United States
Environmental Protection
Agency

Regior
230 S
Chicag

Water Division

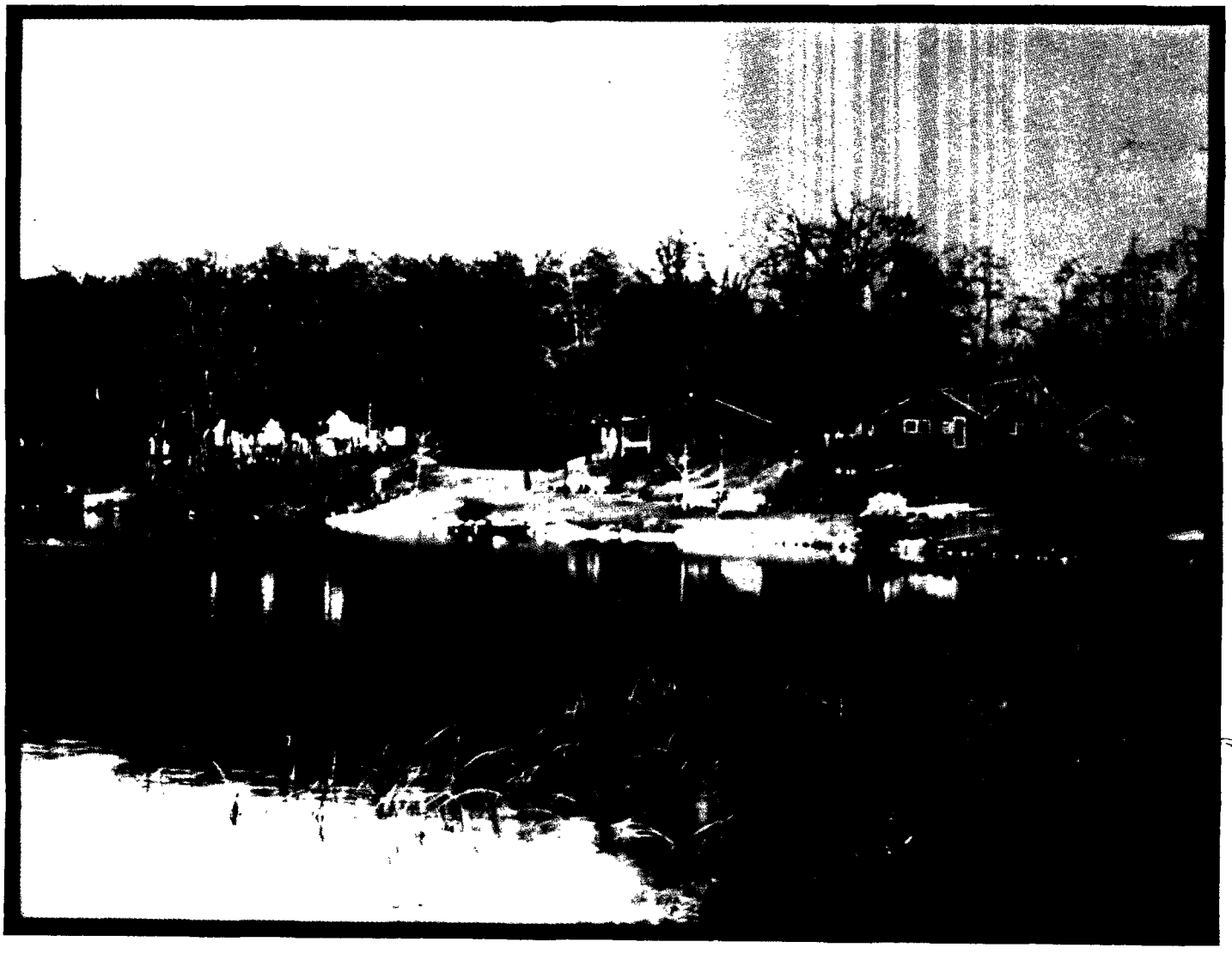
905D82101

EPA

Environmental Impact Statement

Draft

Indian Lake - Sister Lakes Wastewater Treatment System Berrien, Cass, and Van Buren Counties, Michigan



DRAFT ENVIRONMENTAL IMPACT STATEMENT

INDIAN LAKE - SISTER LAKES

WASTEWATER TREATMENT FACILITIES

BERRIEN, CASS AND VAN BUREN COUNTIES, MICHIGAN

Prepared by the

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION V

CHICAGO, ILLINOIS

and

WAPORA, INCORPORATED

CHICAGO, ILLINOIS

August 1982

U.S. Environmental Protection Agency
Region 5, Library (5PL-16)
230 S. Dearborn Street, Room 1670
Chicago, IL 60604

Approved By:

Valdas V. Adamkus
Regional Administrator
August 1982

SUMMARY

(X) Draft Environmental Impact Statement
( ) Final Environmental Impact Statement

US Environmental Protection Agency, Region V
230 South Dearborn Street
Chicago, Illinois 60604

1. NAME OF ACTION

Administrative (X)
Legislative ( )

2. PURPOSE OF AND NEED FOR ACTION

The Federal Water Pollution Control Act of 1972 (Public Law 92-500) established a uniform, nationwide water pollution control program. Section 201 of the Act established grants for planning, design, and construction for water pollution control facilities. At the request of lakeshore residents of Indian Lake, the Cass County Department of Public Works (CCDPW) applied for a facility planning grant in 1975. The Michigan Department of Natural Resources (MDNR) delineated the facilities planning area to include Indian Lake, the Sister Lakes, and Pipestone Lake. The CCDPW was designated the lead agency for the administration of grants.

Concurrent with the facilities planning process, the CCDPW filed an application with the Farmers Home Administration (FmHA) in May 1976 for a grant and loan to construct sewers around Indian Lake only. The FmHA informed the CCDPW in August 1976 that the grant and loan application was approved, with the condition that the facilities planning documents would be approved by MDNR.

The preliminary draft of the Indian Lake-Sister Lakes Facility Plan was submitted to MDNR in October 1977 by Gove Associates, Inc., the consulting engineer. Collector sewers and centralized treatment was proposed for the lake areas. The Facility Plan was not approved at that time because of questions regarding the potential impacts of the proposed sewers, system costs, and whether innovative/alternative systems might be a feasible alternative.

In August 1978, USEPA issued a Notice of Intent to prepare an Environmental Impact Statement (EIS). The major considerations were the contribution of present on-site systems to lake water degradation, the potential for improved treatment by existing systems through upgrading and improving maintenance, the economic impact of the proposed project alternatives, and the potential secondary impacts.

This report contains an evaluation of the existing wastewater-related problems and the treatment needs of the facilities planning area. Centralized collection and treatment alternatives were re-evaluated and decentralized alternatives were developed and analyzed. Considerable emphasis was devoted to the decentralized alternatives because the potential to reduce costs was great. The residences not immediately adjacent to the lakes were not included in the analysis because no need for improved sewage treatment was determined.

3. ALTERNATIVES CONSIDERED

Eleven wastewater system alternatives were evaluated in detail during this study. Six alternatives include collection of sewage from the lake areas and transmission to various treatment sites where different treatment processes would occur. The other alternatives include the No Action Alternative and the various on-site and cluster system (off-site) alternatives. Each alternative provides service to the residences near the lakes in the study area (except Keeler Lake).

Alternative 1

The No Action Alternative presumes that neither USEPA nor FmHA would provide funds to build, upgrade, or expand existing on-site treatment systems, although local health authorities would continue to have the responsibility for improving existing systems that cause public health problems. No costs were calculated for this alternative.

Alternative 2

Alternative 2 proposes construction of septic tank effluent (STE) pressure collection sewers and separate treatment plants for Indian Lake and Sister Lakes with discharges to surface waters. The treatment plants would include waste stabilization ponds with 9.5 months of storage. The Sister Lakes treatment plant would discharge to Silver Creek and the Indian Lake treatment plant would discharge to the Indian Lake outlet. The capital cost of this alternative is $24,106,200 and the annual operation and maintenance costs are $261,700.

Alternative 3

Alternative 3 proposes construction of pressure collection sewers and a regional treatment plant utilizing application of wastewater effluent to land. Pretreatment prior to land application would be accomplished by waste stabilization ponds that incorporate 6 months of winter storage. The capital cost of this alternative is $23,819,600 and the annual operation and maintenance costs are $285,900.

Alternative 4

This alternative proposes construction of STE pressure collection sewers and a regional treatment plant utilizing waste stabilization ponds for treatment. The treatment plant is proposed to be located in Section 11 of Silver Creek Township. It would incorporate 9.5 months of storage and would discharge to Silver Creek. The estimated capital cost is $24,573,700 and the estimated annual operation and maintenance costs are $252,500.

Alternative 5A

This alternative is similar to Alternative 4, except the regional treatment plant would be located near Indian Lake and would discharge to the Indian Lake outlet. This alternative has an estimated capital cost of $23,614,200 and estimated annual operation and maintenance costs of $247,000.

