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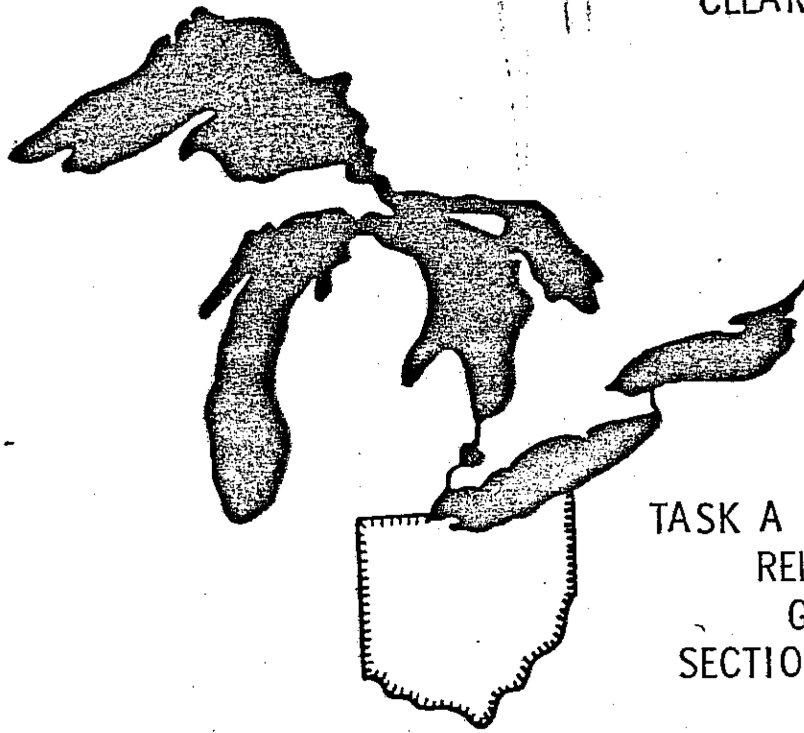

TASK A LAND USE/WATER QUALITY RELATIONSHIPS IN THE GREAT LAKES BASIN
SECTION 12 UNDEVELOPED LAND

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TABLE 7 (Con't).

Planning Subarea	Lake Basin	Area in 1,000 Acres (400 Hectares)							
		1967		1980		2000		2020	
		Forest Areas	Other Natural Areas	Forest Areas	Other Natural Areas	Forest Areas	Other Natural Areas	Forest Areas	Other Natural Areas
4.1	Erie	666	222	605	222	519	173	462	154
4.2	Erie	453	349	449	346	441	339	432	333
4.3	Erie	539	288	494	264	411	220	343	183
4.4	Erie	1,365	109	1,337	107	1,288	103	1,243	99
5.1	Ontario	872	98	860	97	843	95	823	93
5.2	Ontario	2,546	428	2,510	422	2,465	415	2,417	407
5.3	Ontario	2,215	136	2,215	136	2,210	136	2,205	135
Basin Total	Great Lakes	39,625	4,853	39,327	4,706	38,863	4,493	38,430	4,317
Percent of 1967 Area	Great Lakes	100.0%	100.0%	99.7%	95.6%	98.1%	93.5%	97.0%	90.0%

12.4 Summary of Ongoing or Proposed Research, Demonstration, or Monitoring Programs

12.4.1 Nature of Studies and Relevancy

Owing to the fact that natural pollution is not a major contributor to the degradation of stream and lake water quality (other than the long-term natural eutrophication process) and the realization that these kinds of impurities would be difficult to control, there has been only a limited amount of research on this topic. The present inventory has uncovered only a few investigations that are presently ongoing or proposed. These are summarized below:

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1. Project Topic: Natural Weatering and Chemical Load in the Great Lakes
2. Investigator(s): Dr. Sam B. Upchurch and Associates
3. Institution or Agency: Michigan State University, Department of Geology and Lake Survey Center, NOAA
4. Period of Program: 1968-present
5. Objectives: To determine the natural and cultural chemical loads to each of the Great Lakes and develop mathematical models.
6. Relevancy: Study will yeild an estimate of steady state inputs prior to habitization of the Basin.

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1. Project Topic: The Nutrient Cycles of a Forest and Stream Ecosystem
2. Investigator(s): Gene E. Likens and Associates
3. Institution or Agency: Cornell University, Ithica, New York
4. Period of Program: 1970-present
5. Objectives: To determine how a natural ecosystem works, what the inputs and outputs are and how they occur.
6. Relevancy: The study will provide data on the effect of a forested watershed on the stream.

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1. Project Topic: Shoreline Studies of Great Lakes States
2. Investigator(s): North Central Division, U.S. Army Corps of Engineers
3. Institution or Agency: U.S. Army Corps of Engineers
4. Period of Program: 1877-present
5. Objectives: To study shoreline erosion and land use.
6. Relevancy: This study indicates shore uses and shoreline erosion rates.

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1. Project Topic: Shore Erosion on the Southern Shore of Lake Erie
2. Investigator(s): Charles Carter and Associates
3. Institution or Agency: Ohio Geological Survey
4. Period of Program: 1953-present
5. Objectives: To study shore erosion along the Ohio shoreline of Lake Erie.
6. Relevancy: This study provides data concerning bedrock geology and erosion rates.

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1. Project Topic: Red Clay Soils of Northwestern Wisconsin and Lake Superior Shoreline
2. Investigator(s): Interagency Red Clay Committee
3. Institution or Agency: Wisconsin Soil Conservation Board
4. Period of Program: 1958-present
5. Objectives: To study land use problems on the red clay soils of northwestern Wisconsin and to determine the cause of extreme sedimentation in lakes and streams.
6. Relevancy: Study provides data on natural pollution from the red clay soils.

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1. Project Topic: Water Resource Planning in the Great Lakes Region
2. Investigator(s): Forest Service Scientists
3. Institution or Agency: U.S. Forest Service
4. Period of Program: Continuing
5. Objectives: To determine objectives and needs for those land areas and waters influenced by the National Forests
6. Relevancy: Information concerning quantity, timing, and quality of flows and lakes is available.

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1. Project Topic: Water Resource Management in the Great Lakes Region
2. Investigator(s): National Forest Service Scientists
3. Institution or Agency: U.S. Forest Service
4. Period of Program: Continuing
5. Objectives: To evaluate the influence of various land management practices of the Forest Service upon the quality of the water resources of the seven National Forests within the Great Lakes Basin.
6. Relevancy: Provides information concerning the quality of water entering the Great Lakes from the forested watershed.

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1. Project Topic: Abatement, Prevention and Control of Water Quality Problems in the Great Lakes Basin
2. Investigator(s): Environmental Protection Agency
3. Institution or Agency: Environmental Protection Agency
4. Period of Program: Continuing
5. Objectives: To abate, prevent, and control all water quality problems.
6. Relevancy: Provides information on water quality problems in the Great Lakes Basin.

