are used in this analysis   *
C* however, the results are not directly comparable with those from the   *
C* Needs Survey because of two differences . First, the Needs Survey      *
C* based its treatment selection criteria on recieving water quality      *
C* assimilative capacity and water quality objectives, while this study   *
C* simply selected the treatment alternatives on the basis of solids      *
C* removal efficiency and cost-effectiveness.                             *
C*       The second, and perhaps even more significant difference in the  *
C* two methodologies is the definition of the area to be served by the    *
C* stormwater treatment system. The Needs Survey based its stormwater     *
C* service area on the difference between the total urbanized area and    *
C* the estimated combined sewer service area.  For this study, the storm- *
C* sewer service area was adjusted (using factors developed in another    *
C* EPA study, 'A Nationwide Evaluation of Combined Sewer Overflows and    *
C* Urban Stormwater Discharges, Volume II:  Cost Assessment and Impacts', *
C* March, 1977) to subtract the estimated undeveloped and unsewered       *
C* areas from the total.                                                  *
C*        The variables used in the program are defined as follows:       *
C*                                                                        *
C* ADR      :   average no. of days per year with percipitation           *
C* AFFECT   :   internal variable used in comparing the cost-effectiveness *
C*               of low efficiency control combinations                   *
C* ARF      :   average annual rainfall, inches                           *
C* ASCO     :   state average combined sewer overflow drainage area, acres *
C* ALAND    :   unadjusted urban area, acres                              *
C* BASINS   :   annual capital cost of constructing new stormwater        *
C*               detention ponds in developing areas                      *
C* C1       :   flag to identify potential bacteria sources               *
C* C3       :   flag to identify high, medium, and low contribution       *
C*               index                                                    *
C* CAPITL   :   capital cost of control combination (i,j)                 *
C* CITY     :   name of city                                              *
C* CLRCP1   :   capital cost of chlorinating combined sewer overflows     *
C* CLRCP2   :   capital cost of chlorinations combined sewer overflows and *
```

```
C*                stormwater runoff                                          *
C* CLROM1   :    annual operation and maintenance cost of chlorinating       *
C*                combined sewer overflows                                   *
C* CLROM2   :    annual operating and maintenance cost of chlorinating       *
C*                combined sewer overflows and stormwater runoff             *
C* CLRTC1   :    total discounted cost of chlorinating combined sewer over-  *
C*                flows                                                      *
C* CONTRL   :    a 3-dimensional array used to store information on the      *
C*                combinations of combined sewer (i) and stormwater (j)      *
C*                control alternatives.  The K elements are:                 *
C*                          CONTRL (i,j,1):  solids removal efficiency       *
C*                          CONTRL (i,j,2):  capital cost of combination     *
C*                             (i,j)                                         *
C*                          CONTRL(i,j,3):  annual O&M cost of combination   *
C*                             (i,j)                                         *
C*                          CONTRL (i,j,4):  total discounted cost of        *
C*                             combination (i,j)                             *
C* COST     :    Cost (capital or O&M depending on location in program) of   *
C*                stormwater control alternative 2 through 5                 *
C* CS       :    Fraction of area served by combined sewers                  *
C* CSL      :    Combined sewer solids load, pounds                          *
C* CST1     :    Cost (capital or O&M, depending on location in program)     *
C*                   of stormwater BMPs                                      *
C* CTR      :    Daily treatment rate of each consolidated treatment         *
C*                facility, mgd                                              *
C* DS90     :    design storm rainfall depth, inches                         *
C* DVSS     :    design storm runoff volume, million gallons                 *
C* EFFECT   :    cost-effectiveness of control combination (i,j)             *
C*               in $/pound of solids removed                                *
C* FIX      :    variable used in finding integer values                     *
C* FLAG1    :    logical variable used to determine whether or not           *
C*                output should be stored in a file                          *
C* GROWTH   :    estimated annual growth rate, percent                       *
C* HA       :    hydrologic area number                                      *
C* I        :    index variable for combined sewer controls, I=1 to 5        *
C* ICOM     :    similar to LCOM for high efficiency combination             *
C* IFLAG    :    variable used in input prompting                            *
C* IL       :    length of new interceptors, feet                            *
C* IMAR     :    impervious land area in storm sewered area, acres           *
C* INDEX    :    EPA cost adjustment factor                                  *
C* ISTORM   :    similar to LSTORM for high efficiency combination           *
C* J        :    index variable for stormwater controls, J=1 to 5            *
C* JFLAG    :    variable used in output prompting                           *
C* KFLAG    :    variable used in output prompting                           *
C* KOST     :    cost (capital or O&M, depending on location in program)     *
C*                of combined sewer overflow control                         *
C* KST      :    variable used to hold subproduct of combined sewer          *
C*               control capital kost                                        *
C* LAND     :    adjusted urban area in acres                                *
C* LCOM     :    used to save index number of most cost-effective            *
C*                combined sewer control used in low efficiency              *
C*                combination                                                *
C* LFLAG    :    variable used in output prompting                           *
C* LNR      :    counter used to calculate output file lines numbers         *
C*                   if FLAG1 is TRUE                                        *
```

```
      C* LSTORM   :   used to save index number of most cost-effective           *
      C*                 stormwater control used in the low-efficiency           *
      C*                 combination                                             *
      C* MCOM     :   similar to LCOM for medium efficiency combination          *
      C* NCSP     :   number of combined sewer overflow storage facilities       *
      C* NSSP     :   number of stormwater treatment facilities                  *
      C* NTP      :   number of consolidated treatment facilities                *
      C* OBASIN   :   annual detention pond maintenance cost                     *
      C* OFFECT   :   similar to AFFECT for medium efficiency combinations       *
      C* OM       :   O&M cost for control combination (i,j)                     *
      C* OM1MD    :   variable used to hold subproduct of stormwater O&M cost    *
      C* OM2MD    :   variable used to hold subproduct of combined sewer         *
      C*                 O&M cost                                                *
      C* POP      :   adjusted urban population                                  *
      C* PPRS     :   percent of pollutant removal from streets                  *
      C* PRDS     :   percent of urban area runoff from street surface           *
      C* RATE     :   discount rate                                              *
      C* RE1      :   pounds of solids removed by a given stormwater control     *
      C* RE2      :   pounds of solids removed by a given combined sewer         *
      C*                 control                                                 *
      C* REMOVE   :   combined stormwater and combined sewer removal efficiency  *
      C* ROCS     :   runoff coefficient                                         *
      C* SAR      :   percent impervious area due to streets                     *
      C* SAVEHI   :   similar to SAVELO for high efficiency control              *
      C*               combinations                                              *
      C* SAVELO   :   a one-dimension, four element array used for saving        *
      C*               information on the most cost-effective low-efficiency     *
      C*               combination of controls.  The elements are                *
      C*                      SAVELO(1):  overall removal efficiency             *
      C*                      SAVELO(2):  overall capital cost                   *
      C*                      SAVELO(3):  overall annual O&M cost                *
      C*                      SAVELO(4):  overall total discounted cost          *
      C* SAVEMD   :   similar to SAVELO for medium-efficiency control            *
      C*               combinations                                              *
      C* SEDCON   :   annual cost of construction sediment control               *
      C* SM       :   street  miles in storm sewered area                        *
      C* SSI      :   estimated percent imperviousness                           *
      C* SSL      :   storm sewer solids load, pounds                            *
      C* STATE    :   name of state                                              *
      C* STCS     :   storage volume of each combined sewer storage              *
      C*               facility, mg                                              *
      C* STSS     :   storage volume of each stormwater treatment                *
      C*               facility, mg                                              *
      C* TCOST    :   total discounted cost of control combination               *
      C* TERSE    :   logical variable used to determine whether or not          *
      C*               abbreiviated output format is desired                     *
      C* TIC      :   cost of interceptors, dollars                              *
      C* TL       :   total load, pounds                                         *
      C* TRCS     :   daily discharge rate from each combined sewer              *
      C*               storage facility, mgd                                     *
      C* TRSS     :   daily stormwater treatment rate, mgd                       *
      C* UA       :   urban area adjustment factor                               *
      C* UFFECT   :   similar to AFFECT for high-efficiency combinations         *
      C***************************************************************************
      C
```

```
C
C
C
C
      INTEGER CITY(3)/3*'    '/,DASH(11)/11*'----'/,TCITY(3)/3*'    '/
      INTEGER HA,C1,C2,C3
      LOGICAL FLAG1,TERSE
      REAL LAND,INDEX,NSSP,NCSP,NTP,IL,KOST,KST,IMAR
      DIMENSION CONTRL(5,5,4),SAVELO(4),SAVEMD(4),SAVEHI(4)
      DATA AFFECT/ 10.E8 /
      DATA OFFECT/ 10.E8 /
      DATA UFFECT/ 10.E8 /
      PRINT 900
      READ (6,800) IFLAG
      IF (IFLAG.EQ.1) FLAG1=.TRUE.
      IF (IFLAG.NE.1) FLAG1=.FALSE.
      PRINT 903
      READ 800, IFLAG
      IF (IFLAG.EQ.1) TERSE=.TRUE.
      IF (IFLAG.NE.1) TERSE=.FALSE.
    1 PRINT 908
      READ (6,802) CITY
      IF (.NOT.FLAG1) GO TO 3
      LNR=1000
  100 FIND (2'LNR)
      READ (2,912,END=101)
      LNR=LNR+1000
      GO TO 100
  101 CONTINUE
      PRINT 910, CITY
      READ 803, STATE,HA,C1,C2,C3
    3 PRINT 911
      READ 804, LAND
      PRINT 916
      READ 804, POP
      PRINT 920
      READ 806, ARF
      PRINT 924
      READ 808, ADR
      PRINT 928
      READ 810, CS
      IF (CS.NE.0) GO TO 9
      PRINT 934
      GO TO 10
    9 PRINT 932
   10 READ 808, ASCO
      PRINT 938
      READ 812, INDEX
      PRINT 942
      READ 814, GROWTH
      PRINT 943
  943 FORMAT ('ENTER URBAN AREA ADJUSTMENT FACTOR')
      READ 815, UA
  815 FORMAT (F3.2)
```