Alternative 5B

This alternative is similar to Alternative 5A, except that a conventional gravity collection sewer system would be utilized rather that the STE pressure sewer system. This alternative is similar to the alternative recommended in the Facilities Plan by Gove Associates, Inc. The estimated capital cost is $29,598,600 and the annual operation and maintenance costs are $278,200.

Alternative 6

Alternative 6 proposes construction of STE pressure collection sewers and a new treatment plant for the Sister Lakes and utilization of the Dowagiac treatment plant for Indian Lake wastewater. The Sister Lakes treatment plant would consist of waste stabilization ponds with 9.5 months of storage capacity and would discharge to Silver Creek. The Dowagiac treatment plant would not be expanded to accommodate the flow from the Indian Lake area. The estimated capital cost for this alternative is $23,487,400 and the annual operation and maintenance costs, including the treatment charge at the Dowagiac treatment plant, are $294,000.

Alternative 7

This alternative proposes construction of STE pressure collection sewers and transmission facilities to the Dowagiac treatment plant. This alternative has an estimated capital cost of $22,457,200 and annual operation and maintenance costs of $466,100.

Alternative 8A

This alternative includes upgrading on-site systems where a subsequent, detailed inspection uncovers a need for upgrading and collecting STE from certain critical areas where upgrading on-site systems is not feasible. The STE would be treated in common cluster drainfields. This alternative utilizes STE pressure collection sewers for the critical areas. The estimated capital cost of this alternative is $9,683,800 and the estimated annual operation and maintenance costs are $280,200.

Alternative 8B

This alternative is similar to Alternative 8A, except STE gravity sewers and lift stations and force mains would be utilized to convey STE to the cluster drainfield site. The estimated capital cost of this alternative is $9,644,200 and the estimated annual operation and maintenance costs are $265,700.

Alternative 9

This alternative consists of upgrading on-site systems where a subsequent, detailed inspection program uncovers a need for upgrading and installing low-flow toilets and blackwater holding tanks for those residences for which on-site upgrading is not feasible. The graywater would be handled by the existing or upgraded septic tank and soil absorption system. The estimated capital cost is $3,710,600 and the estimated annual operation and maintenance costs are $224,000.

The total present worth costs of the major components of the alternatives and their ranking are presented in Table 1. These system alternatives can be grouped into three design/cost categories. The centralized comprehensive sewering alternatives (2, 3, 4, 5A, 5B, 6, and 7) are highest in cost; upgraded on-site systems with certain critical areas served by cluster drainfields (Alternatives 8A and 8B) are intermediate in cost; and upgraded on-site systems with blackwater holding tanks (Alternative 9) are lowest in cost.

4. ENVIRONMENTAL CONSEQUENCES

Construction Phase

Major direct impacts from construction activities that would be associated with the alternatives would be concentrated along the corridors of the collection sewers and at the wastewater treatment facilities sites. Fugitive dust, exhaust emissions from construction equipment, noise, destruction of vegetation, accelerated erosion, disturbance of wildlife, disturbance of streambeds and lakebeds, and interruption of traffic flow and patterns would

Table 1. Summary of all estimated costs of alternatives (June 1981 costs, in thousands of dollars).

Alternative Number and Title	Present Worth				Average Annual Equivalent Cost	Ranking
	Collection	Conveyance	Treatment	Total		
1. No Action	-	-	-	-	-	NA
2. Pressure collection sewers and separate WWTPs for Sister Lakes and Indian Lake areas with discharges to surface water	19,995.9	1,905.4	3,532.9	25,434.2	2,517.9	8
3. Pressure collection sewers and regional treatment and land disposal system located in Section 8 in Silver Creek Township	19,995.9	1,667.5	3,703.2	25,366.6	2,511.3	6
4. Pressure collection sewers and regional WWTP located in Section 11 with discharge to Silver Creek	19,995.9	2,963.8	2,819.7	25,779.4	2,552.2	7
5A. Pressure collection sewers and regional WWTP located in Sections 29 and 32 with discharge to Indian Lake outlet	19,995.9	2,018.5	2,819.7	24,834.1	2,458.6	4
5B. Gravity collection sewers and regional WWTP located in Sections 29 and 32 with discharge to Indian Lake outlet	26,342.6	2,018.5	2,819.7	31,180.8	3,086.9	10
6. Pressure collection sewers and existing Dowagiac WWTP for Indian Lake and WWTP for Sister Lakes located in Section 11 with discharge to Silver Creek	19,995.9	2,259.0	2,949.3	25,204.2	2,495.2	5
7. Pressure collection sewers and existing Dowagiac WWTP	19,995.9	3,449.6	2,676.5	26,122.0	2,586.0	9
8A. On-site systems upgrading and critical area septic tank effluent collected by pressure sewers and conveyed to cluster drainfields	11,685.0[a]	--	1,075.0[b]	12,760.0	1,263.2	3
8B. On-site systems upgrading and critical areas septic tank effluent collected by small diameter gravity sewers and conveyed to cluster drainfields	11,307.5[a]	--	1,075.0[b]	12,382.5	1,225.9	2
9. On-site systems upgradings and holding tanks	5,497.9[c]	--	1,075.0[b]	6,572.9	650.7	1

a Includes costs for upgrading of existing on-site systems, future on-site systems, collection and conveyance of wastewater for some areas with treatment provided at cluster systems.
b Includes administrative and laboratory costs.
c Includes cost for upgrading of existing on-site systems, future on-site systems, and blackwater holding tanks.

NA Not Applicable

create short-term nuisance conditions and environmental damage along the sewer and force main routes. The extent and range of impacts is directly related to the lengths of the proposed sewers. The centralized treatment alternatives have potential for the greatest number of impacts alternatives, the number and extent of impacts would be considerably less for the two alternatives with critical area collection systems and cluster drainfields. Major impacts on the environment would occur at the new treatment plant sites because each site would have a waste stabilization lagoon built on it. All the sites are presently used for agricultural purposes, and the site in Section 29 (near Indian Lake) is mostly prime agricultural land that would be converted irretrievably to treatment plant use. The cluster drainfield sites also would be extensively disturbed for drainfield trenching. The three alternatives with upgraded on-site systems would involve extensive disturbance on individual lots only.

Alternative 9 would require the smallest commitment of public capital. The local share of the capital cost is lowest with Alternative 9, even including some additional private homeowner cost.

Operational Phase

The operation of the facilities proposed in the alternatives would produce some significant long-term impacts. All of the alternatives (except the No Action Alternative) would result in slightly reduced nutrient inputs into the lakes; the greatest reductions could be expected for the complete sewering alternatives. The data were inconclusive as to whether the water quality of the lakes would be noticeably improved under any of the alternatives. Under the No Action Alternative lake water quality may noticeably decline and nuisance algal blooms may increase in extent and density. Occasionally failing on-site systems would cause localized water quality problems, potential health risks, and malodorous conditions. The soil absorption systems that would continue to be used and those proposed for construction would affect the quality of groundwater slightly. Occasional malfunctions and power outages within the wastewater collection system could cause serious short-term impacts on lake water quality. The treatment facilities for the centralized alternatives would be capable of meeting the discharge requirements established by

MDNR. Water quality in the receiving streams would be altered, but not seriously degraded during the annual discharge period. The land application alternative should result in minimal operating impacts because the infiltrated water should be of comparatively high quality.

Septage and holding tank waste hauling would result in minimal adverse impacts. Some ephemeral odors from the pumping operation would be detected and truck traffic would be present. Septage disposal would be conducted in an environmentally compatible way with application to agricultural lands.

5. RECOMMENDED ACTION

The least cost alternative from both an economic and an environmental perspective is Alternative 9 - on-site system upgrading and blackwater holding tanks for some critical areas. Because insufficient data have been developed in the study thus far to conclusively document a need for improved sewage treatment, USEPA, Region V has decided that additional studies will be conducted during the period between publication of the Draft EIS and the Final EIS.

These studies may include:

- A sanitary survey of 30% of the residences in the study area
- A septic leachate detector scan of drinking water samples obtained from each house visited in the sanitary survey for traces of wastewater effluent
- A near-shore hydrology study to determine the direction of groundwater flow.

Based on the available information and the additional studies, a more precisely defined wastewater management system for the study area will be recommended in the Final EIS. An alternative that includes primary reliance on on-site wastewater management systems is clearly justified for the study area. The recommended alternative may include holding tanks, blackwater holding tanks, and cluster drainfields where it is demonstrated that off-site treatment of wastewater is needed.