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1. Project Topic: Nutrient enrichment of Great Lakes Waters
2. Investigator(s): Agricultural Experimental Stations
3. Institution or Agency: U.S. Dept. of Agriculture
4. Period of Program: Continuing
5. Objectives: To determine the contribution of soil erosion and water runoff and the role of sediment-nitrogen and sediment-phosphorus interactions in eutrophication
6. Relevancy: Provides information on various nutrient inputs to the Great Lakes.

12.5 Nature and Availability of Technology to Cope with Pollution Problem

The technology available concerning natural pollution is very limited. Although the problem has exsisted since the geologic formation of the area, man's interest has only recently been aroused.

Upchurch (54) used the formula: natural load=weathering+precipitation when working with levels of natural pollution in the Great Lakes Basin. The formula appears to be an effective tool but only continued testing will be an accurate evaluation of its effectiveness.

Hilty and Kinkle (27) determined the outflow components from natural areas by studying the hydrography of the area. They were then able to express this in a flow diagram. This system was developed for work in the Great Lakes Basin and provides the sources and quantities of the pollutants.

The U.S. Forest Service (21) has developed a method to relate silviculture practices to the quality of the water leaving the forests in the Great Lakes Basin. The method is new and needs to be evaluated.

The Red Clay Interagency Committee (37) has developed a number of techniques that can and are being used in Wisconsin to prevent the natural pollution of Lake Superior from the red clay banks. Among these techniques are seeding, mulching and bank stabilization. These methods hold promise for the control of the Wisconsin red clay problem.

Likens and associates (6, 12, 5) developed techniques for determining the ecological relationship between a forested watershed and the streams draining it. The study in which the techniques were used was done by the Hubburd Brook Experimental Forest Station, New Hampshire. Meteorological inputs were measured by a network of gauging stations. Geologic outputs were measured by means of a weir built at the foot of each watershed. Using the weir, which also contained a ponding basin, the water leaving the watershed could be measured and, by combining these data with frequent chemical measurements the quantities of chemical substances that are leaving the watershed could be ascertained. This study could provide valuable data indicating how proper management could reduce material pollution levels.

12.6 Need for New Research, Demonstration or Monitoring Programs

The study of natural pollution is a relatively new field, though the problem and processes have been occuring throughout man's exsistence. There are many important questions that need to be answered. A good starting point would be to define, or determine what the natural pollution problem is. This should then be followed by an evaluation program to determine the causes and extent of the problem. A third and final phase of the research effort should deal with two questions: a) can the natural pollution problem be controlled and b) does it need to be controlled.

There is also a need for studies to develop techniques to determine and measure the inputs and outputs of various natural land uses in the many watersheds of the Great Lakes Basin. The continuing projects dealing with natural pollution may provide these answers and techniques. New studies with these goals in mind could greatly speed up the knowledge acquisition process.

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12.8 Glossary

1. Barrens — A tract of natural land consisting mainly of rock, sand or glacial till which will not support vegetation due to the lack of a soil zone or absence of moisture. Oak and Pine Barrens are tracts containing predominately these types of trees which are widely spaced with a lack of understory plants.

2. Beach — The gently sloping shore of a body of water which is washed by waves, generally composed of sand or gravel and a lack of vegetation.

3. Bog — An area of soft, wet spongy ground consisting chiefly of decayed or decaying moss and other vegetable matter. It often forms in shallow, stagnant lakes or ponds, and is largely produced by sphagnum moss, from which eventually peat is evolved. Bogs may also be formed on cold, damp moutain surfaces.

4. Dune — Ridge or mound of loose, wind-blown material, usually sand.

5. Flood plain — The lowland that borders a river, usually dry but subject to flooding when the stream overflows its banks.

6. Marsh — A tract of soft, wet land, usually low-lying and partly or completely under water; the extreme dampness is due to the impermeable nature of the soil (such as clay) and the poor drainage.

7. Muskeg — The water portion of a moss peat bog; characterized by a strong acid reaction, an absence of oxygen and carbonates and a low specific conductance.

8. Natural area — A tract of land or waterway which is undisturbed by human activity.

9. Natural pollution — Soil, mineral or bidogical impurities picked up by water from the earth's surface, apart from any human activity.

10. Perched water body — A suspended, isolated body of groundwater occurring in a saturated zone, separated from the main body of groundwater by unsaturated, impermeable rock. The isolated body has its own local water table (perched water table).

11. Prairie — A tract of broad, flat land with chief vegetation being grasses; often treeless.

12. Swamp

A tract of low-lying land that is saturated with moisture and usually overgrown with vegetation. A marsh, unlike a swamp, is ordinarily covered with water; a bog, unlike a swamp, consists largely of decaying vegetation. The dampness of a swamp is due to some obstruction to normal drainage, because of the flatness of the land, the presence of impermeable rocks, or the growth of vegetation. A swamp is often formed in a lake basin as it fills up; because the surface is flat the rain water runs off very slowly, and the growth of vegetation in the damp soil helps maintain the swampy condition.

13. Undeveloped land

A tract of land that has not been altered for human purposes; also formerly developed land that has been abandoned and allowed to return or proceed toward a natural state.

14. Wetlands

Lowlands which are covered with shallow water most of the time; subject to temporary uncovering during dry periods.

12.3 Review of Findings of Previous Studies

12.3.1 General Description of Land Use Category

This section addresses a somewhat unique land use category in that the land under consideration is undeveloped and has no major land use. This type of land use can be considered synonomous with the term "natural areas". Natural areas within the Great Lakes region can be subdivided into many ecological types (Table 1). However, many of these classifications account for for only a small percentage of the undeveloped land in the Great Lakes drainage basin. This report will deal with those classifications which may have a significant impact on water quality.

TABLE 1

CLASSIFICATION OF NATURAL AREAS IN THE GREAT LAKES REGION

I. Wetlands
   A. Submerged lands (stream and lake bottoms)
   B. Marshes
   C. Muskegs
   D. Swamps

II. Marginal Lands
   A. Bogs
   B. Beaches and dunes
   C. Flood plains
   D. Banks and bluffs (stream and lake)
   E. Lands periodically flooded by perched water bodies

III. Uplands
   A. Barren lands (rock, sand, and glacial till)
   B. Praries and grasslands
   C. Forests and woodlots
   D. Old fields and abandoned lands

Forest lands occupy 15,850,000 hectares (39,625,000 acres) (46 percent) of the surface area of the Great Lakes Basin, submerged lands under small lakes and streams (exclusive of the Great Lakes) account for another 2,927,000 acres (3 percent), and all other natural areas total 4,853,000 acres or 55 percent of the Basin. Table 2 presents a breakdown of these three types of undeveloped areas by the Great Lakes Basin Commission Planning Subareas. The boundaries of the planning subareas (22) are shown in Figure 1.