```
      ALAND=LAND/UA
      PRINT 946, CITY,LAND,POP,ARF,ADR,CS,ASCO,INDEX,GROWTH
C
C
C
C
C
C     THIS SECTION OF THE PROGRAM USES THE INPUT DATA TO CALCULATE THE
C     DESIGN STORM (90-TH PERCENTILE STORM) CHARACTERISTICS AND THE
C     RESULTANT SOLIDS LOADS FROM THE COMBINED SEWER AND STORMWATER
C     SYSTEMS.
C
C
C
   14 SSI=9.6*(POP/LAND)**(.573-.0391*ALOG10(POP/LAND))
      ROCS=.15+.75*(SSI/100.)
      DS90=2.3*(ARF/(1.0026*ADR-2.58))
      DVSS=DS90*ROCS*LAND*.027158
      CSL=CS*LAND*(39.2*DS90*(.142+.218*(POP/LAND)**.54)+25.94+DS90)
      SSL=(1-CS)*LAND*(9.52*DS90*(.142+.218*(POP/LAND)**.54)+25.94+DS90)
      TL=CSL+SSL
      IF (TERSE) GO TO 2100
      PRINT 954, SSI,ROCS,DS90,DVSS,CSL,SSL
      PRINT 956, TL
 2100 CONTINUE
C
C
C
C
C     THIS SECTION OF THE PROGRAM CALCULATES THE DESIGN PARAMETERS FOR THE
C     VARIOUS TREATMENT ALTERNATIVES:  I.E.  NUMBER OF STORAGE AND TREAT-
C     MENT FACILITIES NEEDED, DAILY CAPACITIES, ETC.
C
C
C
C         STORMSEWERED AREAS
C
C
C
      NSSP=0.
      STSS=0.
      TRSS=0.
      IF (CS.EQ.1.) GO TO 2001
      NSSP=(1-CS)*LAND/ASCO
      FIX=IFIX(NSSP)
      IF (FIX.NE.NSSP) FIX=FIX+1
      NSSP=FIX
      STSS=(1-CS)*DVSS/NSSP
      TRSS=STSS/(365./(1.0026*ADR-2.58))
      NCSP=0.
      STCS=0.
      TRCS=0.
      NTP=0.
      CTR=0.
      IF(CS.EQ.0) GO TO 21
```

```
C
C
C
C
C       COMBINED SEWERED AREAS
C
C
C
 2001 NCSP=CS*LAND/ASCO
      FIX=IFIX(NCSP)
      IF (FIX.NE.NCSP) FIX=FIX+1
      NCSP=FIX
      STCS=CS*DVSS/NCSP
      TRCS=STCS/(365./(1.0026*ADR-2.58))
      NTP=(CS*LAND/1000.)**.435
      IF (NTP.GT..5) GO TO 20
      PRINT 958
      GO TO 21
   20 FIX=IFIX(NTP)
      IF (FIX.NE.NTP) FIX=FIX+1
      NTP=FIX
   21 IF (TERSE) GO TO 2101
      PRINT 960, NSSP,STSS,TRSS
 2101 IF (CS.EQ.0.) GO TO 23
      CTR=DVSS*CS/(NTP*(365./(1.0026*ADR-2.58)))
      IL=CS*LAND*2.8876
      TIC=IL*28.*TRCS**.3
      IF (TERSE) GO TO 23
      PRINT 962, NCSP,STCS,TRCS,NTP,CTR,IL
      PRINT 964
   23 CONTINUE
C
C
C
C
C     THE COST AND REMOVAL EFFICIENCY CALCULATION SEQUENCE FOR EACH OF THE
C     25 COMBINATIONS OF COMBINED SEWER (INDEXED ON VARIABLE I) AND STORM-
C     SEWER (INDEXED ON VARIABLE J) CONTROLS BEGINS HERE.  TWO NESTED DO-
C     LOOPS ARE USED TO GENERATE THE VARIOUS CONTROL COMBINATIONS.  THE
C     COST AND EFFICIENCY ESTIMATING EQUATIONS ARE FOUND ELSEWHERE IN THE
C     PROGRAM.
C
C
C
C
   24 DO 25 I=1,5
      DO 26 J=1,5
      GO TO (201,202,203,204,205), J
   27 CONTRL(I,J,2)=CAPITL
      GO TO (211,212,213,214,215), J
   28 CONTRL(I,J,3)=OM
C
C    COSTS ARE DISCOUNTED AT A RATE OF 6.625% OVER 20 YEARS
C
      RATE=1.06625
```

```
      TCOST=CAPITL+OM*((1-(1/RATE)**21)/(1-(1/RATE)))
      CONTRL(I,J,4)=TCOST
      GO TO (221,222,223,224,225), J
   29 CONTRL(I,J,1)=REMOVE
   26 CONTINUE
   25 CONTINUE
      IF (TERSE) GO TO 39
      PRINT 970
      READ 800, IFLAG
      IF (IFLAG.NE.1) GO TO 30
      PRINT 972
      READ 820, IFLAG,JFLAG,KFLAG,LFLAG
      IF (IFLAG.NE.1) GO TO 31
      PRINT 974
      PRINT 976
      PRINT 978, (I,(CONTRL(I,J,1),J=1,5),I=1,5)
   31 IF (JFLAG.NE.1) GO TO 32
      PRINT 980
      PRINT 976
      PRINT 982, (I,(CONTRL(I,J,2),J=1,5),I=1,5)
   32 IF (KFLAG.NE.1) GO TO 33
      PRINT 984
      PRINT 976
      PRINT 982, (I,(CONTRL(I,J,3),J=1,5),I=1,5)
   33 IF (LFLAG.NE.1) GO TO 30
      PRINT 986
      PRINT 976
      PRINT 982, (I,(CONTRL(I,J,4),J=1,5),I=1,5)
C
C
C
C
C     AT THIS POINT ALL TREATMENT ALTERNATIVES HAVE BEEN CALCULATED AND
C     SORTED BY THEIR EFFICIENCY.  THE NEXT SECTION PRINTS THE MOST
C     COST-EFFECTIVE  ALTERNATIVE FOR EACH LEVEL OF TREATMENT.
C
C
C
C
   30 IF (CS.EQ.0) GO TO 34
      PRINT 988, LSTORM, LCOM, (SAVELO(I),I=1,4)
      GO TO 35
   34 PRINT 990, LSTORM, (SAVELO(I), I=1,4)
   35 IF (CS.EQ.0) GO TO 36
      PRINT 992, MSTORM,MCOM, (SAVEMD(I),I=1,4)
      GO TO 37
   36 PRINT 994, MSTORM, (SAVEMD(I),I=1,4)
   37 IF (CS.EQ.0.) GO TO 38
      PRINT 996, ISTORM, ICOM, (SAVEHI(I),I=1,4)
      GO TO 39
   38 PRINT 998, ISTORM, (SAVEHI(I),I=1,4)
   39 CONTINUE
C
C     CALCULATION OF CHLORINATION COSTS (NOT DONE FOR THE LOW LEVEL OF
C       TREATMENT ALTERNATIVE).
```

```
C
      CLRCP1=1.25*INDEX*NTP*(5343.*CTR**.724+63040.+5190.*CTR)
      CLROM1=INDEX*NTP*(86.*CTR**.884+26.*CTR**.698+54.*CTR+1780.*CTR**
     1.597+1139.*CTR**.69)
      CLRCP2=CLRCP1+1.25*INDEX*NSSP*(5343.*TRSS**.724+63040.+(5190.)
     1*TRSS)
      CLROM2=CLROM1+INDEX*NSSP*(86.*TRSS**.884+26.*TRSS**.698+54.*TRSS+
     11780.*TRSS**.597+1134.*TRSS**.69)
      CLRTC1=CLRCP1+CLROM1*((1-(1/RATE)**21)/(1-(1/RATE)))
      CLRTC2=CLRCP2+CLROM2*((1-(1/RATE)**21)/(1-(1/RATE)))
      IF (TERSE) GO TO 2102
      PRINT 1002, CLRCP1,CLRCP2,CLROM1,CLROM2,CLRTC1,CLRTC2
 2102 CONTINUE
C
C
C
C
C    ESTIMATION OF THE COST OF CONSTRUCTION SEDIMENT CONTROLS AND THE
C     USE OF STORMWATER DETENTION BASINS AT ALL NEW DEVELOPMENTS.
C
C
C
C
 2003 SEDCON=GROWTH*ALAND*400.
      BASINS=GROWTH*ALAND*DS90*ROCS*.027158*500000.
      OBASIN=.02*BASINS
      IF (TERSE) GO TO 2103
      PRINT 1008, GROWTH,SEDCON,BASINS,OBASIN
      IF (.NOT.TERSE) GO TO 2200
 2103 PRINT 1500, CITY,SSL,CSL,TL,LSTORM,LCOM,SAVELO(2),SAVELO(3),
     1SAVELO(4),MSTORM,MCOM,SAVEMD(2),SAVEMD(3),SAVEMD(4),ISTORM,ICOM,
     2SAVEHI(2),SAVEHI(3),SAVEHI(4),SEDCON,BASINS,OBASIN
      PRINT 1501, SAVELO(1),SAVEMD(1),SAVEHI(1)
 1501 FORMAT (' THE EFFICIENCIES OF THE THREE LEVELS OF TREATMENT ARE:'/
     15X,'LOW  =',F6.2/5X,'MID  =',F6.2/5X,'HIGH =',F6.2)
      PRINT 1002, CLRCP1,CLRCP2,CLROM1,CLROM2,CLRTC1,CLRTC2
 2200 IF (.NOT.FLAG1) GO TO 2201
      WRITE (2'LNR,1600) CITY,STATE,HA,C1,C2,C3,LAND,POP,ARF,ADR,CS,
     1ASCO,INDEX,GROWTH
      WRITE (3'LNR,1601) CITY,SSI,ROCS,DS90,DVSS,CSL,SSL,TL,NSSP,STSS,
     1TRSS,NCSP,STCS,TRCS,NTP,CTR
      WRITE (4'LNR,1602) CITY,LSTORM,LCOM,(SAVELO(I),I=1,4),MSTORM,MCOM,
     1(SAVEMD(I),I=1,4),ISTORM,ICOM,(SAVEHI(I),I=1,4)
      WRITE (8'LNR,1603) CITY,CLRCP1,CLROM1,CLRTC1,CLRCP2,CLROM2,CLRTC2,
     1SEDCON,BASINS,OBASIN
 2201 CONTINUE
      AFFECT=10.E8
      OFFECT=10.E8
      UFFECT=10.E8
C     PRINT 1010
      READ 800, IFLAG
      IF (IFLAG.EQ.1) GO TO 1
      GO TO 9999
C
C
```