TABLE OF CONTENTS

	Page
COVER SHEET	i
SUMMARY	ii
TABLE OF CONTENTS	x
LIST OF APPENDICES	xv
LIST OF TABLES	xvi
LIST OF FIGURES	xix
1.0. PURPOSE OF AND NEED FOR ACTION	1-1
1.1. Project Background	1-1
1.2. Legal Basis for Action and Project Need	1-5
1.3. Study Process and Public Participation	1-8
1.4. Issues	1-8
2.0. DISCUSSION OF WASTEWATER TREATMENT ALTERNATIVES	2-1
2.1. Existing Wastewater Treatment Systems	2-1
2.1.1. Existing On-site Systems	2-1
2.1.2. Summary of Data on Operation of Existing Systems	2-3
2.1.2.1. Septic Leachate Survey	2-3
2.1.2.2. Aerial Survey	2-4
2.1.2.3. Mailed Questionnaire	2-5
2.1.2.4. Indian Lake Sanitary Surveys	2-8
2.1.2.5. Pipestone Lake Surveys	2-10
2.1.3. Problems Caused by Existing Systems	2-11
2.1.3.1. Backups	2-12
2.1.3.2. Ponding	2-12
2.1.3.3. Groundwater Contamination	2-12
2.1.3.4. Surface Water Quality Problems	2-13
2.1.3.5. Indirect Evidence	2-15
2.1.4. Identification of Problem Areas	2-16
2.1.5. Septage Disposal Practices	2-18
2.2. Identification of Wastewater Treatment System Options	2-23
2.2.1. Design Factors	2-23
2.2.1.1. Wastewater Load Factors	2-23
2.2.1.2. Effluent Requirements	2-24
2.2.1.3. Economic Factors	2-26
2.2.2. System Components	2-28
2.2.2.1. Flow and Waste Reduction	2-28
2.2.2.2. Collection System	2-35
2.2.2.3. Wastewater Treatment Processes	2-41

TABLE OF CONTENTS (Continued)

		Page
	2.2.2.4. Effluent Disposal Methods	2-41
	2.2.2.5. Sludge Treatment and Disposal	2-46
	2.2.2.6. On-site System	2-47
	2.2.2.7. Cluster System	2-51
	2.2.2.8. Septage Disposal	2-53
	2.2.3. Centralized Collection System Alternatives	2-53
	2.2.4. Centralized Wastewater Treatment Plant Alternatives	2-57
2.3.	System Alternatives	2-61
	2.3.1. Alternative 1 - No Action Alternative	2-63
	2.3.2. Alternative 2 - Pressure Collection Sewers and Separate WWTPs for the Sister Lakes and Indian Lake Areas with Discharge to Surface Waters	2-64
	2.3.3. Alternative 3 - Pressure Collection Sewers and Regional Treatment and Land Treatment System	2-64
	2.3.4. Alternative 4 - Pressure Collection Sewers and Regional WWTP located in Section 11	2-66
	2.3.5. Alternative 5A - Pressure Collection Sewers and a Regional WWTP Located in Sections 29 and 32	2-68
	2.3.6. Alternative 5B - Gravity Collection Sewers and a Regional WWTP Located in Sections 29 and 32	2-68
	2.3.7. Alternative 6 - Pressure Collection Sewers and Existing Dowagiac WWTP for Indian Lake and new WWTP for Sister Lakes	2-71
	2.3.8. Alternative 7 - Pressure Collection Sewers and Existing Dowagiac WWTP	2-73
	2.3.9. Alternative 8A - On-Site Systems Upgrading and Critical Areas Septic Tank Effluent Collected by Pressure Sewers and Conveyed to Cluster Drain Fields	2-73
	2.3.10. Alternative 8B - On-Site Systems Upgrading and Critical Areas Septic Tank Effluent Collected by Small Diameter Gravity Sewers and Conveyed to Cluster Drain Fields	2-76
	2.3.11. Alternative 9 - On-Site Systems Upgrading and Blackwater Holding Tanks	2-77
2.4.	Flexibility and Reliability of System Alternatives	2-77
	2.4.1. Flexibility	2-77
	2.4.2. Reliability	2-78
2.5.	Comparison of Alternatives and Selection of the Recommended Action	2-82
	2.5.1. Comparison of Alternatives	2-82
	2.5.1.1. Project Costs	2-82

	Page
2.5.1.2. Environmental Impacts	2-84
2.5.1.3. Implementability	2-86
2.5.2. Conclusions	2-91
3.0. AFFECTED ENVIRONMENT	3-1
3.1. Natural Environment	3-1
3.1.1. Atmosphere	3-1
3.1.1.1. Climate	3-1
3.1.1.2. Air Quality	3-2
3.1.1.3. Noise	3-3
3.1.1.4. Odor	3-3
3.1.2. Land	3-3
3.1.2.1. Geology	3-3
3.1.2.2. Soils	3-8
3.1.3. Water Resources	3-16
3.1.3.1. Rivers and Lakes in the Study Area	3-16
3.1.3.2. Water Quality of the Major Rivers and Lakes in the Study Area	3-18
3.1.3.3. Groundwater in the Study Area	3-31
3.1.3.4. Nutrient Inputs in Inland Lakes	3-38
3.1.4. Aquatic Biota	3-44
3.1.4.1. Phytoplankton	3-44
3.1.4.2. Mollusks	3-45
3.1.4.3. Fisheries	3-45
3.1.5. Terrestrial Biota	3-48
3.1.5.1. Amphibians and Reptiles	3-48
3.1.5.2. Birds	3-48
3.1.5.3. Mammals	3-49
3.1.5.4. Vegetation	3-51
3.1.6. Wetlands	3-52
3.2. Man-Made Environment	3-53
3.2.1. Demography	3-53
3.2.1.1. Historic and Current Population	3-53
3.2.1.2. Service Area Population Estimates	3-56
3.2.1.3. Population Projections	3-61
3.2.2. Land Use	3-65
3.2.2.1. Local Land Use Trends	3-65
3.2.2.2. Study Area Land Use Trends	3-66
3.2.2.3. Prime and Unique Farmland	3-71
3.2.2.4. Future Land Use	3-72
3.2.2.5. Development Potential	3-74

TABLE OF CONTENTS (Continued)

		Page
3.2.3.	Economics	3-76
3.2.3.1.	Regional Employment Trends	3-76
3.2.3.2.	Income	3-77
3.2.3.3.	Unemployment	3-78
3.2.4.	Recreation and Tourism Resources	3-80
3.2.4.1.	Public Facilities	3-80
3.2.4.2.	Private Facilities	3-81
3.2.5.	Public Finance	3-83
3.2.5.1.	Assessed Valuation and Market Value	3-83
3.2.5.2.	Total Revenues	3-84
3.2.5.3.	Debt, Debt Service, and Debt Limits	3-84
3.2.6.	Transportation	3-84
3.2.6.1.	Highways	3-84
3.2.6.2.	Airport Facilities	3-87
3.2.6.3.	Port Facilities	3-87
3.2.7.	Energy	3-87
3.2.8.	Cultural Resources	3-88
3.2.8.1.	Early History	3-88
3.2.8.2.	Archaeological Sites	3-90
3.2.8.3.	Historic Sites	3-91
4.0.	ENVIRONMENTAL CONSEQUENCES	4-1
4.1.	Primary Impacts	4-14
4.1.1.	Construction Impacts	4-14
4.1.1.1.	Atmosphere	4-14
4.1.1.2.	Soil Erosion and Sedimentation	4-14
4.1.1.3.	Surface Water	4-15
4.1.1.4.	Groundwater	4-15
4.1.1.5.	Terrestrial Biota	4-15
4.1.1.6.	Land Use	4-17
4.1.1.7.	Demography	4-20
4.1.1.8.	Economics	4-20
4.1.1.9.	Recreation and Tourism	4-21
4.1.1.10.	Transportation	4-21
4.1.1.11.	Energy Resources	4-21
4.1.1.12.	Cultural Resources	4-22
4.1.2.	Operation Impacts	4-22
4.1.2.1.	Atmosphere	4-22
4.1.2.2.	Soils	4-24
4.1.2.3.	Surface Waters	4-28
4.1.2.4.	Groundwater	4-33
4.1.2.5.	Terrestrial Biota	4-37
4.1.2.6.	Land Use Impacts	4-37
4.1.2.7.	Demographics	4-37
4.1.2.8.	Economics	4-37
4.1.2.9.	Recreation and Tourism	4-38

		Page
	4.1.2.10. Transportation	4-38
	4.1.2.11. Energy	4-39
	4.1.3. Public Finance	4-39
4.2.	Secondary Impacts	4-44
	4.2.1. Demographics	4-44
	4.2.2. Land Use	4-45
	4.2.3. Surface Water	4-46
	4.2.4. Recreation and Tourism	4-47
	4.2.5. Economics	4-47
	4.2.6. Threatened and Endangered Species	4-47
4.3.	Mitigation of Adverse Impacts	4-48
	4.3.1. Mitigation of Construction Impacts	4-48
	4.3.2. Mitigation of Operation Impacts	4-52
	4.3.3. Mitigation of Secondary Impacts	4-53
4.4.	Unavoidable Adverse Impacts	4-53
4.5.	Irretrievable and Irreversible Resource Commitments	4-54
5.0.	LITERATURE CITED	5-1
6.0.	LIST OF PREPARERS	6-1
7.0.	GLOSSARY OF TECHNICAL TERMS	7-1