TABLE 2

UNDEVELOPED AREAS IN THE GREAT LAKES BASIN

Planning Subarea	Lake Basin	Area in 1,000 Acres (400 Hectares)				
		Forest Lands	Other Natural Areas	Rivers, Lakes and Embayments	Total Undeveloped	Tota All U.
1.1	Superior	8,355	305	851	9,511	10,32
1.2	Superior	5,910	66	232	6,208	6,67
2.1	Michigan	5,117	757	391	6,265	10,40
2.2	Michigan	341	580	104	1,025	5,31
2.3	Michigan	1,705	598	171	2,474	9,12
2.4	Michigan	5,434	412	345	6,191	8,43
3.1	Huron	2,914	219	149	3,282	4,16
3.2	Huron	1,194	285	37	1,516	4,46
4.1	Erie	666	222	82	970	4,06
4.2	Erie	453	349	49	851	6,36
4.3	Erie	539	288	24	851	2,33
4.4	Erie	1,365	109	43	1,517	3,11
5.1	Ontario	872	98	18	988	2,47
5.2	Ontario	2,546	428	255	3,229	5,68
5.3	Ontario	2,215	136	176	2,527	3,56
Basin Total	Great Lakes	39,625	4,853	2,927	47,405	86,50
Percent of Basin	Great Lakes	46.0%	6.0%	3.0%	55.0%	100.0

Data Source: Benzmann and Kerr (4).

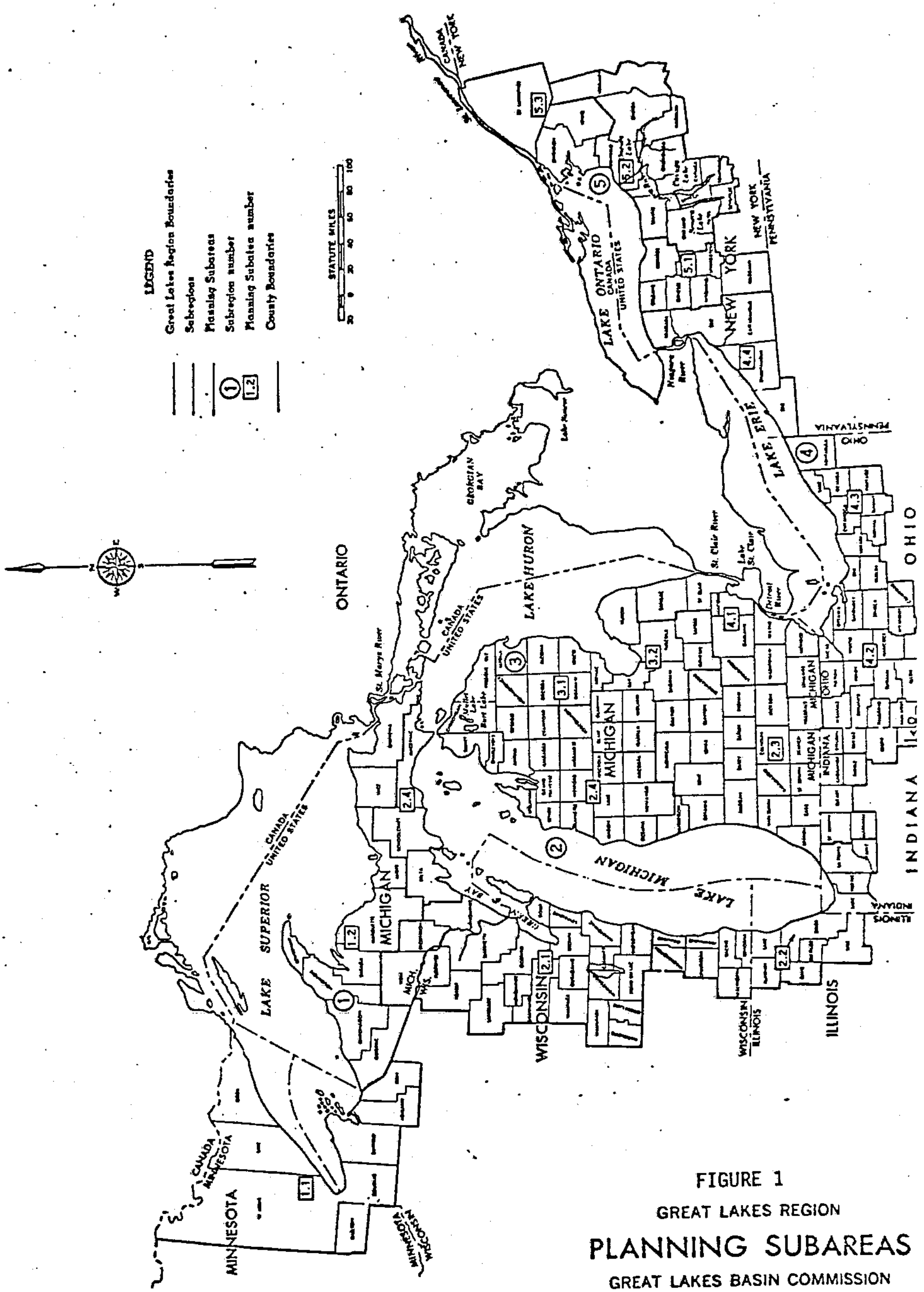

FIGURE 1

GREAT LAKES REGION

PLANNING SUBAREAS

GREAT LAKES BASIN COMMISSION

Forest lands taken together represent 84 percent of the total natural or undeveloped area in the Great Lakes Basin. These forest areas can be divided in terms of whether deciduous (hardwoods) or conifers (softwoods) predominate. Hardwoods have broad leaves and retain them only in the warmer part of the year. The hardwoods are the major component (76 percent) of the Basin's forest land. Conifers have needle-like leaves and with a few exceptions are in leaf throughout the year. The softwoods represent only 24 percent of the forest land in the Basin (4).

Two hardwood forest regions exist in the Great Lakes Basin. They differ in species, growing conditions and hydrologic characteristics. The northern hardwood region occupies the most northerly and elevated portion of the Basin and makes up 70 percent of the hardwood forest. To the north and east it merges imperceptibly into the conifer forests as the growing season becomes shorter and plant growth is limited by temperature rather than moisture availability. To the south it merges into the eastern hardwood region as the growing season becomes longer, and as rising summer temperatures reduce the available supply of soil moisture during the growing season. The major forest types are the maple-beech-birch type and the aspen-birch type. The eastern hardwood region is 30 percent of the hardwood forests and covers a great range in growing conditions. In the north and at higher elevations in the east its range is limited by low temperatures. There is a great variety in the natural vegetation and a growing season that is long and well supplied with rainfall. A great number of tree species can be found in this region. In the high land of the region, the oak-hickory type is present. The elm-ash-cottonwood forest type is dominant in the lowland (4).

The softwoods are made up of two distinct forest types, the spruce-fir type and the white-red-jack pine type. There distinction has a hydrologic significance. The spruce-fir type makes up 64 percent of the conifer forests and is variable in composition, depending primarily upon soil drainage conditions. In poorly drained locations conifers occupy the soil almost completely, but on well-drained areas it can be found mixed with northern hardwoods. The over-all appearance of spruce-fir type is of dense growth, with large openings present only where swamp waters are deep or where large areas of bare rock are exposed. The climate in which it is found is humid and temperature rather than moisture availability limits plant growth. The pine type is scattered throughout the northern portions of the Basin. The species involved are white, red, and jack pine. The climate over their range is cool and humid. This type is usually most closely associated with well-drained sandy soils and usually possess single-storied crown and open spaces beneath (4).