```
C
C
C
C
C
C     THE FOLLOWING SECTION OF THE PROGRAM CONTAINS THE CAPITAL AND  OPERATING
C     COST FUNCTIONS FOR THE VARIOUS STORMWATER (200 SERIES LABELS), AND
C     COMBINED SEWER TREATMENT (300 SERIES LABELS) ALTERNATIVES.
C
C
C
C     CAPITAL COSTS OF STORMWATER CONTROLS
C
C
C     STORMWATER TREATMENT 1:  BMPS
C
  201 CST1=17.33*(1-CS)*LAND*(.0782-.0668*(.839**(POP/LAND)))*INDEX
      GO TO (301,302,303,304,305), I
  251 CAPITL=CST1+KOST
      GO TO 27
C
C     STORMWATER TREATMENT 2:  SEDIMENTATION
C
  202 COST=1.25*INDEX*NSSP*(15200.*STSS**.717+177500.*STSS**.598+
     1150000.*TRSS**.602+43120.*TRSS**.817+247655.*TRSS**.503+50112.*TR
     2SS**.698+3130.*TRSS**.484)+CST1
      GO TO (301,302,303,304,305), I
  252 CAPITL=COST+KOST
      GO TO 27
C
C     STORMWATER TREATMENT 3: AIR FLOATATION
C
  203 COST=1.25*(15200.*STSS**.717+177500.*STSS**.598+150000.*TRSS**
     1.602+5343.*TRSS**.724+48000.*TRSS**.611+147830.*TRSS**.83+
     2247655.*TRSS**.503+50112.*TRSS**.608+3130.*TRSS**.484)*NSSP*
     3INDEX+CST1
      GO TO (301,302,303,304,305), I
C
C     STORMWATER TREATMENT 4: FLOCCULATION/SEDIMENTATION
C
  204 COST=1.25*(15200.*STSS**.717+177500.*STSS**.598+150000.*TRSS**
     1.602+48000.*TRSS**.611+5343.*TRSS**.724+19420.*TRSS**.612+43120.
     2*TRSS**.817+247655.*TRSS**.503+50112.*TRSS**.698+3130.*TRSS**
     3.484)*NSSP*INDEX+CST1
      GO TO (301,302,303,304,305), I
C
C     STORMWATER TREATMENT 5:  FILTRATION
C
  205 COST=1.25*(15200.*STSS**.717+177500.*STSS**.598+150000.*TRSS**.602
     1+48000.*TRSS**.611+5343.*TRSS**.724+19420.*TRSS**.612+43120.*TRSS
     2**.817+104940.*TRSS**.736+247655.*TRSS**.503+50112.*TRSS**.698+
     33130.*TRSS**.484)*NSSP*INDEX+CST1
      GO TO (301,302,303,304,305), I
C
C
```

```
C
C
C     OPERATING AND MAINTENANCE COST SECTION FOR STORMWATER CONTROLS
C
C
C
C
C    BMPS
C
C
  211 CST1=5.46*(1-CS)*LAND*(.0782-.0668*(.839**(POP/LAND)))*INDEX
      GO TO (311,312,313,314,315), I
  261 OM=CST1+KOST
      GO TO 28
C
C
C     SEDIMENTATION
C
C
  212 OM1MD=INDEX*NSSP*(200.*TRSS**.463+75.*TRSS**.471+10800.+875.*TRSS
     1**.798+57.*TRSS**.838+1000.*STSS**.47+480.*STSS**.4+14.*STSS**.51+
     22500.+1930.*TRSS**.468+240.*TRSS+1790.*TRSS**.426+92.*TRSS**
     3.642+8587.5*TRSS)+CST1
      COST=OM1MD+INDEX*NSSP*(2900.*TRSS**.732+1229.*TRSS**.207+6.8*TRSS
     1**.913)
      GO TO (311,312,313,314,315), I
  262 OM=COST+KOST
      GO TO 28
C
C
C     AIR FLOATATION
C
C
  213 COST=OM1MD+INDEX*NSSP*(85.*TRSS**.884+26.*TRSS**.698+54.*TRSS+
     13465.*TRSS**.332+36.*TRSS**.662+20.*TRSS**.86+2700.*TRSS**.618+
     21915.*TRSS**.203+2220.*TRSS)
      GO TO (311,312,313,314,315), I
C
C
C     FLOCCULATION/SEDIMENTATION
C
C
  214 COST=OM1MD+INDEX*NSSP*(3465.*TRSS**.332+36.*TRSS**.662+20.*TRSS**
     1.86+86.*TRSS**.884+26.*TRSS**.698+338.*TRSS+140.*TRSS**.624+2900.*
     2TRSS**.732+1230.*TRSS**.207+6.8*TRSS**.913)
      GO TO (311,312,313,314,315), I
C
C
C     FILTRATION
C
C
  215 COST=OM1MD+NSSP*INDEX*(3465.*TRSS**.332+36.*TRSS**.662+20.*TRSS**
     1.86+86.*TRSS**.884+338.*TRSS+26.*TRSS**.698+140.*TRSS**
     2.624+2900.*TRSS**.732+1230.*TRSS**.207+6.8*TRSS**.913+22780.+27.8*
     3TRSS+761.*TRSS**.256)
```

```
      GO TO (311,312,313,314,315), I
C
C
C
C
C     COMBINED SEWER TREATMENT COST SECTION
C
C
C
C
C
C     CAPITAL COSTS
C
C
C
C     COMBINED SEWER TREATMENT ALTERNATIVE ONE:  SCREENING/SWIRL CON-
C     CENTRATION OF FIRST-FLUSH.
C
C
C
  301 KOST=1.25*INDEX*((98800.*(2.*STCS)**.602+13309.*(2.*STCS)**.598+
     1(106500.*(.154*STCS)**.598)+(271500.*(.154*STCS)**.803)+150000.*
     2(.154*TRCS)**.602)*NCSP+(13110.*(.154*CTR)**.955+3130.*(.154*CTR)
     3**.484)*NTP)+TIC
      GO TO (251,252,252,252,252), J
C
C
C     COMBINED SEWER TREATMENT ALTERNATIVE TWO:  SEDIMENTATION
C
C
  302 KST=1.25*INDEX*((106500.*STCS**.598+271500.*STCS**.803+150000.*
     1TRCS**.602)*NCSP+(247655.*CTR**.503+50112.*CTR**.698+3130.*CTR**
     2.484)*NTP)+TIC
      KOST=KST+1.25*INDEX*(43120.*CTR**.817)*NTP
      GO TO (251,252,252,252,252), J
C
C
C     COMBINED SEWER TREATMENT ALTERNATIVE THREE:  AIR FLOATATION
C
C
  303 KOST=KST+INDEX*1.25*(5343.*CTR**.724+48000.*CTR**.611+147830.*CTR
     1**.83)*NTP
      GO TO (251,252,252,252,252), J
C
C
C     COMBINED SEWER TREATMENT ALTERNATIVE FOUR:  FLOCULATION/SEDIMENTATION
C
C
  304 KOST=KST+INDEX*1.25*NTP*(48000.*CTR**.611+5343.*CTR**.724+19420.*
     1CTR**.612+43120.*CTR**.817)
      GO TO (251,252,252,252,252), J
C
C
C     COMBINED SEWER ALTERNATIVE FIVE:  FILTRATION
C
```