LIST OF APPENDICES

APPENDIX A - EXISTING ON-SITE SYSTEMS

APPENDIX B - SEPTIC LEACHATE SURVEY INDIAN LAKE-SISTER LAKES

APPENDIX C - ESTIMATED ON-SITE SYSTEMS TO BE UPGRADED UNDER ALTERNATIVES 8A, 8B, AND 9

APPENDIX D - PRELIMINARY COST ESTIMATES FOR ALTERNATIVES

APPENDIX E - INDIAN LAKE-SISTER LAKES AREA COMMUNITY ATTITUDE QUESTIONNAIRE

APPENDIX F - CLIMATOLOGICAL AND AIR QUALITY DATA

APPENDIX G - PHOSPHORUS SORPTION AND PARTICLE SIZE ANALYSIS OF SOILS

APPENDIX H - SURFACE WATER QUALITY DATA

APPENDIX I - AQUATIC BIOTA SAMPLING PROGRAM - PHYTOPLANKTON ANALYSIS

APPENDIX J - TERRESTRIAL BIOTA DATA

APPENDIX K - RECREATION PARTICIPATION DATA

APPENDIX L - METHODOLOGY FOR THE COUNTY DEBT TO PER CAPITA INCOME RATIOS

APPENDIX M - RESIDENTIAL FUEL REQUIREMENT DATA

APPENDIX N - ANALYSIS OF GRANT ELIGIBILITY

APPENDIX O - PERTINENT CORRESPONDENCE

LIST OF TABLES

		Page
2-1	Category and number of discernable on-site septic systems around the lakes in study area	2-6
2-2	Partial results of 1978 sanitary questionnaire as tabulated by Gove Associates, Inc. for lakeshore areas in Cass County.	2-7
2-3	Results of pollution survey of Indian Lake	2-9
2-4	Description of site limitations and results of surveys pertinent to on-site systems for each district	2-19
2-5	Wastewater load factors projected for Sister Lakes and Indian Lake, Michigan, for the year 2000	2-24
2-6	Service factor	2-27
2-7	Economic cost criteria	2-28
2-8	Summary of all estimated costs of centralized collection system alternatives	2-60
2-9	Summary of all estimated costs of centralized wastewater plant (WWTP) alternatives	2-62
2-10	Summary of all estimated costs of alternatives	2-83
3-1	Soils series characteristics and ratings	3-14
3-2	Physical characteristics of major lakes in the study area	3-18
3-3	Existing and proposed water quality standards for the State of Michigan	3-20
3-4	Selected water quality parameters for the rivers in the study area	3-22
3-5	Selected data by station, for the aquatic biota program for the Indian Lake-Sister Lakes study area	3-25
3-6	Nygaard's trophic state (NTS) for lakes in the Indian Lake-Sister Lakes study area	3-27

		Page
3-7	Palmer's Organic Pollution Indices	3-27
3-8	Results of groundwater survey	3-35
3-9	Mean nutrient export from non-point sources by land use/ cover type	3-41
3-10	Total phosphorus inputs by source	3-41
3-11	Septic leachate and septic system aerial surveys . .	3-44
3-12	Species of mollusks designated as endangered and threatened	3-45
3-13	Species of fish designated as endangered and threatened	3-46
3-14	Species of amphibians and reptiles designated as endangered and threatened	3-49
3-15	Species of birds designated as endangered and threatened	3-50
3-16	Species of mammals designated as endangered and threatened	3-51
3-17	Population growth in the four-township area, and Michigan between 1950 and 1980	3-54
3-18	Population growth in the four-township area, 1970 to 1980	3-55
3-19	Population growth rates in the four-township area, three-county area, and Michigan, 1950 - 1980	3-56
3-20	Comparison of counts of residential dwelling units in the service areas	3-58
3-21	Number of new residences constructed on undeveloped lots in the service areas	3-59
3-22	Housing units and population by service area, 1980 .	3-60
3-23	Population projections by township	3-61
3-24	Service area permanent population projections . . .	3-63

		Page
3-25	Service area total population, based on four methods for forecasting seasonal population	3-64
3-26	Total acres of land use in the four-township area . . .	3-67
3-27	Acres of land use by watershed	3-69
3-28	Percentage of watersheds covered by each land use type	3-70
3-29	Land use in the watershed by number of acres and by percentage of the total acreage	3-71
3-30	Per capital income by county	3-78
3-31	Unemployment rates by county	3-79
3-32	Private recreation facilities in the study area	3-82
3-33	Financial characteristics of the three-county area . .	3-85
3-34	County debt measures	3-86
3-35	Energy consumption by fuel type for residential heating	3-89
4-1	Potential major primary and secondary impacts from the construction of wastewater treatment facilities in the Indian Lake-Sister Lakes area	4-2
4-2	Comparison of phosphorus loading rates associated with the various alternatives to the current loading rates	4-28
4-3	Annual residential user costs	4-40
4-4	Cass County debt as a percentage of state equalized assessed valuation under four local share capital cost scenarios	4-41
4-5	Average annual user charges for the "build" alternatives expressed as a percentage of median household income for Berrien, Cass, and Van Buren Counties	4-43

LIST OF FIGURES

		Page
1-1	Location and boundary of the Indian Lake-Sister Lakes Study Area	1-2
2-1	Example strategies for management of segregated human wastes	2-34
2-2	Example strategies for management of residential greywater	2-34
2-3	Septic tank effluent gravity sewer layout	2-37
2-4	Pressure sewers vs. water main	2-39
2-5	Types of pressure sewer systems	2-40
2-6	Septic tank - soil absorption systems	2-48
2-7	Septic tank - raised drain bed system	2-50
2-8	Layout of gravity collection systems, both conventional (C1) and septic tank effluent (C3)	2-58
2-9	Layout of septic tank effluent pressure sewers with some gravity sewers (C2)	2-59
2-10	Alternative 2 - Pressure collection sewers and separate WWTPs for the Sister Lakes and Indian Lake areas with discharge to surface waters	2-65
2-11	Alternative 3 - Pressure collection sewers and regional treatment and land treatment system	2-67
2-12	Alternative 4 - Pressure collection sewers and regional WWTP located in Section 11	2-69
2-13	Alternative 5A - Pressure collection sewers and Alternative 5B - Gravity collection sewers and regional WWTP located in Sections 29 and 32	2-70
2-14	Alternative 6 - Pressure collection sewers and existing Dowagiac WWTP for Indian Lake and a new WWTP for Sister Lakes	2-72
2-15	Alternative 7 - Pressure collection sewers and existing Dowagiac WWTP	2-73
2-16	Alternative 8A - On-site systems upgrading and critical areas septic tank effluent collected by pressure sewers and conveyed to cluster drain fields	2-74

		Page
3-1	Topography and physiography of the study area	3-4
3-2	Surficial geology of the study area	3-7
3-3	Soil associations in the study area	3-9
3-4	Groundwater contours in the study area	3-33
3-5	Well sampling sites for groundwater survey	3-34
3-6	Surface watersheds in the study area	3-40
3-7	Population growth, historic and projected, for the four-township area	3-62
3-8	Spatial distribution of land use/cover	3-68
3-9	Prime farmland in areas where soil mapping is available	3-73
4-1	Future phosphorus loading conditions for the centralized wastewater management alternatives	4-30

1.0. PURPOSE AND NEED FOR ACTION

1.1. Project Background

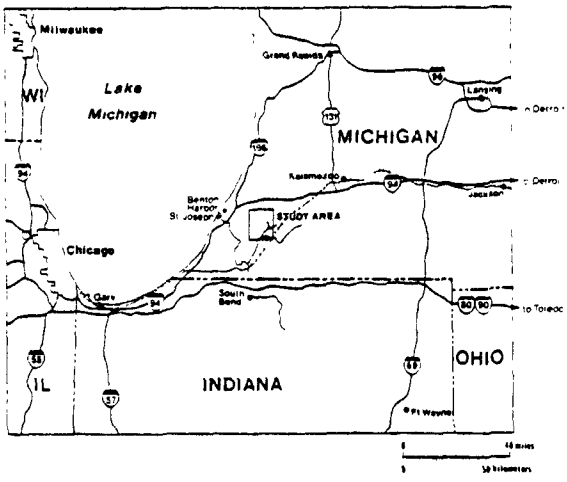
The study area, covering an area of approximately 50 square miles in rural southwestern Michigan includes the southern half of Keeler Township in Van Buren County, the northern and western portions of Silver Creek Township in Cass County, a small portion of Pokagon Township in Cass County, and the southeastern portion of Bainbridge Township in Berrien County (Figure 1-1). The most dominant geographical features are the six Sister Lakes (Round Lake, Crooked Lake, Cable Lake, Magician Lake, Pipestone Lake, and Dewey Lake,) Keeler Lake, and Indian Lake.

On-site systems are the predominant means of wastewater treatment in the study area; there is no centralized wastewater treatment or collection system. Water quality problems have been observed in some of these lakes. These problems may have been influenced by the shoreline development that has occurred around each lake in the area.

Until the 1960s, public control over septic tank system installation was nonexistent or only advisory. During the 1960s and 1970s, the State government and local health departments formulated and implemented procedures for preconstruction approval of septic tank systems. These procedures and standard design requirements have reduced the occurrence of surface malfunctions and plumbing backups for new systems.