Submerged lands under major streams and lakes greater than 40 acres account for 10 percent of the undeveloped areas of the Great Lakes Basin. The remaining 6 percent of the undeveloped land in the Basin consists of all the other types of natural areas listed in Table 2 plus a minor amount of land use such as farm roads, ditch banks, fence and hedge rows, and idle land (4).

Natural fish and wildlife wetlands and marshes are located on Lakes Michigan, Huron, Erie, Ontario, St. Clair and in the St. Marys River.

However, the most extensive wetland areas are located along the west shore of Green Bay on Lake Michigan and in Saginaw Bay on Lake Huron and in Lake St. Clair. Other major wetland areas are located at the western end of Lake Erie and at the outlet of Lake Ontario to the St. Lawrence River. Lake Superior has the least amount of wetlands of any of the Great Lakes. Almost all of the wetlands in the Great Lakes are undiked. The only diked areas are located in Ohio. The State of Ohio pumps water in and out of these diked marshes to maintain a desirable water level for waterfowl (24).

12.3.2 Length of Time Activity in Practice

Undeveloped land or no activity is of course the oldest type and predates any other use of the land within the basin. The present landscape was formed as the last ice sheets of the Wisconsin glacier (Pleistocene Epoch) receded from the basin during the interval from 32,000 to 7,000 years ago. Due to crustal readjustment following deglaciation, the present water levels in the Great Lakes were not stabilized until about 4,000 years ago. Since that time soil zones have formed on the glacial till, many kettle lakes have passed through trophic stages to become bogs, and grasses and forests have undergone biological succession over most of the basin.

Some of the land area that has been lumbered, pastured or tilled during the past 200 years is no longer supporting these activities and has been allowed to return to undeveloped areas but still remains greatly altered from its natural state. The total acreage for such lands is not available but it is believed to be small for agricultural land but sizable for forested areas.

12.3.3 Types and Nature of Pollutants Associated with Land Use.

Because of the absence of any major use of the land under consideration in this section, impurities in the water drained from these areas can be considered as "natural pollutants." Natural waters, of course, are never pure. Turk, et al (51) have outlined the sources and nature of impurities found in natural waters (Table 3). All of the pollutants listed in Table 3 are contributed to the Great Lakes system from undeveloped land. The magnitude of this contribution has been determined for only a few parameters but is only vaguely known for others.

Chemical loading to the Great Lakes is a result of the interaction of natural weathering and cultural wastes. Natural weathering yields loads of constituents that reflect the lithology of the source terrane. Streams that drain areas of igneous and metamorphic bedrock (Figure 2) are generally subjected to lower chemical loads than streams from shale and limestone-dolomite terranes because weathering rates of silicate minerals are slower than those of calcite and dolomite. Streams that drain areas of glacial materials (Figure 3) are also high in chemical loads because of the unconsolidated nature and small particle sizes of the sediment (54). Natural or predevelopment rates have been estimated from historical data from Beeton(2).

TABLE 3

IMPURITIES IN NATURAL WATER

Source	Particle Size Classification				
	Suspended	Colloidal	Dissolved		
			Molecules	*Positive ions*	*Negative ions*
Atmosphere	←Dusts→		Carbon dioxide, CO_2 Sulfur dioxide, SO_2 Oxygen, O_2 Nitrogen, N_2	Hydrogen, H^+	Bicarbonate, HCO_3^- Sulfate, SO_4^{2-}
Mineral soil and rock	←Sand→ ←Clays→ ←Mineral soil particles→		Carbon dioxide, CO_2	Sodium, Na^+ Potassium, K^+ Calcium, Ca^{2+} Magnesium, Mg^{2+} Iron, Fe^{2+} Manganese, Mn^{2+}	Chloride, Cl^- Fluoride, F^- Sulfate, SO_4^{2-} Carbonate, CO_3^{2-} Bicarbonate, HCO_3^- Nitrate, NO_3^- Various phosphates
Living organisms and their decomposition products	Algae Diatoms Bacteria ←Organic soil (topsoil)→ Fish and other organisms	Viruses Organic coloring matter	Carbon dioxide, CO_2 Oxygen, O_2 Nitrogen, N_2 Hydrogen sulfide, H_2S Methane, CH_4 Various organic wastes, some of which produce odor and color	Hydrogen, H^+ Sodium, Na^+ Ammonium, NH_4^+	Chloride, Cl^- Bicarbonate, HCO_3^- Nitrate, NO_3^-

Data source: Turk, et al (51).

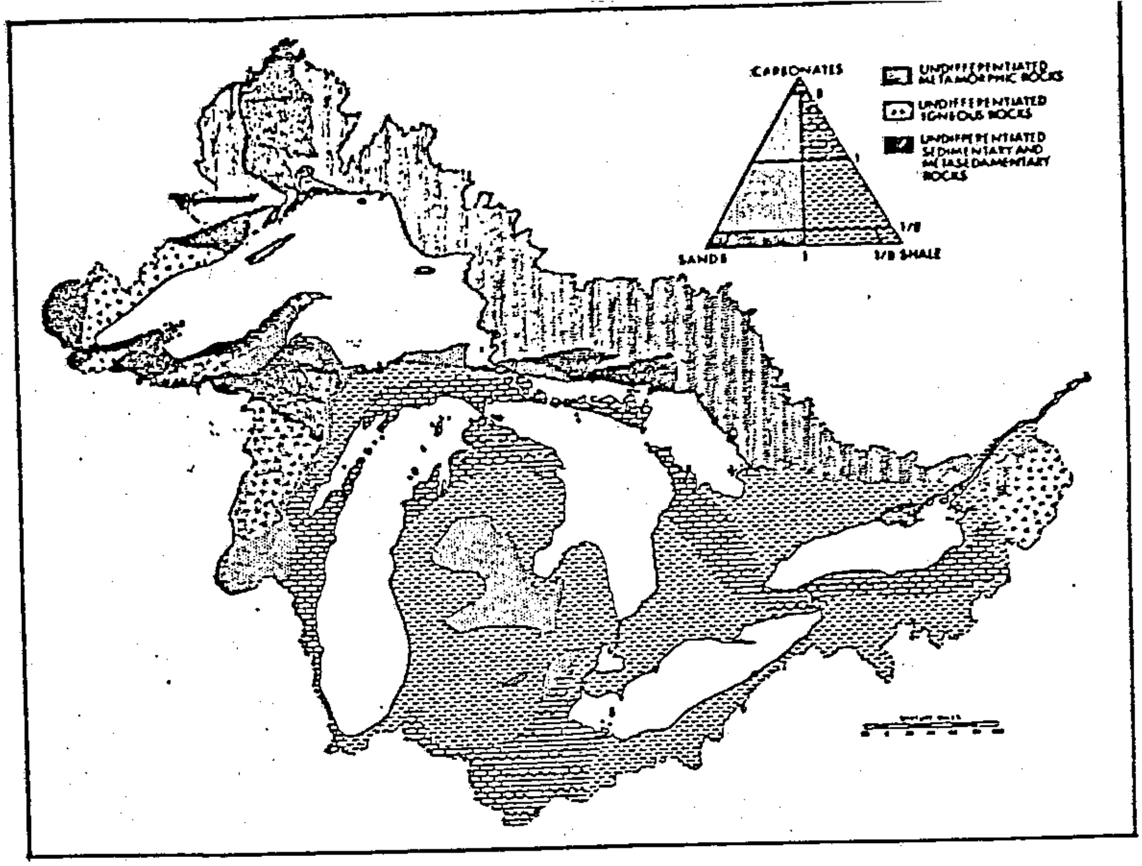

FIGURE 2. Composition of rock exposed at the pre-Pleistocene erosional surface (Upchurch, 54).