```
C
  305 KOST=KST+INDEX*1.25*NTP*(48000.*CTR**.611+5343.*CTR**.724+19420.*
     1CTR**.612+43120.*CTR**.817+104940.*CTR**.736)
      GO TO (251,252,252,252,252), J
C
C     COMBINED SEWER O&M COST CALCULATIONS
C
C
C     SCREENING/SWIRL CONCENTRATION
C
C
  311 KOST=INDEX*((200.*(.154*CTR)**.463+75.*(.154*CTR)**.471+10800.+
     11530.*(.154*CTR)**.466+678.*(.154*CTR)**.281)*NTP+(875.*(.154*TRCS
     2)**.798+57.*(.154*TRCS)**.838+6760.+1930.*(2.*STCS)**.468+240.*(2.
     3*STCS)+2571.*(2.*STCS)**.214+415.*(.154*STCS)**.47+227.*(.154*STCS
     4)**.4+5.4*(.154*STCS)**.51+1930.*(.154*TRCS)**.468+240.*(.154*TRCS
     5))*NCSP)
      GO TO (261,262,262,262,262), J
C
C
C     SEDIMENTATION
C
C
  312 OM2MD=INDEX*((200.*CTR**.463+75.*CTR**.471+10800.+1790.*CTR**.426+
     192.*CTR**.642+8587.5*CTR)*NTP+(875.*TRCS**.798+57.*TRCS**.838+1000
     2.*STCS**.47+480.*STCS**.4+14.*STCS**.51+2500.+1930.*TRCS**.468+240
     3.*TRCS)*NCSP)
      KOST=OM2MD+INDEX*(2900.*CTR**.732+1229.*CTR**.207+6.8*CTR**.913)*
     1NTP
      GO TO (261,262,262,262,262), J
C
C
C     AIR FLOATATION
C
C
  313 KOST=OM2MD+INDEX*NTP*(85.*CTR**.884+26.*CTR**.698+2274.*CTR+3465.*
     1CTR**.332+36.*CTR**.662+20.*CTR**.86+2700.*CTR**.618+1915.*CTR**
     2.203)
      GO TO (261,262,262,262,262), J
C
C
C     FLOCCULATION/SEDIMENTATION
C
C
  314 KOST=OM2MD+INDEX*NTP*(3465.*CTR**.332+36.*CTR**.662+20.*CTR**.86+
     186.*CTR**.884+26.*CTR**.698+338.*CTR+140.*CTR**.624+2900.*CTR**.73
     22+1230.*CTR**.207+6.8*CTR**.913)
      GO TO (261,262,262,262,262), J
C
C
C     FILTRATION
C
C
  315 KOST=OM2MD+INDEX*NTP*(3465.*CTR**.332+36.*CTR**.662+20.*CTR**.86+
     186.*CTR**.884+26.*CTR**.698+338.*CTR+140.*CTR**.62
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```
      24+2900.*CTR**.732+1230.*CTR**.207+6.8*CTR**.913+22780.+27.8*CTR+
      3761.*CTR**.256)
        GO TO (261,262,262,262,262), J
C
C     TREATMENT REMOVAL EFFICIENCY CALCULATION SEQUENCE
C
  221 IF (CS.EQ.1.) RE1=0.
      IF (CS.EQ.1.) GO TO 2002
      IMAR=(1.-CS)*LAND*(SSI/100.)
      SM=((1.-CS)*LAND*(.0782-.0668*.839**(POP/LAND)))*.5
      SAR=(SM*87720.)/(43560.*IMAR)
      PRDS=SAR*(.9*(SSI/100.)/ROCS)
      PPRS=1.1*PRDS/(1+PRDS)
      RE1=PPRS*SSL
 2002 GO TO (321,322,323,324,325), I
  271 REMOVE=(RE1+RE2)/TL
      GO TO 280
  222 RE1=.35*SSL
      GO TO (321,322,323,324,325), I
  223 RE1=.6*SSL
      GO TO (321,322,323,324,325), I
  224 RE1=.8*SSL
      GO TO (321,322,323,324,325), I
  225 RE1=.93*SSL
      GO TO (321,322,323,324,325), I
  321 RE2=.2*CSL
      GO TO 271
  322 RE2=.35*CSL
      GO TO 271
  323 RE2=.6*CSL
      GO TO 271
  324 RE2=.8*CSL
      GO TO 271
  325 RE2=.93*CSL
      GO TO 271
C
C     EFFICIENCY SORTING ROUTINE
C
  280 IF (REMOVE.GT..3) GO TO 281
      EFFECT=CONTRL(I,J,4)/(RE1+RE2)
      IF (EFFECT.GT.AFFECT) GO TO 29
      AFFECT=EFFECT
      SAVELO(1)=REMOVE
      SAVELO(2)=CONTRL(I,J,2)
      SAVELO(3)=CONTRL(I,J,3)
      SAVELO(4)=CONTRL(I,J,4)
      LSTORM=J
      LCOM=I
      GO TO 29
  281 IF (REMOVE.GT..65) GO TO 282
      EFFECT=CONTRL(I,J,4)/(RE1+RE2)
      IF (EFFECT.GT.OFFECT) GO TO 29
      OFFECT=EFFECT
      SAVEMD(1)=REMOVE
      SAVEMD(2)=CONTRL(I,J,2)
```