A 1970 Cass County Health Department study of Indian Lake concluded that sewage was entering the lake from on-site systems and that as seasonal dwellings were converted to permanent houses the problem would become worse. Small lot sizes, high groundwater tables and poor soils were considered to be factors which contributed to failures and malfunctions of on-site systems. The study recommended that "an engineering feasibility study should be conducted to determine the cost and public support for a public sewage system".

The Michigan Department of Natural Resources (MDNR), Michigan Water Resources Commission (MWRC) Staff Report (1971) stated that most residences around Indian Lake have disposal systems located too close to the normal groundwater table. The MWRC did not have sufficient data in 1971 to recom-



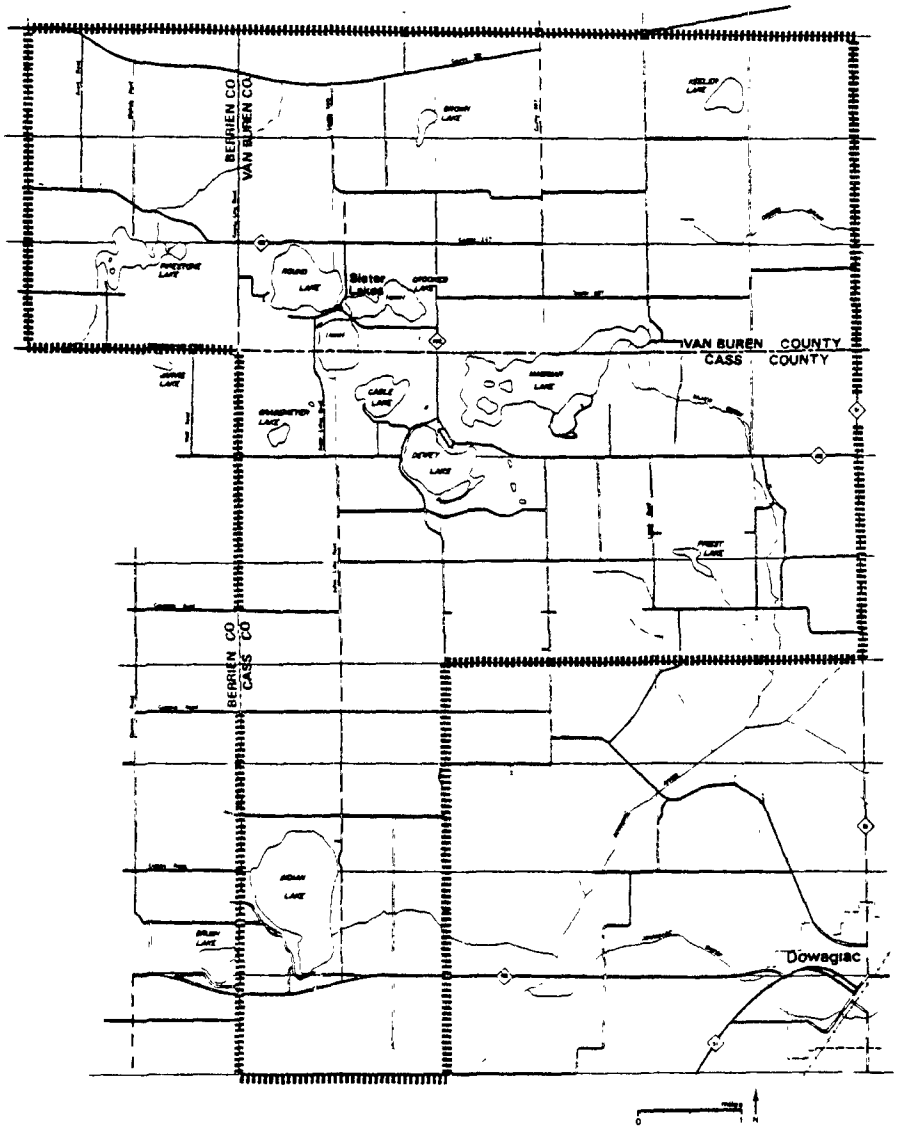


Figure 1-1. Location and boundary of Indian Lake-Sister Lakes Study Area.

mend action to cite Silver Creek Township for allowing unlawful pollution to exist in the lake area. The MWRC recommended that Silver Creek Township proceed with a program to provide a central collection and treatment system for Indian Lake.

Pipestone Lake community-wide programs to ascertain lake water quality and to upgrade on-site sewage disposal systems in order to gain compliance with the Berrien County Sewage Disposal Regulations began in the late 1960s. A 1969 survey conducted by the Berrien County Health Department (1971) determined that as many as 41% of the total residences on the north side of the lake and 25% of the residences in the southern region had sewage problems of some sort, requiring immediate attention and corrective work. In 1970, a sanitary survey conducted by the MWRC reported direct septic system discharges on the north side of the lake. Laboratory analysis showed that three discharges were sources of human waste contamination. In 1970 and 1971, MWRC follow-up studies and Health Department surveys located more direct discharges and drew attention to the Dacon-Peters Drain which was shown to have high *coliform* levels (Berrien County Health Department 1971). A 1972 water pollution and nutrient source study of Pipestone Lake conducted by the MWRC Water Quality Division concluded that the lake was adversely affected by local waste disposal problems (MDNR 1972). The MWRC then recommended construction of a municipal wastewater collection and treatment system to protect public health and lake aesthetics.

In 1971, Barger Engineering completed an engineering study for Bainbridge Township that recommended construction of a sewage collection system and aerated lagoons. Unavailability of planning and construction grants have scuttled these plans.

A limnological study of Dewey Lake conducted by Snow (1976) concluded that Dewey Lake has a natural potential to be mesotrophic (moderately enriched and productive) and that on-site systems contributed less than 10% of the phosphorus load to the lake. The study noted that a sewer system would reduce the nutrient input slightly.

Michigan DNR delineated the study area in a letter dated 20 February 1976. Pipestone Lake was added to the study area shortly afterward. Cass County Department of Public Works (DPW) is the lead applicant and the Van Buren County Road Commission and Berrien County DPW have concurred.

In May 1976, the Cass County Department of Public Works filed an application with the Farmers Home Administration (FmHA) for a grant and loan to construct a waste disposal system around Indian Lake. In August 1976, Cass County was notified by FmHA that a $900,000 grant and a $1,000,000 loan at 5% for 40 years was set aside for construction of a waste disposal system. In April 1977, an additional $300,000 in grant monies were set aside by FmHA for the Indian Lake project.

In October 1977, Gove Associates, Inc. presented to Cass County the preliminary draft of the Indian Lake - Sister Lakes Area Facility Plan. A collector system was proposed to serve populated portions of the study area, and treatment alternatives were evaluated as to costs, environmental effects, and institutional feasibility. Acceptance of the Facility Plan by MDNR and USEPA was delayed because of questions regarding the potential impacts of the proposed new conveyance lines, system cost, and whether innovative/alternative systems might be feasible.

In August 1978, USEPA issued a Notice of Intent to prepare a Environmental Impact Statement (EIS). WAPORA, Inc. (EIS consultant to USEPA) submitted an initial plan of study to USEPA in November 1978 which specified that the EIS would be prepared in two major phases. Phase I was designed as an initial data collection and evaluation phase. Phase II involved the completion of the work requirements identified in Phase I, the analysis of wastewater collection and treatment alternatives, and the production of the EIS documents. Phase I was completed in July 1979 with the publication of the Affected Environment Chapter of the Preliminary Draft EIS (WAPORA, Inc. 1979). Phase II also included a reanalysis and recosting of centralized treatment alternatives by Gove Associates, Inc. WAPORA would incorporate Gove Associates, Inc. work on centralized alternatives and would analyze both centralized and decentralized alternatives in the preparation of the EIS.

In January 1980, Gove Associates, Inc. submitted a cost effectiveness analysis of a proposed centralized treatment system to USEPA. USEPA presented review comments on the cost effectiveness analysis prepared by Gove Associates, Inc. in May 1980. Gove Associates, Inc. submitted their revised cost effectiveness analysis to USEPA in October 1980.

USEPA directed WAPORA to reanalyze the regional alternatives that were proposed and costed in the Facility Plan. This reanalysis was necessary because of deficiencies in the cost effectiveness analysis. WAPORA submitted a supplemental proposal to USEPA in April 1981 delineating the scope of work required to perform the reanalysis. Work commenced on the reanalysis and completion of the EIS in June 1981 by WAPORA.

1.2. Legal Basis for Action and Project Need

The National Environmental Policy Act of 1969 (NEPA) requires a Federal agency to prepare an EIS on "...major Federal actions significantly affecting the quality of the human environment ...". In addition, the Council on Environmental Quality (CEQ) published regulations (40 CFR Parts 1500-1508) to guide Federal agencies in determinations of whether Federal funds, such as those that may be committed to the Indian Lake-Sister Lakes project through the Construction Grants Program, or Federal approvals, would result in a project that would significantly affect the environment. USEPA developed its own regulations (40 CFR Part 6) for the implementation of the EIS process. Pursuant to these regulations, USEPA Region V determined that an EIS was required for the proposed Indian Lake-Sister Lakes project.