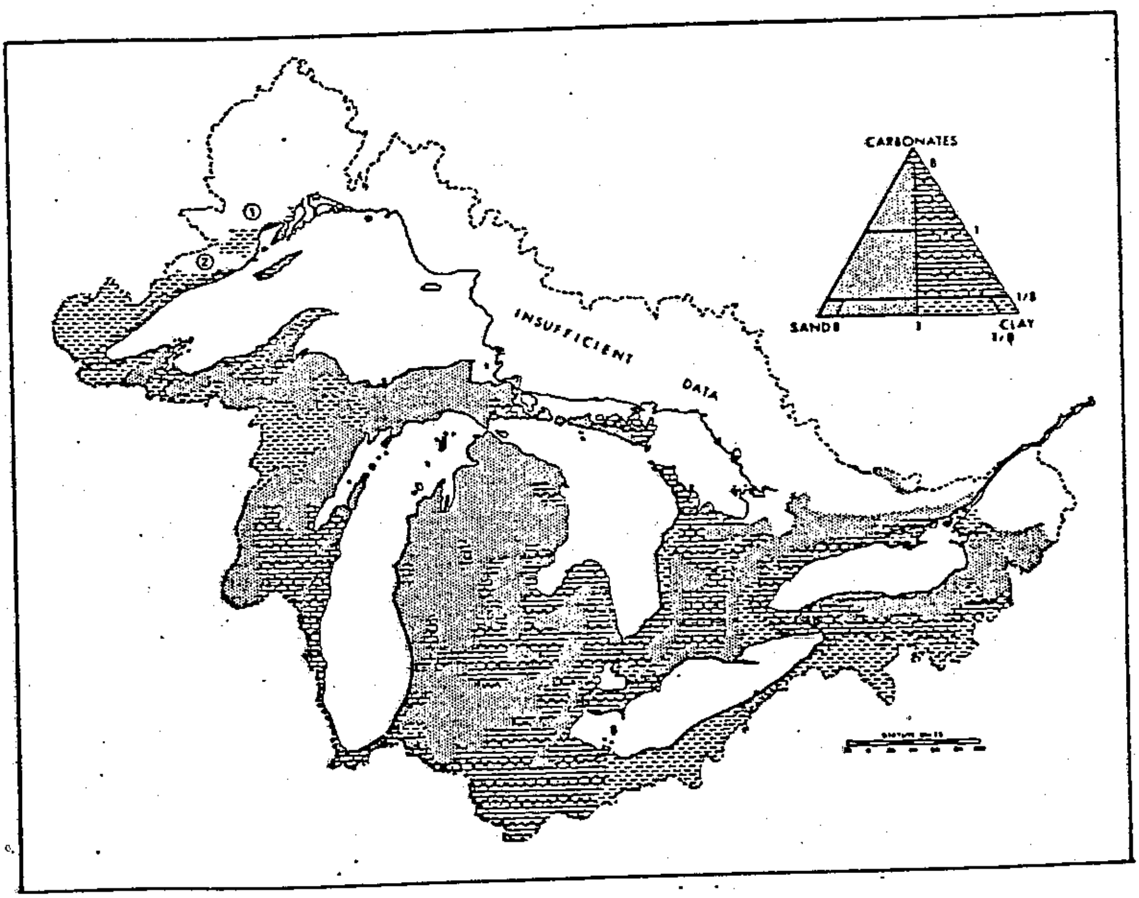

FIGURE 3. Composition of Pleistocene and Recent surficial sediments (Upchurch, 54).

Upchurch (54) considers the earliest chemical records as representing steady state concentrations for the Great Lakes before the recent, rapid rise in population, urbanization and industrialization when weathering on drainage basins with only lumbered, sparse agricultural and forested areas was producing the only loadings to the lakes. This assumption is based on the fact that chemical concentrations in Lake Superior have remained essentially unchanged in the past 100 years which indicated that load of a natural origin reach a steady state concentration in that inflow of a particular constituent equals outflow plus biotic and sediment uptake and that there is no change in composition of the lake (Upchurch and Robb, 55). Table 4 shows the annual natural loads and rates of weathering of several chemical parameters for each lake drainage basin derived from these early records. Lake Superior shows the lowest rate reflecting the poor drainage and slow weathering characteristic of the Canadian Shield, and Lake Erie yields the highest rate because of the early human utilization of the basin and the extensive carbonate terrain. These rates are in general agreement with estimates by Durum, et al (13) of 1×10^4 (5.7×10^4 lbs/mi^2/yr) to 4×10^4 kg/ km^2/yr (22.8 lbs/mi^2/yr) for gross yields of dissolved solids for several drainage basins in eastern United States due to natural weathering. Upchurch (54) points out that rather high weathering should be expected from recently glaciated terrain owing to the relatively high chemical reactivity of the fine grain-sized sediment produced by the glaciation process.

The modern chemical loads to the Great Lakes from natural and cultural activity is shown in Table 5. Upchurch (54) concludes that Lakes Superior and Huron show the least changes in loading and weathering rates with natural loads still accounting for 87 percent. Lakes Michigan, Erie and Ontario receive significant cultural loads with the natural load resulting in only 63, 47, and 38 percent of the total, respectively.

Stream bank and lake shoreline erosion contributes approximately 10 percent of sediment delivered to the Great Lakes (4 and 14). Table 6 shows the tonage delivered to each of the Great Lakes. Siltation of the Great Lakes from these sources is a local problem in harbors where it causes severe discoloration and a need for frequent dredging. To a lesser extent siltation tends to periodically cover coarser sediments and rock which are spawning areas for fish and other aquatic life. One of the principal concerns regarding the silt load to the lakes is the amount of nutrients and other chemicals contained within the silt (16).

Another form of natural pollutants is biological wastes and debris such as leaves, fallen trees, stumps and other detritus. This material chokes streams at many places, blocking flow and collecting floating material. During high flows the debris is flushed downstream to harbor areas and to the lakes where it interfers with commercial navigation and recreational boating (16).