```
      SAVEMD(3)=CONTRL(I,J,3)
      SAVEMD(4)=CONTRL(I,J,4)
      MSTORM=J
      MCOM=I
      GO TO 29
  282 EFFECT=CONTRL(I,J,4)/(RE1+RE2)
      IF (EFFECT.GT.UFFECT) GO TO 29
      UFFECT=EFFECT
      SAVEHI(1)=REMOVE
      SAVEHI(2)=CONTRL(I,J,2)
      SAVEHI(3)=CONTRL(I,J,3)
      SAVEHI(4)=CONTRL(I,J,4)
      ISTORM=J
      ICOM=I
      GO TO 29
C
C
C
C
C
C     THE FOLLOWING SECTION CONTAINS MOST OF THE FORMAT STATEMENTS USED IN
C       THE PROGRAM.  MOST READ FORMATS ARE LABELLED 800, AND THE WRITE/
C       PRINT STATEMENTS ARE 900-1000.
C
C
C
C
C
C
  800 FORMAT (I1)
  802 FORMAT (3A4)
  803 FORMAT (A4,I3,3I1)
  804 FORMAT (F8.0)
  806 FORMAT (F5.2)
  808 FORMAT (F4.0)
  810 FORMAT (F3.2)
  812 FORMAT (F5.4)
  814 FORMAT (F5.2)
  816 FORMAT (16X,2F8.0,F5.2,F3.0,F3.2,F4.0,F5.4,F5.2)
  820 FORMAT (4I4)
  900 FORMAT ('-       DO YOU WANT THE OUTPUT TO BE PUT INTO A FILE (ENTER
     1 1 FOR YES)?')
  902 FORMAT (5X,'WILL INPUT DATA BE FROM A FILE (ENTER 1 FOR YES)?'/)
  903 FORMAT (5X,'TERSE OUTPUT DESIRED (ENTER 1 FOR YES)?')
  908 FORMAT ('ENTER CITY NAME'/)
  910 FORMAT ('0',3A4,' IS THE CITY TO BE EVALUATED.  ENTER THE'/
     1' FOLLOWING INFORMATION:'/5X,'1. STATE'/5X,'2. HYDROLOGIC AREA'/
     25X,'3. WITHIN 10 KM OF RIVER MOUTH?'/5X,'4. WITHIN 150 KM OF RIVER
     3 MOUTH?'/5X,'5. LOW/MEDIUM/HIGH CON. INDEX?'/' ENTER EACH, AS ONE
     4STRING OF FORM "SSSSHHHXYZ".')
  911 FORMAT (' ENTER LAND AREA, IN ACRES')
  912 FORMAT (3A4)
  916 FORMAT (' ENTER POPULATION'/)
  920 FORMAT (' ENTER AVERAGE ANNUAL RAINFALL'/)
  924 FORMAT (' ENTER AVERAGE DAYS WITH PRECIPITATION'/)
  928 FORMAT (' ENTER THE FRACTION OF THE AREA SERVED BY COMBINED SEWERS
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     1 (ENTER 0 IF THERE ARE NONE).'/)
 932 FORMAT (' ENTER THE AVERAGE COMBINED SEWER DRAINAGE AREA'/)
 934 FORMAT (' ALTHOUGH THERE ARE NO COMBINED SEWERS  IN THIS AREA, THE
     1'/' AVERAGE COMBINED SEWER DRAINAGE AREA MUST STILL BE ENTERED'//)
 938 FORMAT (' ENTER THE COST CORRECTION INDEX'/)
 942 FORMAT (' ENTER THE ASSUMED ANNUAL GROWTH RATE'/)
 946 FORMAT ('OTHE VALUES FOR ALL VARIABLES ENTERED FOR ',3A4,' ARE:'
     1/'01. LAND    = ',F8.0/' 2. POP      = ',F8.0/' 3. ARF     = ',F10.2/
     2' 4. ADR     = ',F8.0/' 5. CS       = ',F10.2/' 6. ASCO    = ',F8.0/
     3'7. INDEX  = ',F12.4/' 8. GROWTH = ',F10.3//)
 954 FORMAT ('-THE FOLLOWING DESIGN STORM CHARACTERISTICS HAVE BEEN CAL
     1CULATED FOR THIS AREA:'/'OPERCENT OF AREA IMPERVIOUS :',F9.2/
     2' RUNOFF COEFFICIENT',9X,':',F9.2/' DESIGN STORM DEPTH (INCHES):'
     3,F9.2/' RUNOFF VOLUME (MG)',9X,':',F9.2/' COMBINED SEWER LOAD (LBS
     4)  :',F9.0/' STORM SEWER LOAD (LBS)      :',F9.0//)
 956 FORMAT (' THE TOTAL LOAD FROM THIS AREA IS',F10.0,' POUNDS')
 958 FORMAT ('ONO NEW TREATMENT FACILITIES WILL BE REQUIRED TO TREAT
     1THE COMBINED SEWER LOAD'/' (I.E., THE FLOW WILL BE ROUTED THROUGH
     2THE SANITARY TREATMENT PLANT).  A "FRACTIONAL PLANT" WILL BE
     3'/' CARRIED THROUGH TO ALLOW FOR PLANT EXPANSION.')
 960 FORMAT ('OTHE STORMWATER TREATMENT FACILITY NEEDS ARE:  '/1X,F5.0
     1,' STORMWATER TREATMENT PLANTS'/1X,F7.2,' MILLION GALLONS OF STOR
     2AGE EACH'/1X,F5.2,' MGD DAILY TREATMENT RATE')
 962 FORMAT ('OTHE COMBINED SEWER TREATMENT FACILITY NEEDS ARE:'/1X,F4.
     10,' COMBINED SEWER STORAGE FACILITIES'/1X,F5.2,' MILLION GALLONS O
     2F STORAGE EACH'/1X,F7.2,' MGD DISCHARGE RATE FROM EACH'/1X,F4.0,
     3' CONSLIDATED TREATMENT PLANTS'/1X,F5.2,' MGD CONSOLIDATED TREAT
     4MENT RATE'/1X,F7.0,' FEET OF NEW INTERCEPTORS')
 964 FORMAT ('ONOTE:  IF LESS THAN ONE CONSOLIDATED TREATMENT PLANT IS
     1SHOWN'/' IT IS ASSUMED THAT EXISTING (EXPANDED) SANITARY PLANTS
     2ARE USED.'/)
 970 FORMAT ('ODO YOU WANT THE CONTROL ALTERNATIVE MATRICES DISPLAYED'
     1/' (ENTER 1 FOR YES)?'/)
 972 FORMAT (' THERE ARE FOUR MATRICES AVAILABLE:'/5X,'1. REMOVAL EFFI
     1CIENCY'/5X,'2. CAPITAL COSTS'/5X,'3. ANNUAL O&M COST'/5X,'TOTAL
     2DISCOUNTED COST'/' INDICATE THE MATRIX(S) DESIRED BY ENTERING A
     3FOUR DIGIT NUMBER'/' OF 1'S AND 0'S, WITH 1 INDICATING YES, 0 NO.
     4  FOR EXAMPLE:'/5X,'1111:  ALL FOUR MATRICES'/5X,'1000:  ONLY THE
     5 FIRST MATRIX'/5X,'1010:  THE FIRST AND THIRD MATRICES'//5X,'ENT
     6ER THE NUMBER'/)
 974 FORMAT ('0',20X,'TABLE 1:  REMOVAL EFFICIENCY')
 976 FORMAT ('0 COMBINED SEWER',8X,'STORMWATER TREATMENT'/4X,'TREATME
     1NT',4X,'1',9X,'2',9X,'3',9X,'4',9X,'5')
 978 FORMAT (('0',7X,I1,7X,5(F5.2,5X)))
 980 FORMAT ('0',20X,'TABLE 2:  CAPITAL COSTS')
 982 FORMAT (('0',7X,I1,5X,5(F10.0)))
 984 FORMAT ('0',20X,'TABLE 3:  ANNUAL O&M COSTS')
 986 FORMAT ('0',20X,'TABLE 4:  DISCOUNTED TOTAL COSTS')
 988 FORMAT ('OTHE MOST COST-EFFECTIVE LOW LEVEL OF TREATMENT USES STO
     1RM-'/' WATER CONTROL',I2,' AND COMBINED SEWER CONTROL',I2,'.'/' T
     2HEIR COMBINED EFFICIENCY IS',F5.2,' AND THE COSTS ARE:'/5X,'CAPITA
     3L COST=',F10.0/5X,'O&M COST   =',F10.0/5X,'TOTAL COST =',F10.0)
 990 FORMAT ('OTHE MOST COST-EFFECTIVE LOW LEVEL OF TREATMENT USED STOR
     1M-'/' WATER CONTROL',I2,'.'/' ITS EFFICIENCY IS',F5.2,' AND THE CO
     2STS ARE:'/5X,'CAPITAL COST=',F10.0/5X,'O&M COST   =',F10.0/5X,'TOT
```

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        3AL COST =',F10.0)
  992 FORMAT ('OTHE MOST COST-EFFECTIVE MEDIUM LEVEL OF TREATMENT USED S
     1TORM-'/' WATER CONTROL',I2,' AND COMBINED SEWER CONTROL',I2,'.'/
     2' THEIR COMBINED EFFICIENCY IS',F5.2,' AND THE COSTS ARE:'/5X,'C
     3APITAL COST=',F10.0/5X,'O&M COST    =',F10.0/5X,'TOTAL COST =',F10.
     40)
  994 FORMAT ('OTHE MOST COST-EFFECTIVE MEDIUM LEVEL OF TREATMENT IS STO
     RM-'/' WATER CONTROL',I2,'.'/' ITS EFFICIENCY IS',F5.2,' AND THE CO
     2OSTS ARE:'/5X,'CAPITAL COST=',F10.0/5X,'O&M COST    =',F10.0/5X,'TO
     3TAL COST =',F10.0)
  996 FORMAT ('OTHE MOST COST-EFFECTIVE HIGH LEVEL OF TREATMENT USES STO
     1RM-'/' WATER CONTROL',I2,' AND COMBINED SEWER CONTROL',I2,'.'/' TH
     2E COMBINED EFFICIENCY IS',F5.2,' AND THE COSTS ARE:'/5X,'CAPITAL C
     3OST=',F10.0/5X,'O&M COST    =',F10.0/5X,'TOTAL COST =',F10.0)
  998 FORMAT ('OTHE MOST COST-EFFECTIVE HIGH LEVEL OF TREATMENT IS STORM
     1-'/' WATER CONTROL',I2,'.'/' ITS EFFICIENCY IS',F5.2,' AND THE COS
     2TS ARE:'/5X,'CAPITAL COST=',F10.0/5X,'O&M COST    =',F10.0/5X,'TOT
     3AL COST =',F10.0)
 1002 FORMAT ('OTHE COSTS OF ADDING CHLORINATION TO THE MEDIUM AND HIGH'
     1/' EFFICIENCY TREATMENT ARE:'/15X,'COMBINED SEWERS',5X,'COMBINED A
     2ND'/19X,'ONLY',13X,'STORM SEWERS'/5X,'CAPITAL',5X,F10.0,11X,F10.0
     3/7X,'O&M',7X,F10.0,11X,F10.0/6X,'TOTAL',6X,F10.0,11X,F10.0)
 1004 FORMAT (6F10.0)
 1008 FORMAT ('OBASED ON A GROWTH RATE OF',F4.2,' CONSTRUCTION SEDIMENT
     1CONTROLS'/' WOULD COST $',F10.0,' ANNUALLY.  PROVISION OF DETENTIO
     2N'/' PONDS IN NEWLY DEVELOPED AREAS WOULD HAVE A CAPITAL COST (OCC
     3UR-'/' ING EACH YEAR) OF $',F10.0,'AND OPERATING COSTS OF $',F8.0,
     4'PER YEAR.')
 1010 FORMAT ('-DO YOU WANT TO ENTER MORE DATA (ENTER 1 FOR YES)?'/)
 1500 FORMAT ('-',30X,'URBAN CONTROL SUMMARY'/32X,'FOR ',3A4//'0  STORM
     1SEWER LOAD    =',F12.0,' POUNDS'/'  COMBINED SEWER LOAD =',F12.0,'
     2POUNDS'/'   TOTAL LOAD',10X,'=',F12.0,' POUNDS'/'0  TREATMENT',5X,'
     3STORM COMBINED    CAPITAL     OPERATION    TOTAL'/4X,'LEVEL',7X,'SEWE
     4R    SEWER',5X,'COST',8X,'COST',7X,'COST'//5X,'LOW',10X,I2,5X,I2,3X
     5,2F12.0,F14.0/'    MEDIUM',9X,I2,5X,I2,3X,2F12.0,F14.0/'     HIGH',1
     60X,I2,5X,I2,3X,2F12.0,F14.0/'0  CONSTRUCTION SEDIMENT CONTROLS WOU
     7LD COST $',F10.0,' ANNUALLY'/'  DETENTION PONDS IN NEW DEVELOPMENT
     8S WOULD HAVE ANNUAL CAPITAL COSTS OF $',F10.0/6X,'AND ANNUAL MAINT
     9ENANCE COSTS OF $',F8.0)
 1600 FORMAT (3A4,A4,I4,3I2,2F10.0,F6.2,F5.0,F4.2,F6.0,F8.4,F5.3)
 1601 FORMAT (3A4,F6.2,F4.2,F5.2,F8.2,3F10.0,2(F5.0,F6.2,F5.2),F4.0,F6.
     12)
 1602 FORMAT (3A4,3(2I1,F3.2,3F11.0))
 1603 FORMAT (3A4,9F12.0)
 9999 STOP
      END
```

APPENDIX 2

URBAN AREA DATA USED IN ESTIMATING STORMWATER AND COMBINED SEWER OVERFLOW CONTROL COSTS

The following table displays the data used in the Urban Stormwater and Combined Sewer Overflow Control Program (listed in Appendix 1). The column headings are defined as follows:

City: name of city, truncated or abbreviated in some cases to fit in a 12-character field. In some cases two listings are included for a given city (e.g. Milwaukee 1 and Milwaukee 2) where the area has been split into sub-areas, one served by combined sewers, the other by storm sewers.