The Federal Water Pollution Control Act of 1972 (FWPCA, Public Law 92-500), as amended in 1977 by the Clean Water Act (CWA, Public Law 95-217), establishes a uniform, nationwide water pollution control program within which all water quality programs operate. MDNR has been delegated the responsibility and authority to administer this program in Michigan, subject to the approval of USEPA.

The dispersal of Federal funds is made to local applicants via the Municipal Wastewater Treatment Works Construction Grants Program administered by USEPA. Prior to the Amentments of 1981, the program consisted of a three-step grant process: Step 1 included wastewater facilities planning; Step 2 in-

volved the development of detailed engineering plans and specifications; and Step 3 covered construction of the pollution control system.

The Municipal Wastewater Treatment Construction Grants Amendments of 1981 became law (Public Law 97-217) on 29 December 1981, and changed significantly the procedural and administrative aspects of the municipal construction grants program. The changes reflected in these amendments have been incorporated into Construction Grants - 1982 (CG-82) Municipal Wastewater Treatment (Draft March 1982). Under the 1981 Amendments, separate Federal grants are no longer provided for facilities planning and design of projects. However, the previous designation of these activities as Step 1, facilities planning, and Step 2, design, are retained in the CG-82. The term Step 3 grant refers to the project for which grant assistance will be awarded. The Step 3 grant assistance will include an allowance for the planning (Step 1) and design (Step 2) activities.

The CG-82 states that projects which received a Step 1 and/or Step 2 grant prior to the enactment of the 1981 amendments should be completed in accordance with the terms and conditions of their grant agreement. Step 3 grant assistance will include an allowance for design for those projects which received a Step 1 grant prior to 29 December 1981. A municipality may be eligible, however, to receive an advance of the allowance for planning and/or design if the population of the community is under 25,000 and the State reviewing agency (MDNR) determines the municipality would be unable to complete the facilities planning and design to qualify for grant assistance (Step 3). The Indian Lake-Sister Lakes project currently is in Step 1.

The State of Michigan, through the MDNR, administers the Federal Construction Grants Program at the State level. The State also makes a provision for an additional 5% of the costs for planning, design, and construction, except where the Federal share is larger than 75%. No monies for this purpose have been appropriated by the State legislature.

Communities may choose to construct wastewater treatment facilities without financial support from the USEPA/State Grants Program. In such cases, the only requirements are that the design be technically sound and that the MDNR is satisfied that the facility will meet discharge standards.

If a community chooses to construct a wastewater collection and treatment system with USEPA grant assistance, the project must meet all requirements of the Grants Program. The CWA stresses that the most cost-effective alternative be identified and selected. USEPA defines the cost-effective alternative as the one that will result in minimum total resource costs over the life of the project, yet meet Federal, State, and local requirements. However, the cost-effective alternative is not necessarily the lowest cost proposal. The analysis for choosing the cost-effective alternative is based on both the capital construction costs and the operation and maintenance costs for a 20-year period, although only the capital costs are funded. Non-monetary costs also must be considered, including social and environmental factors.

Federal funding for wastewater treatment projects is provided under Section 201 of the FWPCA. The USEPA will fund 75% of the grant eligible costs for conventional sewers and treatment. For alternative collection systems and treatment systems (e.g., pressure sewers, septic tank effluent sewers, septic tanks, and soil absorption systems), the funding level increases to 85% of the eligible costs. The costs for conventional sewers that USEPA will not assist in funding for are land and easement costs, sewers for which less than two-thirds of the planned flow originates before 28 October 1972, pipes in the street or easements for house connections, and building sewers for connection to the system. The costs for alternative systems that the USEPA will not assist in funding are easement costs and building sewers for connection to the septic tank. The grant eligibility of the on-site portions of alternative systems varies depending on their ownership and management. Publicly and privately-owned systems constructed after 27 December 1977 are not eligible for Federal grants.

Michigan was required by the Federal law to establish water quality standards for lakes and streams and effluent standards for discharge to them. Federal law stipulates that, at a minimum, discharges must meet secondary treatment requirements. In some cases, even stricter effluent standards are subject to USEPA approval and must conform to Federal guidelines.

A new wastewater treatment facility also is subject to the requirements of Section 402 of the FWPCA, which established the National Pollutant Discharge Elimination System (NPDES) permit program. Under the NPDES regula-

tions, all wastewater discharges to surface waters require an NPDES permit and must meet the effluent standards identified in the permit. The USEPA has delegated authority to establish effluent standards and to issue discharge permits to the MDNR. The USEPA, however, maintains review authority. Any permit proposed for issuance may be subject to a State hearing, if requested by another agency, the applicant, or other groups and individuals. A hearing on an NPDES permit provides the public with the opportunity to comment on a proposed discharge, including the location of the discharge and level of treatment. Normally the hearing is before a State Hearing Examiner. Findings and recommendations are subject to review and approval by the Michigan Water Resources Commission.

1.3. Study Process and Public Participation

The major efforts in the preparation of this Draft EIS occurred during 1979 and 1981. During this period, WAPORA, Inc. submitted various interim reports to USEPA, including the "Affected Environment, Preliminary Draft Chapter of the Indian Lake-Sister Lakes Environmental Statement". The "Affected Environment" report described the existing conditions in the project area.

Participants in the wastewater planning process during the past four years have included: USEPA; WAPORA, Inc. (EIS consultant); Gove Associates, Inc. (Facilities Planner); Cass County (Grantee); Berrien County; Van Buren County; Southwestern Michigan Regional Planning Commission; Michigan Department of National Resources; and other Federal, State, local, and private agencies and organizations. USEPA will sponsor public meetings to facilitate public involvement during the preparation of the EIS. Several informational newsletters also will be prepared during this time and mailed to persons who express interest in the project.

1.4. Issues

Based on a review of USEPA's Notice of Intent, the Directive of Work, and the Facility Plan, the following issues have been determined to be significant and require resolution in the Environmental Statement:

- Extent of the present problems resulting from the use of on-site wastewater treatment systems

- Contribution made to water pollution by point sources and nonpoint sources other than on-site wastewater treatment systems

- Future impacts resulting from continued use of on-site systems

- Potential for improved treatment of wastewater by existing systems through improved maintenance and operation

- Cost-effectiveness of various methods of wastewater treatment, including alternative technologies

- Potential for wastewater treatment projects to change the rural character of the area by affecting wetlands and agricultural lands

- Economic impact of the capital and monthly operating costs of the project on local citizens

- Ability of local governments to finance the costs of the project

- Impact of the project on environmentally sensitive areas (e.g., endangered and threatened species' habitats, archaeological resources, and sections of the Dowagiac River nominated as "natural" by Michigan)

- Type and extent of secondary impacts resulting from the project

- Examination and analysis of local zoning and subdivision ordinances, and land use regulations that could mitigate the negative impacts of the project

- Secondary impacts that would result from the implementation of all treatment alternatives

- Commitment of resources including, but not limited to: construction materials, financial resources, and labor and energy resources.

2.0. DISCUSSION OF WASTEWATER TREATMENT ALTERNATIVES

2.1. Existing Wastewater Treatment Systems

The study area is currently served almost exclusively by on-site systems that include soil absorption of the septic tank effluent. Information on existing systems was gathered from the health department records in the respective counties. Interviews with health department personnel were also useful in assessing the environmental conditions and the suitability of septic tank soil absorption systems for treating wastewater. A septic leachate detector survey, color infrared aerial photography, and a mailed questionnaire also were used to assess the effectiveness of the existing treatment systems.

2.1.1. Existing On-site Systems

Septic tanks and soil absorption systems for individual residences are utilized almost exclusively for wastewater treatment and disposal in the study area. One noteworthy exception is the Old German Village area on the west side of Indian Lake. A collection system and community septic tank and drainfield serves 20 (or 21) residences. While early septic tanks were constructed of anything that would hold out soil, a very high percentage of the septic tanks in use are precast concrete. Soil absorption systems consist primarily of drain beds and dry wells. Prior to 1970, the homeowner and his contractor could install any system they desired. Since 1970 the health departments have regulated the design and installation of on-site systems. The records of the health departments and additional site limitations are summarized in detail in Appendix A.

Each county health department utilizes its own standards for soil absorption systems. The Van Buren County Health Department permits block trench and precast concrete dry wells for both replacement and new systems. The Cass County Health Department requires drain beds for new and replacement systems and will permit dry wells for replacement systems where site limitations prevent installation of drain beds. The Berrien County Health Department employs standards similar to those utilized by the Cass County Health Department. Based on homeowner reports, repairs to systems are frequently completed with-

out health department involvement. In Van Buren County, additionally, dry wells can be "restoned" when flow rates through the gravel-soil interface becomes too slow and backups occur. Restoning involves excavation of the gravel surrounding the dry well and replacement with clean stone.

Less than 10% of the soil absorption systems have been replaced since 1970, according to records of the health departments. These records do not indicate whether systems are operating satisfactorily or whether nutrient enriched effluent is being discharged to the lakes.