Lake Superior is by far the least polluted of the Great Lakes. Because of its relatively pure nature, natural pollutants are more readily recognized and are not masked by cultural wastes. Three specific natural inputs have been identified. Water quality of the Ontonagon River Basin (Michigan and Wisconsin) is generally excellent except for a natural silt load attributed to the clay lands of the basin (25). The Tahquamenon River which discharges

TABLE 4

NATURAL CHEMICAL LOADS AND BASIN WEATHERING RATES FOR GREAT LAKES DURING THE PERIOD 1870-1910

Parameter	Superior		Michigan		Huron		Erie		Ontario	
	Load[1]	W Rate[2]	Load	W Rate	Load	W Rate	Load	W Rate	Load	W Rate
Total Dissolved Solids	39.0	3.1	61.0	5.2	-	6.0	80.0	10.0	40.0	6.3
Chloride (Cl^{-1})	1.9	0.19	2.2	0.19	4.0	0.30	1.2	0.15	-	-
Calcium (Ca^{+})	7.9	0.63	15.0	1.30	16.0	1.20	17.0	2.30	8.0	1.30
Sulfate (SO_4^{-2})	2.3	0.18	3.8	0.32	4.9	0.37	13.0	1.70	6.0	0.95
Sodium (Na^{+}) and Potassium (K^{+})	2.1	0.17	1.4	0.12	3.3	0.25	5.2	0.68	2.0	0.32

Data Sources: Beeton (3) and Upchurch (54).

1 loads in 10^8 kg/yr (22^8 lb/yr)

2 W rates in 10^4 kg/km^2/yr (5.7×10^4 lb/mi^2/yr)

TABLE 5

MODERN NATURAL AND CULTURAL CHEMICAL LOADS TO THE GREAT LAKES

Lake	Total Dissolved Solids					
	Natural		Cultural		Total	W R
	10^8 kg/yr[1]	% total	10^8 kg/yr[1]	% total	10^8 kg/yr[1]	10^4 kg/
Superior	39	87%	6	13%	45	3.
Michigan	61	63%	36	37%	97	8.
Huron	Insufficient Data				58	4.
Erie	80	47%	90	53%	170	22
Ontario	40	38%	67	62%	107	18

Data Source: Upchurch (54).
[1] 10^8 kg/yr = 22^8 lb/yr
[2] 10^4 kg/km^2/yr = 5.7×10^4 lb/mi^2/yr

TABLE 6

SEDIMENT DELIVERED TO THE GREAT LAKES

Lake	Erosion in Tons/Year (0.9MT/Year)				
	Sheet	Streambank	Shoreline	Urban and Roadside	Total
Superior	117,600	29,400		37,000	
Michigan	1,929,000	61,000		53,000	
Huron	Data not available.				
Erie	2,610,300	36,800	16,000	127,000	2,790,100
Ontario	Data not available.				
Total					

Data Sources: Benzmann and Kerr (4), Federal Water Pollution Control Agency (16), and U. S. Army Corps of Engineers (53).

into Whitefish Bay is noted for its unusual color. The surface waters are colored because of tannins naturally present in the basin (25). The tannins are produced in acid bogs and muskegs which are abundant in the region. The shoreline at the western end of the lake and the interior drainage basins contain an easily erodible red clay which discolors the streams and lake (29). Several trout streams have been destroyed by sedimentation of the material (37).

Bormann and Likens (6) studied nutrient cycles in a natural deciduous forest ecosystem in New Hampshire and found net losses for most elements. They found the average annual budget for the following elements:

	Input		Release	
	kg/km^2	lb/mi^2	kg/km^2	lb/mi^2
Calcium	260	1653	1180	6726
Sodium	150	855	690	3933
Magnesium	70	399	290	1653
Potassium	110	627	170	969

The generalized calcium cycle for an undisturbed beech-maple forest ecosystem is shown on Figure 4.

A 15.6 hectare (39.0 Acres) segment of the forest was deforested in 1956 and nutrient inputs and releases were monitored at the test area and in undisturbed portions of the forest. The experiment demonstrated that net losses of potassium were 21 times higher in the test plot than in the undisturbed watershed; calcium 10X; aluminum 9X; magnesium 7X; and sodium 3X.

The releases of chemicals from the undisturbed forest lands are considerably lower than (2 to 5X) the natural weathering rate for Lake Superior calculated by Upchurch (54). However, release rates for the deforested areas are twice as high as the natural rate for Lake Superior, but compare well with the natural rate for the lower lakes.

Fisher and Likens (18) studied the natural organic energy budget of a stream ecosystem in a deciduous forest in New Hampshire. They found that energy entered the stream by a variety of pathways. Meteorologic inputs consist of litter (leaves, branches, twigs, etc.) which fall or are blown into the stream in through-fall (precipitation which has passed through the forest canopy). Geologic fluxes consist of groundwater inputs and dissolved and particulate matter imported or exported in stream water. Biological input consists of in situ primary production. Respiratory heat lost is a biological output. Meteorological, geologic and biological vectors accounted for 44.2, 45.5 and 10.3 percent of total energy input, respectively. Energy lost by stream flow to downstream areas was 66 percent of the output. The remaining 34 percent represented respiratory loss, mostly by microorganisms. Similar values can probably be assumed for hardwood forests of the Great Lakes Basin.