State: state name abbreviated to four characters or less.

HA: 3-digit hydrologic area number within which the city is located.

Bacti: indicates whether or not a given city was considered to be a potential bacteria source.

Adjusted Urban Area: the estimated urban area served by combined or storm sewers, in acres.

Adjusted Population: the estimated urban area population served by combined or separate sewers.

Average Precip: the estimated average annual precipitation, in inches.

Days With Precip: the average number of days per year with measurable precipitation.

Combined Sewers: the fraction of the area served by combined sewers.

CS Drain Area: the average drainage area for a combined sewer overflow estimated on a statewide basis, in acres.

Cost Index: the U.S. EPA regional cost adjustment factor used to correct for variations in labor and capital costs.

Growth Rate: the estimated average annual growth rate, in precent, based on projections from the Great Lakes Regional National Assessment.

URBAN AREA DATA USED IN ESTIMATING

STORMWATER AND COMBINED SEWER OVERFLOW CONTROL COSTS

CITY	STATE	HA	BACTI?	ADJUSTED AREA (ACRES)	ADJUSTED POPULATION	AVERAGE PRECIP	DAYS WITH PRECIP	COMBINED SEWERS	CS DRAIN AREA	COST INDEX	GROWTH RATE
DULUTH	MINN	112	YES	5300.	64000.	28.97	135.	0.49	256.	0.9091	0.001
CLOQUET	MINN	112	NO	440.	6180.	28.97	135.	0.34	256.	0.9091	0.001
SILVER BAY	MINN	111	NO	870.	2490.	28.97	135.	0.34	256.	0.9091	0.001
TWO HARBORS	MINN	111	NO	400.	3150.	28.97	135.	0.34	256.	0.9091	0.001
SUPERIOR	WISC	112	YES	1800.	18000.	28.97	135.	0.0	228.	0.9091	0.001
ASHLAND	WISC	113	YES	2200.	6440.	28.97	135.	0.19	228.	0.9091	0.001
MARQUETTE	MICH	125	YES	2460.	16700.	28.97	121.	0.0	442.	0.9091	0.001
NEGUANEE	MICH	125	NO	3140.	3990.	26.51	121.	1.00	442.	0.9091	0.001
ISHPEMING	MICH	125	NO	1950.	6270.	26.51	121.	0.25	442.	0.9091	0.001
HOUGHTON	MICH	123	NO	450.	4610.	28.97	135.	1.00	442.	0.9091	0.001
HANCOCK	MICH	123	NO	400.	3660.	28.97	135.	1.00	442.	0.9091	0.001
MUNISING	MICH	126	NO	1190.	2790.	26.51	121.	0.50	442.	0.9091	0.001
L'ANSE	MICH	124	NO	510.	1930.	26.51	121.	0.60	442.	0.9091	0.001
IRONWOOD	MICH	115	NO	1300.	6880.	26.51	121.	0.60	442.	0.9091	0.001
APPLETON	WISC	216	YES	7000.	100000.	28.23	121.	0.29	208.	1.0330	0.004
GREEN BAY	WISC	216	YES	5400.	58000.	26.51	121.	0.17	217.	1.0330	0.004
MARINETTE	WISC	212	NO	1030.	8930.	26.51	121.	0.19	216.	1.0330	0.004
OCONTO	WISC	214	NO	1080.	3130.	26.51	121.	0.19	216.	1.0330	0.004
MANITOWOC	WISC	217	YES	1710.	22400.	26.51	121.	0.19	216.	1.0330	0.004
SHEBOYGAN	WISC	217	YES	1600.	32480.	28.12	121.	0.19	216.	1.0330	0.004
SHEBOYGAN FA	WISC	217	NO	330.	3160.	28.12	121.	0.19	216.	1.0330	0.004
ALGOMA	WISC	217	NO	370.	2690.	28.12	121.	0.19	216.	1.0330	0.004
KEWAUNEE	WISC	217	NO	530.	1940.	26.51	121.	0.19	216.	1.0330	0.004
KIEL	WISC	217	NO	200.	1910.	28.12	121.	0.19	216.	1.0330	0.004
PLYMOUTH	WISC	217	NO	370.	3890.	28.12	121.	0.19	216.	1.0330	0.004
PESHTIGO	WISC	213	NO	960.	1900.	26.51	121.	0.19	216.	1.0330	0.004
OCONTO FALLS	WISC	214	NO	830.	1686.	26.51	121.	0.19	216.	1.0330	0.004
P. WASHINGTO	WISC	221	NO	520.	6210.	27.57	119.	0.19	216.	1.0330	0.008
WEST BEND	WISC	221	NO	1060.	11090.	27.57	119.	0.19	216.	1.0330	0.008
UNION GROVE	WISC	221	NO	150.	1810.	27.57	119.	0.19	216.	1.0330	0.008
MILWAUKEE 1	WISC	221	YES	17800.	419000.	27.57	119.	1.00	154.	1.0330	0.008
MILWAUKEE 2	WISC	221	YES	55900.	362000.	27.57	119.	0.0	230.	1.0330	0.008
RACINE	WISC	221	YES	8800.	99000.	31.95	119.	0.0	230.	1.0330	0.008
KENOSHA 1	WISC	221	YES	1400.	20000.	31.95	119.	1.00	154.	1.0330	0.008
KENOSHA 2	WISC	221	YES	6800.	65000.	31.95	119.	0.0	230.	1.0330	0.008
MICHIGAN CIT	INDI	221	YES	3690.	29920.	33.49	120.	0.75	365.	1.1570	0.008
TRAIL CREEK	INDI	221	NO	210.	2050.	33.49	120.	0.75	365.	1.1570	0.008
LONG BEACH	INDI	221	NO	200.	2080.	33.49	120.	0.75	365.	1.1570	0.008
CHICAGO METR	INDI	221	YES	54000.	757000.	33.49	120.	0.60	365.	1.1570	0.008
SOUTH BEND	INDI	231	YES	20200.	175000.	33.59	136.	1.00	365.	1.1570	0.008
ESCANABA	MICH	211	YES	2820.	12140.	26.51	121.	0.60	442.	1.0330	0.001
MENOMINEE	MICH	212	YES	990.	13020.	26.51	121.	0.60	442.	1.0330	0.001

URBAN AREA DATA (CONTINUED)

CITY	STATE	HA	BACTI?	ADJUSTED AREA (ACRES)	ADJUSTED POPULATION	AVERAGE PRECIP	DAYS WITH PRECIP	COMBINED SEWERS	CS DRAIN AREA	COST INDEX	GROWTH RATE
BENTON HARBO	MICH	231	YES	800.	13020.	35.59	136.	0.60	442.	1.1570	0.008
ST. JOSEPH	MICH	231	NO	830.	8720.	35.59	136.	0.60	442.	1.1570	0.008
GRAND HAVEN	MICH	235	NO	1160.	9360.	31.19	137.	0.60	442.	1.0330	0.008
SPRING LAKE	MICH	235	NO	340.	2400.	31.19	137.	0.60	442.	1.0330	0.008
BUCHANAN	MICH	231	NO	450.	3670.	35.59	136.	0.60	442.	1.1570	0.008
DOWAGIC	MICH	231	NO	580.	5200.	35.59	136.	0.60	442.	1.1570	0.008
ST. JOHNS	MICH	235	NO	670.	5270.	31.18	137.	0.60	442.	1.0080	0.008
IONIA	MICH	235	NO	560.	5020.	31.19	137.	0.60	442.	1.0080	0.008
LOWELL	MICH	235	NO	670.	2420.	31.19	137.	0.60	442.	1.0330	0.008
HARTFORD	MICH	231	NO	220.	1980.	34.48	137.	0.60	442.	1.1570	0.008
SOUTH HAVEN	MICH	232	NO	540.	5110.	34.48	137.	0.60	442.	1.1570	0.008
GRAND RAPIDS	MICH	235	YES	18400.	248000.	31.19	137.	0.27	442.	1.0330	0.008
M SOUTH BEND	MICH	231	NO	3050.	18500.	35.59	136.	0.60	442.	1.1570	0.008
NILES	MICH	231	NO	1170.	10260.	34.48	137.	0.60	442.	1.1570	0.008
CHARLEVOIX	MICH	244	NO	400.	2780.	26.73	129.	0.60	442.	1.0330	0.005
PETOSKEY	MICH	244	NO	900.	5010.	26.73	129.	0.60	442.	1.0330	0.005
TRAVERSE CIT	MICH	244	YES	1750.	14260.	30.07	140.	0.60	442.	1.0330	0.005
MANISTEE	MICH	243	NO	760.	6100.	30.07	140.	0.60	442.	1.0330	0.005
LUDINGTON	MICH	242	NO	720.	7130.	30.07	140.	0.60	442.	1.0330	0.005
MANISTIQUE	MICH	245	NO	740.	3420.	26.51	126.	0.60	442.	1.0330	0.005
MUSKEGON	MICH	241	NO	11720.	83520.	30.07	140.	0.60	442.	1.0330	0.005
S. ST. MARIE	MICH	311	YES	3520.	11960.	26.73	129.	0.60	442.	0.9091	0.001
CHEBOYGAN	MICH	312	NO	1550.	4390.	26.73	129.	0.60	442.	0.9091	0.020
ALPENA	MICH	314	YES	1660.	10910.	26.73	129.	0.60	442.	0.9091	0.020
ROGERS CITY	MICH	313	NO	940.	3380.	26.73	129.	0.60	442.	0.9091	0.020
BAY CITY	MICH	322	YES	5200.	45000.	26.73	129.	1.00	442.	1.0080	0.010
FLINT	MICH	322	YES	20700.	248000.	26.73	129.	0.05	442.	1.0080	0.010
SAGINAW	MICH	322	YES	11500.	103000.	26.73	129.	1.00	442.	1.0080	0.010
BURTON	MICH	322	NO	2240.	25710.	26.73	129.	0.60	442.	1.0080	0.010
ITHACA	MICH	322	NO	900.	2170.	26.73	129.	0.60	442.	1.0080	0.010
CHESANING	MICH	322	NO	630.	2270.	26.73	129.	0.60	442.	1.0080	0.010
CARO	MICH	322	NO	360.	3180.	26.73	129.	0.60	442.	1.0080	0.010
DURAND	MICH	322	NO	270.	2910.	26.73	129.	0.60	442.	1.0080	0.010
OWOSSO	MICH	322	NO	1050.	13570.	26.73	129.	0.60	442.	1.0080	0.010
SWARTZ CREEK	MICH	322	NO	920.	3890.	26.73	129.	0.60	442.	1.0080	0.010
HOWELL	MICH	322	NO	690.	4130.	26.73	129.	0.60	442.	1.0080	0.010
CORRUNNA	MICH	322	NO	690.	13570.	26.73	129.	0.60	442.	1.0080	0.010
DETROIT1	MICH	414	YES	166200.	2475000.	30.95	130.	1.00	442.	1.0080	0.008
DETROIT2	MICH	414	YES	67400.	804000.	30.95	130.	0.0	442.	1.0080	0.008
PORT HURON	MICH	412	YES	1680.	28280.	30.95	130.	0.60	442.	1.0080	0.008
ST CLAIR	MICH	412	NO	720.	3770.	30.95	130.	0.60	442.	1.0080	0.008
ADRIAN	MICH	417	NO	1300.	16100.	31.84	131.	0.60	442.	1.0080	0.008
TECUMSEH	MICH	417	NO	940.	5630.	30.67	130.	0.60	442.	1.0080	0.008
MONROE	MICH	417	YES	2060.	18876.	31.84	131.	0.60	442.	1.0080	0.008
ALGONAC	MICH	412	NO	270.	2910.	30.95	130.	0.60	442.	1.0080	0.008