The systems that were replaced were primarily dry wells that were undersized and sited with less than the required distance above the water table. Lot sizes and shapes and land slopes are the major constraints to installing soil absorption systems that meet the applicable standards of each county.

Approximately 50% of the replacement systems have been dry wells or block trenches. Some were installed because lot configurations precluded utilization of drain beds in Cass and Berrien counties where they are preferred.

The conventional drain bed accounted for 25% of the replacements and raised drain beds (sand mounds) accounted for 20%. The majority of the raised drain beds were located in the Gilmore Beach and Beechwood subdivisions, the Polk leases, and the Pipestone Lake area. Miscellaneous replacement systems comprised the remaining 5%. These include systems where only the septic tank was replaced, those for which no design information was available, and two holding tank systems.

Regular maintenance, primarily removal of solids from the tankage, probably is the major factor in the successful operation of on-site systems. In addition to maintenance, water conservation practices in the homes are essential for the continued successful operation of many of the on-site systems that have extreme site limitations. These factors, in conjunction with seasonal use, probably account for the successful operation of many of the on-site systems, particularly the older, undersized systems.

2.1.2. Summary of Data on Operation of Existing Systems

Operating data on the on-site systems must be obtained from individual homeowners. From an operational viewpoint, homeowners could provide data on regularity of pumping and overloading of the soil absorption system that results in surface breakouts of effluent or backups in the residence. Data on the wastewater treatment capability of the systems are not generally available except by way of limited well water quality testing performed on samples submitted by concerned homeowners. Operational data from individual homeowners on a comprehensive basis have not been collected.

Three surveys for evidence of failures have been conducted: a septic leachate survey (K-V Associates, Inc. 1980), an aerial survey (USEPA 1979c), and a questionnaire prepared and tabulated by Gove Associates, Inc. (1978a, 1978b). A failure can be positively identified by evidence of recurring backups in the dwelling resulting from inadequate seepage from the soil absorption system, surface breakout of septic tank effluent over the soil absorption system, or contamination of groundwaters or surface waters from inadequately treated effluent. These surveys are discussed in the following sections.

2.1.2.1. Septic Leachate Survey

The septic leachate survey was conducted by K-V Associates, Inc. (1980) and is reproduced as Appendix B. The components of the survey included the continuous monitoring of the shoreline by the recording leachate instrument (Septic Snooper) and water quality analyses of identified stream or groundwater plume sources for evidence of domestic wastewater breakthrough of excessive nutrients and coliform bacteria. Groundwater plumes are either erupting plumes (breakthrough of organics and inorganics, principally chlorides, sodium, and other salts) or dormant plumes (slow release of residual organics after the inorganic breakthrough has receded). Stream source plumes are those surface inflows that have the indicator organics present. The methodology and the results are presented in Appendix B. It should be noted that a total of 12 miles (19 kilometers) of shoreline were not surveyed and that only Keeler Lake was completely surveyed.

A summary of the type and number of plume sources is given in Table 3-11. In general, Dewey, Cable, Lower Crooked, Round, and Keeler lakes have few or no active, erupting plumes and few dormant plumes. Magician, Indian, Upper Crooked, and Pipestone lakes have significant numbers of wastewater plumes.

Plumes were tested for water quality parameters and for flow direction and velocity. Generally, where the groundwater velocity was high in the direction of the lake, numerous active plumes were identified. These vectors must be interpreted on an extremely localized basis as conditions existing at one point in time and must not be interpreted as generalized groundwater flow vectors.

Water quality samples collected from the plumes were analyzed for orthophosphorus (reported as total phosphorus), ammonia, and nitrate-nitrogen; other samples were analyzed for fecal coliform. Generally, the only elevated fecal coliform levels measured were along the north shore of Pipestone Lake where several pipes discharge into the lake. Elevated nutrient levels were measured, but in few cases were the levels excessive enough to identify any strong breakthroughs of nutrients from soil absorption systems.

2.1.2.2. Aerial Survey

The USEPA Environmental Monitoring Systems Laboratory acquired aerial color photography and multispectral scanner imagery of the study area on 16 May and 19 July 1979 (USEPA 1979c). The color photography was stereoscopically examined for apparent on-site septic system malfunctions and for detection of algal blooms in the lakes of the study area. The photographs also were used to update a land use/cover survey prepared by the Southwestern Michigan Regional Planning Commission (SMRPC). The multispectral scanner imagery was computer-analyzed to assess the relative temperatures of the lakes.

The technique requires detection of variations in color tones of vegetation resulting from septic effluent rising to or near the soil surface. The majority of the deciduous trees and shrubs had fully leafed out, which obscured the aerial view of many of the older residential lots where a greater

proportion of failures would likely occur. The 16 May photography was used for detecting septic systems; thus, seasonal residences would likely show no failure characteristics.

The analysis categorized the discernable on-site septic systems and identified these systems on enlarged photographs. The category and number of systems are presented in Table 2-1. Only two systems were identified as probable failures and 63 systems were discernable systems that may be failing. During a field inspection, 25 of the identified systems were inspected. Of these, two had definitely failed and 15 would require further testing and monitoring.

Surface breakouts of septic tank effluent from permanent residences occur rarely in the study area as demonstrated by the aerial photography. Those that do occur are repaired quickly. Since the photography that was analyzed was obtained in May, the study is much less conclusive concerning surface breakouts from seasonal residences and from older residences under tree canopies.

2.1.2.3. Mailed Questionnaire

In 1978 Gove Associates, Inc. mailed questionnaires to property owners in Cass County to gather information concerning on-site systems and concerning attitudes toward the proposed sewage collection and treatment system. The questionnaire is included in Appendix E. (A questionnaire was also mailed to property owners in Van Buren County, but the results were not tabulated.) Generally, the results showed that less than 15% of the residents on any one lake returning questionnaires had problems with their on-site systems (Table 2-2). Within the 10 years prior to the questionnaire, as many as 28% of the residents on Magician Lake indicated that they had replaced part of their system. Considering that design standards promulgated by the county health departments had been applied only since the 1970s, it is not surprising that the percentages are what they are. The questionnaire results also indicated that apparently many residents repair their on-site systems without the benefit of the design and inspection services of county sanitarians because the county records do not indicate nearly as high a percentage of replacements.

Table 2-1. Category and number of discernable on-site septic systems around the lakes in study area (USEPA 1979c).

Lake	Effluent Disposal Area	Lateral Disposal Trench	Standing Water/Fluid	Discharge into Water Body	Vegetation Damage
Indian	8	4	0	1	0
Pipestone	3	0	1	0	0
Round	1	1	0	0	0
Upper Crooked	4	2	0	0	0
Lower Crooked	2	0	0	0	0
Cable	1	0	0	0	0
Dewey	7	1	0	0	0
Magician	22	3	0	0	0
Keeler	3	0	0	0	0
Total	51	11	1	0	0

Table 2-2. Partial results of 1978 sanitary questionnaire as tabulated by Gove Associates, Inc. for lakeshore areas in Cass County (Gove Associates, Inc. 1978b).

Lakeshore Area	Number of Respondents	Continuing Problems with System	Replacement of Part of System in last 10 years	Suitable Area for Expansion Available
Dewey	78	7.7%	20.5%	70.5%
Cable	66	4.5	6.1	66.7
Crooked	37	10.8	18.9	86.5
Magician				
North-northeast	16	6.3	25	75
Northeast-east	20	10	25	60
East-southeast-	11	18.2	18.2	45.5
Southeast-south	33	9	30	51
South-southwest	40	10	20	65
Southwest-west	52	19.2	34.6	53.8
West-northwest	29	10.3	24.1	55.2
Northwest-north	43	11.6	25.6	72.1
Summary	252	12.6	28.2	58.4
Indian				
North-northeast	29	20.7	24.1	65.5
Northeast-east	9	22.2	22.2	33.3
East-southeast	37	18.9	35.1	51.4
Southeast-south	22	9.1	18.2	45.4
South-southwest	22	9.1	18.2	63.6
Southwest-west	20	15	45	70
West-northwest	34	11.8	23.5	70.6
Northwest-north	47	14.9	12.8	53.2
Summary	232	14.5	24.6	55.2

For this reason also, it is not surprising that continuing problems are in evidence. Residents are apparently trying to escape the costlier design solutions that the sanitarians would propose by conducting repairs independent of them.

For Magician and Indian lakes, Gove Associates, Inc. tabulated the results by segments of lakeshore. Residents of the Indian Lake lakeshore reported varying percentages for the different segments (Table 2-2). On Magician Lake, the southwest-west shoreline exhibited the greatest problems. On Indian Lake, the southwest-west and the east-southeast shorelines appear to have more problems than do the other shoreline areas.

2.1.2.4. Indian Lake Sanitary Surveys

The Cass County Health Department (1970) conducted a field survey of on-site systems around Indian Lake in an effort to determine whether the systems were operating properly. Approximately 60% of the dwellings were surveyed and of these 75% were seasonal residences at that time. Results of the survey are summarized in Table 2-3. Approximately 20% of the respondents stated that they had discharges to the lake or ground surface, and yet only 4% claimed to have a problem with their system. The former statistic must not imply what it purports to reveal. Responses to questions 2, 3, 6, 7, and 10 indicate that some potential for lake pollution exists, but is not proved.