12.3.4 State-of-the-Art in Assessing and Quantifying Problem

Models for assessing the contribution of various lithologic components

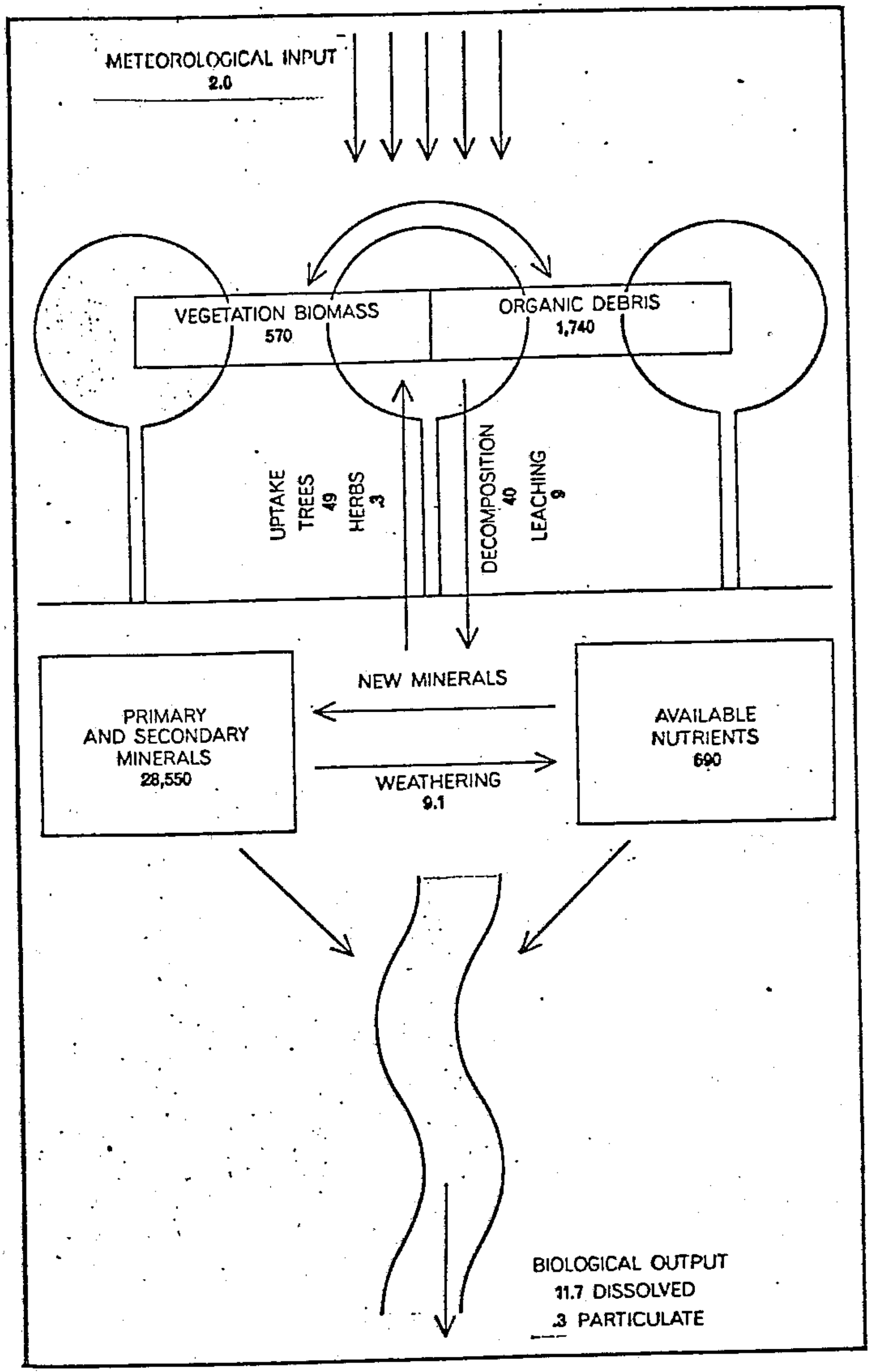

FIGURE 4. Calcium cycle for a forest ecosystem. Numerals represent the average number of kilograms per hectare per year; developed by Bormann and Likens (5). (1 kilogram per hectare per year equals 0.88 pounds per acre per year).

features resemble lakes. In the Great Lakes, the planktonic algae are the principal producers. To complete the cycle, an important group of organisms occupying the niche of decomposers (bacteria, yeast and fungi) perform the task of breaking down dead organisms and their waste products into simpler substances that can be reused by the producers (green plants).

12.3.6 Probable Changes in Land Use and Projected Pollution

Benzmann and Kerr (4) have projected the use of forest and other natural areas for the years 1980, 2000 and 2020. They predict that forest acreage will decrease by only 3 percent in 46 years and that other natural areas will diminish by 10 percent (Table 7). Because natural areas are normally at equilibrium and have been for some time, it is unlikely pollution loads will increase from these areas or change in constituents. Considering the projected decrease in the area of this land use category as a result of forest loss and shoreline developments future pollution loads will likewise be less.

12.3.7 Review of Institutional Arrangements to Regulate Land Use

The regulation of federally owned undeveloped land is normally assumed by the managing agency. Most of the federal lands in this category within the Great Lakes Basin are administered by the U.S. Forest Service of the Department of Agriculture. Some wetlands areas are designated as wildlife sanctuaries and are administered by the U.S. Fish and Wildlife Service of the Department of the Interior.

State-owned natural areas are usually managed by natural resources and conservation departments. Other undeveloped public lands are owned by universities, conservation districts, museums, park districts, municipalities and similar groups.

Considerable undeveloped acreage is also owned by private corporations or individuals. These include investment tracts, hunting associations, abandoned farm and timber lands, etc.

Because of the non-use nature of this category and the lack of significant pollution loadings, regulations have not been imposed upon discharges from these lands. Most states have some form of legislation designed to preserve such lands or to provide incentives to encourage private owners to restrict development on natural areas.

TABLE 7

PROJECTED UNDEVELOPED LAND USE IN THE GREAT LAKES BASIN

Planning Subarea	Lake Basin	Area in 1,000 Acres (400 Hectares)							
		1967		1980		2000		2020	
		Forest Areas	Other Natural Areas	Forest Areas	Other Natural Areas	Forest Areas	Other Natural Areas	Forest Areas	Other Natural Areas
1.1	Superior	8,355	305	8,354	305	8,347	304	8,334	304
1.2	Superior	5,910	66	5,910	66	5,909	66	5,906	66
2.1	Michigan	5,117	757	5,104	755	5,081	752	5,052	748
2.2	Michigan	341	580	297	505	240	408	197	335
2.3	Michigan	1,705	598	1,683	590	1,649	579	1,608	564
2.4	Michigan	5,434	412	5,424	411	5,403	410	5,380	408
3.1	Huron	2,914	219	2,908	219	2,900	218	2,889	217
3.2	Huron	1,194	285	1,179	281	1,156	276	1,141	270

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Section 12

UNDEVELOPED LAND

12.1 Summary

12.1.1 Introduction

The Great Lakes Basin has undergone a tremendous change in land use in the past 150 years. Nearly half of the landscape has been transformed from forests, prairies and wetlands to farms, cities, and industrial areas. The objective of this section is to discuss the relationships between the remaining undeveloped lands in the Basin and water quality in the boundary waters in the Great Lakes.

Undeveloped or natural areas predominate in the basins of Lakes Superior and Huron and major portions of the basins of northern Lake Michigan and eastern Lake Ontario. The Lake Erie Basin is highly developed with only 26 percent in undeveloped lands. The pollutants contributed from these areas consist of dissolved substances leached from the rock and soil, suspended natural material, plant detritus and animal wastes.

12.1.2 Summary of Findings and Conclusions

The landscape of the Great Lakes Basin and the formation of the Great Lakes themselves owe their present form to the molding action of the continental glaciers of the Pleistocene era. Innumerable lakes, marshes, and bogs mark places where the glacier gouged the rock, or blocked older drainage with debris, or left a stranded ice block partly buried in an outwash apron. Moraines, formed of ridges of mixed glacial debris, stretch across the Basin and mark the forward positions of the glaciers. Behind them lie striated bedrock and deposits of glacial till (14).

In the several thousands of years since glaciation, soil zones have formed in the Basin from this wide variety of parent material. Prior to 1820 when the first land settlement began in the Basin, nearly all of the area was forested except for small cultivated areas near Indian villages. The southern half of the lower peninsula of Michigan, northwestern Ohio, Indiana and southern Wisconsin had several small open prairies that later became focal points for early settlements. Most of the remaining land was covered with mixed hardwoods, primarily maple, beech, hickory, elm, ash and basswood. Forests containing pines were found in some parts of southern Michigan, for example, in the Saginaw Valley and in sandy areas along Lake Michigan. Pine was the most common component of the forests in the northern two-thirds of Michigan, northern Wisconsin and east central Minnesota where they were found associated with stands of other conifers and hardwoods (14).