URBAN AREA DATA (CONTINUED)

CITY	STATE	HA	BACTI?	ADJUSTED AREA (ACRES)	ADJUSTED POPULATION	AVERAGE PRECIP	DAYS WITH PRECIP	COMBINED SEWERS	CS DRAIN AREA	COST INDEX	GROWTH RATE
MARINE CITY	MICH	412	NO	520.	3610.	30.95	130.	0.60	442.	1.0080	0.008
MARYSVILLE	MICH	412	NO	1500.	4430.	30.95	130.	0.60	442.	1.0080	0.008
MILAN	MICH	417	NO	360.	3580.	30.67	130.	0.60	442.	1.0080	0.008
SALINE	MICH	417	NO	560.	3800.	30.67	130.	0.60	442.	1.0080	0.008
TOLEDO, MICH	MICH	417	NO	1550.	4520.	31.84	131.	0.60	442.	1.0080	0.008
ARCHBOLD	OHIO	422	NO	270.	2320.	31.84	131.	0.43	142.	1.0080	0.011
FINDLAY	OHIO	422	NO	2040.	27210.	36.28	132.	0.43	142.	1.0080	0.011
FOSTORIA	OHIO	423	NO	990.	12190.	31.84	131.	0.43	142.	1.0080	0.011
NAPOLEON	OHIO	422	NO	1060.	5920.	31.84	131.	0.43	142.	1.0080	0.011
BELLEVUE	OHIO	425	NO	570.	6540.	34.03	156.	0.43	142.	1.0740	0.011
NORWALK	OHIO	425	NO	1040.	10170.	34.03	156.	0.43	142.	1.0740	0.011
WILLARD	OHIO	425	NO	970.	4190.	34.03	156.	0.43	142.	1.0740	0.011
WATERVILLE	OHIO	422	NO	300.	2230.	31.84	131.	0.43	142.	1.0080	0.011
CELINA	OHIO	422	NO	410.	6140.	36.28	132.	0.43	142.	1.0080	0.011
PORT CLINTON	OHIO	423	NO	320.	5470.	31.84	131.	0.43	142.	1.0080	0.011
OAK HARBOR	OHIO	422	NO	200.	2133.	31.84	131.	0.43	142.	1.0080	0.011
ADA	OHIO	422	NO	180.	4040.	31.84	131.	0.43	142.	1.0080	0.011
PAULDING	OHIO	422	NO	160.	2267.	34.21	129.	0.43	142.	1.0080	0.011
OTTAWA	OHIO	422	NO	360.	2750.	36.28	132.	0.43	142.	1.0080	0.011
FREMONT	OHIO	424	YES	950.	14050.	31.84	131.	0.43	142.	1.0080	0.011
CLYDE	OHIO	425	NO	430.	4180.	31.84	131.	0.43	142.	1.0740	0.011
GIBSONBURG	OHIO	423	NO	180.	1960.	31.84	131.	0.43	142.	1.0080	0.011
TIFFEN	OHIO	424	NO	1000.	16410.	31.84	131.	0.43	142.	1.0080	0.011
LIMA	OHIO	422	NO	10100.	70000.	36.28	132.	1.00	142.	1.0080	0.011
CAREY	OHIO	424	NO	230.	2680.	36.28	132.	0.43	142.	1.0080	0.011
DELPHOS	OHIO	422	NO	270.	5780.	36.28	132.	0.43	142.	1.0080	0.011
WAPAKONETA	OHIO	422	NO	730.	5570.	36.28	132.	0.43	142.	1.0080	0.011
ST. MARYS	OHIO	422	NO	680.	5850.	36.28	132.	0.43	142.	1.0080	0.011
BUCYRUS	OHIO	424	NO	590.	9960.	36.28	132.	0.43	142.	1.0080	0.011
CRESTLINE	OHIO	424	NO	360.	4520.	31.84	131.	0.43	142.	1.0080	0.011
DEFIANCE	OHIO	422	NO	1090.	12370.	36.28	132.	0.43	142.	1.0080	0.011
HURON	OHIO	425	NO	930.	5240.	34.03	156.	0.43	142.	1.0740	0.011
SANDUSKY	OHIO	425	YES	1630.	24830.	34.03	156.	0.43	142.	1.0740	0.011
SWANTON	OHIO	422	NO	140.	2220.	31.84	131.	0.43	142.	1.0080	0.011
DELTA	OHIO	422	NO	269.	1930.	31.84	131.	0.43	142.	1.0080	0.011
WAUSEON	OHIO	422	NO	680.	3750.	31.84	131.	0.43	142.	1.0080	0.011
VAN WERT	OHIO	422	NO	720.	8600.	36.28	132.	0.43	142.	1.0080	0.011
BOWLING GREE	OHIO	423	NO	1170.	16540.	31.84	131.	0.43	142.	1.0080	0.011
N. BALTIMORE	OHIO	423	NO	290.	2390.	31.84	131.	0.43	142.	1.0080	0.011
U. SANDUSKY	OHIO	424	NO	470.	4290.	36.28	132.	0.43	142.	1.0080	0.011
TOLEDO 1	OHIO	422	YES	15900.	204000.	31.84	131.	1.00	142.	1.0080	0.011
TOLEDO 2	OHIO	422	YES	11900.	142000.	31.84	131.	0.0	142.	1.0080	0.011
AKRON	OHIO	432	YES	28600.	389000.	37.26	141.	0.0	142.	1.0740	0.006
CLEVELAND	OHIO	432	YES	93600.	1589000.	32.08	156.	0.42	142.	1.0740	0.006
CHARDON	OHIO	434	NO	900.	3030.	32.08	156.	0.43	142.	1.0740	0.006

URBAN AREA DATA (CONTINUED)