First logging, then agriculture, and now industrialization and urbanization greatly reduced these forests throughout most of the Basin and have virtually eliminated the natural prairies. Today only 46 percent of the Basin is forest land (developed and undeveloped) and much of that has been lumbered at one time or another in the past 150 years. Other undeveloped areas, including wetlands and uplands, amount to only 9 percent of the Basin.

The leaching or weathering rates of chemicals from the natural terrain of the Great Lakes Basin has been derived from historical records (3 and 54) and by direct observations (13). The following comparison of dissolved solids loads to the Great Lakes shows the results of man's activities (54):

Lake	Natural	Cultural
Superior	87%	13%
Michigan	63%	37%
Huron	-	-
Erie	47%	53%
Ontario	38%	62%

Lakes Superior and Huron show the least changes in loading and weathering rates. For these two lake basins, chemical weathering rates are approximately 4×10^4 kg/km^2/yr (22.8×10^4 lb/mi^2/yr). Lakes Michigan, Erie and Ontario receive significant cultural loads. The total loads received by each of the Great Lakes have increased by factors of 1.5 to 10 in the past 100 years which can be interpreted as cultural loading.

Other significant forms of natural pollution include stream bank and lake shore erosion, biological debris such as leaves, fallen trees and other detritus, and atmospheric contributions such as dust and other suspended material. Taken together these account for approximately 10 to 15 percent of the total suspended material delivered to the lakes.

12.1.3 Recommendations

Although some models have been developed, particularly for natural weathering and forest ecosystems, many aspects of natural pollution are imperfectly known. The fate of natural organic compounds and role in ecosystem of the lakes deserves attention. Mechanical means have been used to remove debris and dredge sediment from harbor areas but no effective upland or water treatment controls have been devised to cope with these problems.

12.2 Supporting Material

12.2.1 Introduction and Scope

The Great Lakes Basin was molded into its present form by pleistocene glaciers. This unique method of formation characterized the Great Lakes topography with certain soil conditions. The soils range from sandy loam to loamy sand types (14). Each soil type contributes a natural input to the watershed in which it is located. Depending on the soil type this can range from a high hydrogen ion concentration to a high nitrogen, calcium or magnesium input to the Great Lakes (35). Other sources of impurities are precipitation (46) and the geologic character of the bedrock (35). The problem of natural contributions from the watershed began with the formation of the area and will always be a contributing factor although land use can dwarf the natural input.

The literature reviewed includes data from 1845 to the present.

12.2.2 Study Procedure

Information on natural pollution was acquired by: 1) interviewing university faculty members; 2) correspondence to federal and state agencies and universities; and 3) reviewing the literature.

Interviews were conducted with Ohio State University professors in geology, botany and limnology and with the agricultural extension agent located on campus. A number of additional interviews were conducted by telephone.

Written contact was made with: the Cooperative Extension Service, Pennsylvania State University; Agricultural Experimental Station, Michigan State University; Scientific Areas Preservation Council, Madison Wisconsin; Red Clay Interagency Committee, Madison, Wisconsin; Agricultural Experimental Station, Illinois; Michigan Natural Areas Council, Michigan; and Cooperative Extension Service, Indiana.

The literature sources reviewed include: 1) The Great Lakes Framework Study; 2) Proceedings, Great Lakes Research Conferences; 3) Federal Water Pollution Control Administration; 4) U.S. Environmental Protection Agency; and 5) pertinent journals and other government publications.

Six major assumptions were made.

1. Undeveloped or forested land and waterbodies greater than forty acres are natural areas.
2. Therefore, any impurities in the water draining from these areas would be of a natural origin and not man induced.
3. Probable that chemical levels of the Great Lakes prior to the twentieth century indicate steady state concentrations of natural pollutants (Upchurch, 54).

4. Similar natural areas located in the northeastern United States are subject to the same type of pollution as natural areas in the Great Lakes Basin, therefore data from these areas have been extrapolated to the Great Lakes region.

5. Because sediments are being considered separately in Section 7, they are not included as natural pollutants in this Section.

6. Only the United States portion of the Great Lakes Basin is considered in this Section. A list of the counties within the Basin follows:

Illinois
- Cook
- DuPage
- Lake
- Kane
- McHenry
- Will

Indiana
- Adams
- Allen
- DeKall
- Elkhart
- LaGrange
- Lake
- LaPorte
- Marshall
- Noble
- Porter
- St. Joseph
- Steuben

Michigan
- Alcona
- Alger
- Allegan
- Alpena
- Antrim
- Arenac
- Baraga
- Barry
- Bay
- Benzie
- Berrien
- Branch
- Calhoun
- Cass
- Charlevoix
- Cheboygan
- Chippewa
- Clare
- Clenton
- Crawford
- Delta
- Dickinson
- Eaton
- Emmet
- Galdwin
- Genesee
- Gogebic
- Graliot
- Grand Traverse
- Hillsdale
- Houghton
- Huron
- Ingham
- Ionia
- Iasco
- Iron
- Isabella
- Jackson
- Kalamazoo
- Kent
- Keweenaw
- Lake
- Lapeer
- Leelanau
- Lenawee
- Livingston
- Luce
- Mackinac
- Macomb

Michigan (cont.)
- Marquette
- Mason
- Mecosta
- Menominee
- Midland
- Missaukee
- Monistee
- Monroe
- Montclam
- Montmorency
- Muskegon
- Newaygo
- Oakland
- Oceana
- Ogemaw
- Ontonagon
- Osceloa
- Oscoda
- Otsego
- Ottawa
- Presque Isle
- Roscommon
- Saginaw
- St. Clair
- St. Joseph
- Sanilac
- Schoolcraft
- Sheawassee
- Tuscola
- Van Buren
- Washtenaw
- Wayne
- Wexford

Minnesota
- Carlton
- Cook
- Lake
- St. Louis

New York
- Allegany
- Cattaraugus
- Cayuga
- Chautougua
- Erie
- Genesee
- Hamilton
- Herkimer
- Jefferson
- Lewis
- Livingston
- Madison
- Monroe
- Niagara
- Oneida
- Onondage
- Ontario
- Orleans
- Oswego
- St. Lawrence
- Schuyler
- Seneca
- Tompkins
- Waynge
- Wyoming
- Yates

Ohio
- Allen
- Ashtabula
- Auglaize
- Crawford
- Cuyahoga
- Defiance
- Erie
- Fulton
- Geauga
- Hancock
- Hardin
- Henry
- Huron
- Lake
- Lorain
- Lucas
- Medina
- Mercer
- Ottawa
- Paulding
- Portage
- Putnam
- Sandusky
- Seneca
- Summet
- Van Wert
- Williams
- Wood

Pennsylvania
- Erie
- Crawford

Wisconsin
- Ashland
- Bayfield
- Brown
- Calumet
- Door
- Douglas
- Florence
- Fonddu Lac
- Forest
- Iron
- Kenosba
- Kewaunee
- Langlade
- Monitawol
- Marinette
- Marquette
- Milwaukee
- Oconto
- Outagamie
- Ozaukee
- Plaupaca
- Portage
- Racine
- Shawane
- Sheboygan
- Vilas
- Walworth
- Washington
- Waukesha
- Waupach
- Wanshara
- Winnebago