CITY	STATE	HA	BACTI?	ADJUSTED AREA (ACRES)	ADJUSTED POPULATION	AVERAGE PRECIP	DAYS WITH PRECIP	COMBINED SEWERS	CS DRAIN AREA	COST INDEX	GROWTH RATE
ASHTABULA	OHIO	435	YES	1270.	18480.	37.50	157.	0.43	142.	1.0740	0.006
OBERLIN	OHIO	431	NO	590.	6650.	34.03	156.	0.43	142.	1.0740	0.006
WELLINGTON	OHIO	431	NO	720.	3140.	34.03	156.	0.43	142.	1.0740	0.006
MEDINA	OHIO	431	NO	1310.	8290.	37.26	141.	0.43	142.	1.0740	0.006
RAVENNA	OHIO	432	NO	900.	8950.	32.08	156.	0.43	142.	1.0740	0.006
HUDSON	OHIO	432	NO	660.	2990.	37.26	141.	0.43	142.	1.0740	0.006
LOR-EL 1	OHIO	431	YES	100.	5000.	34.03	156.	1.00	142.	1.0740	0.006
LOR-EL 2	OHIO	431	YES	9700.	119000.	34.03	156.	0.0	142.	1.0740	0.006
FORT WAYNE	INDI	422	NO	12000.	170000.	34.21	129.	0.68	365.	1.0080	0.011
AUBURN	INDI	422	NO	540.	5620.	34.21	129.	0.75	365.	1.0080	0.011
GARRETT	INDI	422	NO	290.	3580.	34.21	129.	0.75	365.	1.0080	0.011
BERNE	INDI	422	NO	220.	2270.	34.21	129.	0.75	365.	1.0080	0.011
DECATUR	INDI	422	NO	500.	6420.	34.21	129.	0.75	365.	1.0080	0.011
ERIE	PENN	441	YES	12800.	144000.	37.50	157.	0.16	141.	1.0740	0.003
GIRARD	PENN	441	NO	600.	2220.	37.50	157.	0.18	141.	1.0740	0.003
NORTH EAST	PENN	441	NO	420.	3270.	37.50	157.	0.18	141.	1.0740	0.003
BUFFALO 1	NY	443	YES	38300.	642000.	35.65	165.	1.00	208.	1.0740	0.003
BUFFALO 2	NY	441	YES	32400.	296000.	35.65	165.	0.0	208.	1.0740	0.003
DUNKIRK	NY	441	YES	1740.	16180.	37.50	157.	0.51	208.	1.0740	0.003
FREDONIA	NY	441	NO	2110.	9910.	37.50	157.	0.51	208.	1.0740	0.003
SILVER CREEK	NY	442	NO	450.	3060.	36.50	160.	0.51	208.	1.0740	0.003
WESTFIELD	NY	441	NO	1430.	3510.	37.50	157.	0.51	208.	1.0740	0.003
ALDEN	NY	443	NO	1020.	2540.	35.65	165.	0.51	208.	1.0740	0.003
EAST AURORA	NY	443	NO	910.	6750.	35.65	165.	0.51	208.	1.0740	0.003
SPRINGVILLE	NY	443	NO	1090.	4180.	35.65	165.	0.51	208.	1.0740	0.003
ANGOLA	NY	443	NO	450.	2570.	35.65	165.	0.51	208.	1.0740	0.003
AKRON	NY	443	NO	680.	2750.	35.65	165.	0.51	208.	1.0740	0.003
LOCKPORT	NY	512	NO	3090.	24380.	31.51	153.	0.51	208.	1.0740	0.016
BROCKPORT	NY	512	NO	790.	7560.	31.51	153.	0.51	208.	1.0740	0.016
SPENCERPORT	NY	512	NO	490.	2810.	31.51	153.	0.51	208.	1.0740	0.016
ALBION	NY	512	NO	940.	4920.	31.51	153.	0.51	208.	1.0740	0.016
NIAGARA FALL	NY	511	YES	5060.	82190.	31.51	153.	0.51	208.	1.0740	0.016
LEWISTON	NY	511	NO	380.	3160.	31.51	153.	0.51	208.	1.0740	0.016
ROCHESTER	NY	512	YES	28700.	483000.	31.51	153.	0.50	208.	1.0740	0.016
MT MORRIS	NY	512	NO	1320.	3280.	31.51	153.	0.51	208.	1.0740	0.016
LE ROY	NY	512	NO	1280.	4910.	31.51	153.	0.51	208.	1.0740	0.016
AVON	NY	512	NO	1130.	3130.	31.51	153.	0.51	208.	1.0740	0.016
GENESEO	NY	512	NO	1020.	5480.	31.51	153.	0.51	208.	1.0740	0.016
DANSVILLE	NY	512	NO	870.	5220.	31.51	153.	0.51	208.	1.0740	0.016
WARSAW	NY	512	NO	1510.	3470.	31.51	153.	0.51	208.	1.0740	0.016
FAIRPORT	NY	512	NO	600.	6220.	31.51	153.	0.51	208.	1.0740	0.016
BALDWINSVILL	NY	522	NO	870.	6050.	37.60	167.	0.51	208.	1.3220	0.008
FULTON	NY	522	YES	1400.	13440.	37.60	167.	0.51	208.	1.3220	0.008
OSWEGO	NY	522	YES	2940.	20090.	37.60	167.	0.51	208.	1.3220	0.008
PHOENIX	NY	522	NO	380.	2510.	37.60	167.	0.51	208.	1.3220	0.008
WATERTOWN	NY	531	YES	3470.	29560.	39.73	167.	0.51	208.	1.3220	0.002

URBAN AREA DATA (CONTINUED)

CITY	STATE	HA	BACTI?	ADJUSTED AREA (ACRES)	ADJUSTED POPULATION	AVERAGE PRECIP	DAYS WITH PRECIP	COMBINED SEWERS	CS DRAIN AREA	COST INDEX	GROWTH RATE
CARTHAGE	NY	531	NO	760.	3730.	39.73	167.	0.51	208.	1.3220	0.002
LOWVILLE	NY	531	NO	640.	3520.	39.73	167.	0.51	208.	1.3220	0.002
CANTON	NY	533	NO	530.	6140.	39.73	167.	0.51	208.	1.3220	0.002
OGDENSBURG	NY	534	YES	1770.	13970.	39.73	167.	0.51	208.	1.3220	0.002

APPENDIX 3

LAND COVER DATA

The land cover information presented in Chapters 3 through 7 was taken from "Land Cover Analysis for the United States Great Lakes Watersheds," prepared by Monteith and Jarecki, for PLUARG. The analysis is based on LANDSAT imagery collected primarily in 1976 and 1977. Interpretation of the LANDSAT data tapes was done by the General Electric Corporation.

Eleven land cover classes (described below) were defined and applied throughout the U.S. Great Lakes basin. Two of the classes (evergreen forest and extractive), while not applicable throughout the basin, were of sufficient importance to be extracted whenever possible. In scenes where they were not extractable, these classes were combined with mixed forest and barren, respectively.

Miscellaneous land cover classes found only in local geographic areas were combined with the best suited of the eleven global classes. For example, harvested forest, which was apparent only in Minnesota was combined with the brushland class.

Often, some of the eleven classes were composites of two or more types of land cover. This was particularly the case for the residential class. Residential areas are typically spanned by a wide range of land cover, depending on varying population densities and length of time since development. They do not exhibit unique spectral characteristics. For some of the scenes, up to three local residential classes were extracted and then combined to form the global residential class.

It is important to realize that the information derived from this anlaysis describes the <u>land cover</u> of the Basin watersheds, derived from its reflectance characteristics and recorded by LANDSAT multispectral scanners - it is not an inventory of land uses throughout the Basin.

CLASS DEFINITIONS AND COMMENTS

<u>Water</u> - A geographic distinction was made between water within the Great Lakes themselves and the water within inland lakes and rivers. Area tabulations pertain to inland waters only and thus reflect land cover area in the subbasins.

<u>Wetlands</u> - Areas classified as wetland include those where land cover is a mixture of water and vegetation, and those areas inundated with water often enough to restrict vegetation to marsh species. Forested wetlands with nearly complete canopy closure are not included.

Coniferous or Evergreen Forest - This class was extracted when it covered large enough contiguous areas to create the predominant land cover and thus display, spectrally, a sharp contrast to deciduous forest. The class was apparent only in the northernmost portions of the basin and was particularly good around Lake Superior and in the Adirondack Mountains of New York. Where both types of forest were present, the evergreens seemed concentrated spatially in the poorly drained low lying areas, sometimes appearing as rings around the more well-drained hills.

Deciduous or Mixed Forest - In the southern portions of the basin where forest is predominantly deciduous, and in portions where the percentage of land covered by forest is small, this class represents total forest. In northern areas where evergreens could be classified, the mixed forest class represents only the deciduous component of total forest.

Brushland - This is a class comprised of very low density forest, harvested forest, scrub, and neglected farms. Those picture elements covering a mixture of barren and vegetated areas are also usually included in this class.

Grassland - This class represents most areas other than forest which are completely and densely covered with lush vegetation. Its main component was pastureland, making it a major class in Wisconsin and New York. Also included were open parks, golf course, and any grass crops characterized by full ground coverage at the image acquisition date.

Plowed Field - The plowed field class is defined to contain any areas characterized by bare, recently cultivated soil at the date of image acquisition or which contained crops with a small percent of ground coverage. Image dates were primarily in May, so a shortcoming of the class is that any crops such as winter wheat which had achieved full ground coverage are omitted. In unpopulated areas, total agriculture will be the sum of recently plowed fields and grassland classes.

High Density Residential - This class is especially difficult to extract due to the wide range of land cover involved. For most of the images, a minimum of two spectral signatures were required, one for recently developed suburbs with minimal vegetation, and one for older suburbs containing trees, higher housing densities, and weathered rooftops. The class is quite good near the large population centers of the basin and in small city centers. In some of the more remote areas containing only small villages, no high density residential class was extracted.

Commercial - This class is comprised of areas within cities which were totally devoid of vegetation and areas which have been discolored by industrial practices.

Barren - This class includes any areas of high reflectance devoid of vegetation, such as sand, beaches and areas of recent construction. Outside of the Lake Superior basin, it also includes extractive areas. In the Tables provided the barren class also includes the following three classes:

Extractive - This class was used only in the Lake Superior region where significant mining activity was being carried out. It includes both extractive areas and mine tailings.

Burn Area - One unexpected result of the project was the mapping of the Seney fire burn scar. The fire occurred in Michigan in the fall of 1976. Image #2870-15325, acquired in May of the following year, clearly showed the large area that had been consumed by fire. This is present in Schoolcraft County and the Manistique River basin. The area covered is approximately 212 square kilometers (82 square miles).

Clouds - When they appeared, clouds and cloud shadows were classified. Most areas of the basin were covered by two images because of image side lap and it was possible to work around nearly all the cloud affected areas of the image set. The only place where cloud cover significantly interfered with classification was a small area in the vicinity of Erie, Pennsylvania.