The 1971 MWRC Staff Report (Gove Associates, Inc. 1977) is a summary of a field inspection report for Indian Lake. When the field survey was conducted, most of the septic tank system failures identified the previous year by the Cass County Health Department had either been corrected or were operating properly due to changes in the hydrologic conditions. The cluster septic tank and drainfield of the Old German Village area was still malfunctioning. The report states that insufficient data were available to cite Silver Creek Township for pollution of the surface waters of the State. The report did recommend construction of a central collection and treatment system in the area.

Table 2-3. Results of pollution survey of Indian Lake (Cass County Health Department 1970).

Item		Percent Positive Responses
1.	Owner knows size of sewage disposal system	31
2.	Sewage discharges to lake or ground surface	20
3.	Sewage disposal system is within 25 feet on lakeshore	9
4.	Property fronts on lake or channel	85
5.	Sewage system is located on lake side of house	30
6.	Sewage system is located less than 50 feet from well	69
7.	Owner is having trouble with sewage system	4
8.	Replacement area for sewage disposal system is available	60
9.	Owner has septic tank pumped on schedule	19
10.	Drain pipes are close to septic system	4

2.1.2.5. Pipestone Lake Surveys

An extensive summary of the on-site systems surveys and the actions taken to upgrade failing systems was prepared by the Berrien County Health Department (1971). The first on-site inspection was conducted in 1969 by the Health Department. The results of the survey are not presented in their report. The following summer, another survey was conducted and Lake water samples were collected. Total and fecal coliform counts were very high at two of the five locations sampled. In September 1970, the MWRC sampled several drainpipes (Gove Associates, Inc. 1977). Of the four sampled, three had extremely high total and fecal coliform counts. The following year, 1971, the MWRC sampled ten locations around the Lake and found that five of the ten locations had high total and fecal coliform counts (Gove Associates, Inc. 1977). An overall sampling program for 13 stations was instituted in the autumn of 1971. Phosphates, dissolved oxygen, and phosphorus were analyzed in addition to total and fecal coliform. Pollutant levels in the water samples were elevated to the point of constituting genuine concern for the public health and water quality aspects of the Lake.

These conclusions were presented in the Berrien County Health Department report for Pipestone Lake:

- Nutrients from the Sister Lakes Laundromat formerly significantly enriched the Lake with phosphorus
- Drainage from surrounding agricultural lands, particularly, leachate from the sandy soils, animal wastes, and natural nutrients from the extensive wetland areas were the primary contributors to Lake water quality problems
- Septic tank effluent from certain residences were contributing to the Lake algae problem
- A Lake restoration program consisting of a central collection and treatment system and application of an algicide to the Lake should be considered.

The MWRC continued sampling in 1972. These sample results were published in the Facility Plan (Gove Associates, Inc. 1977). Elevated nutrient and coliform levels were commonly measured in these water samples. Approximately one-third of the estimated phosphorus inputs originated from tile outlets or ditches from residential lots around Pipestone Lake.

The Berrien County Health Department (Shipman 1977) reviewed and updated its activities concerning Pipestone Lake. In March 1973, the Health Department prepared and sent to residents plans for upgrading on-site systems. The Sister Lakes Laundromat upgraded its system by abandoning seepage lagoons and incorporating waste stabilization lagoons. In May 1973, Bainbridge Township officials conducted a hearing for a final resolution of on-site problems. Upgrading existing systems was selected as the appropriate interim approach while an ultimate solution was pursued. In June 1973, the Township building inspector followed through with upgrading the majority of the systems that violated the Sewage Disposal Regulations.

A limnological report on Pipestone Lake (Banks 1977) concludes that one source, the Dakin-Peters Drain contributed considerable amounts of phosphorus and coliform to the Lake. Animal wastes were primarily responsible for the contamination. The residential contribution of phosphorus was estimated to be a very small percentage, although the estimate was not based on testing of these sources.

2.1.3. Problems Caused by Existing Systems

The on-site systems that fail to function properly result in backups in household plumbing, ponding of effluent on the ground surface, groundwater contamination that may affect water supplies, and excessive nutrients and coliform levels in surface water. Region V has prepared guidance that recommends procedures that should be used to demonstrate project need. Since this project was initiated prior to distribution of the USEPA Region V guidance, entitled "Site Specific Needs Determination and Alternative Planning for Unsewered Areas", that guidance is not being applied to this project. However, Program Requirements Memorandum (PRM) 78-9 and 79-8 direct that documented pollution problems be identified and tracked back to the causal factors. Projects would be funded only where a significant proportion of residences are documented as having or causing problems. The Region V staff interpret the regulations to mean that eligibility for USEPA grants be limited to those systems that have direct evidence of failure such as surface ponding. However, in recognition of the potential for future failures, eligibility is extended to existing systems identified as potential failures because of

obvious underdesign or other factors, provided these systems are similar to systems that have already failed. Similarity is measured by system design, usage, soil characteristics, site limitations, site drainage, and groundwater hydrology.

2.1.3.1. Backups

Backups of sewage in household plumbing constitutes direct evidence if they can be related directly to design or site problems. Plugged or broken pipes or full septic tanks would not constitute an evidence of need. No information on backups has been collected as yet. The mailed questionnaire results for Cass County may indirectly indicate that residents may be experiencing backups by responses to the question of how often their system malfunctions. Less than 10% indicated that their system malfunctioned more frequently than once every three years. Specific locations of these respondents were not identified.

2.1.3.2. Ponding

Ponding of effluent above or around the soil absorption system constitutes direct evidence of a system failure. The aerial photography was intended to identify these systems, but problems with the photography limited its interpretation. The May photographs were examined for ponding, thus effectively eliminating seasonal residences from the analysis. Also, extensive tree cover prevented interpretation in many older residential areas. Only one system, located on the west shore of Indian Lake, was identified as exhibiting ponding. Other sources, though, indicate that the ponding problem has been more extensive. The 1970 Cass County Health Department survey of Indian Lake noted numerous discharges to swamps, particularly near the outlet drain from the Lake and along the north shore. Many of these systems have been repaired within the last decade. These failures, though, are indicative of potential problems with neighboring systems because high water tables prevent proper functioning of the soil absorption systems. Evidence of ponding around other lakes is limited, although from replacement records it could be inferred that ponding would be the principal factor in replacing soil absorption systems.

2.1.3.3. Groundwater Contamination

Contamination of water supply wells constitutes direct evidence where concentrations of nutrients greatly exceed the background levels of groundwaters in the area or primary drinking water quality standards. In order for well sampling data to qualify as direct evidence of failures, specific well information must be collected, such as the depth of the well, its orientation with respect to soil absorption systems, the presence or absence of aquitard, and the degree of protection from surface cotamination. Contaminated groundwater was identified by the groundwater sampling program in a few locations (Table 3-8). Most of the wells sampled, though, were associated with permanent residences and these are more likely to be of better construction and deeper than wells for seasonal residences. A number of wells had concentrations of chloride that indicated that septic tank effluent influenced the groundwater, but levels of phosphorus, nitrates, and ammonia were not elevated. This indicates that good treatment of effluent is occurring. High levels of nitrates may originate from other sources, particularly natural decay of organics and fertilizer. For example, the high nitrates in the two samples on the north side of Keeler Lake appear to be from other sources. Other data sources of well water quality indicate that nitrates in some wells were elevated above background levels, but did not violate drinking water quality standards. The health departments of each county provide well water testing services for residents. These results were used in the evaluation as well as water well testing performed in conjunction with the septic leachate detector survey.

2.1.3.4. Surface Water Quality Problems

Surface water quality problems directly attributable to on-site systems must be serious enough to warrant taking action. Problems with public health implications, that is, high fecal coliform counts, are serious enough to warrant attention. Nutrient inputs, though, must be analyzed in terms of their contribution to degradation of water quality and whether water quality would be significantly improved by a project. A variety of means for evaluating the contribution of septic tank effluent to water quality problems are available and have been applied within the study area.

The septic leachate detector survey (Section 2.1.2.1., Appendix B) was conducted to locate and quantify the nutrient inputs from septic tank-soil absorption systems. When the septic leachate plumes were located, surface and groundwater samples were taken at that point. The results (Appendix B) indicate that most plumes of septic leachate had low levels of phosphorus and nitrate in them compared to the typical levels in unattenuated septic tank effluent. Open drain pipes found in Pipestone Lake had high levels of nutrients and coliform. Elsewhere, coliform counts were uniformly low, indicating that public health problems (disease causing organisms) were of minimal concern. The results indicate that, where the wetlands discharge into the lakes, considerable nutrients are contributed to the lakes.

Numerous water quality surveys have been conducted to locate failed septic systems around Pipestone Lake. None of the other lakes have been analyzed to the same degree. Pipestone Lake has numerous pipe drains emptying into the lake; these have been sampled frequently by the Berrien County Health Department and the Michigan Water Resources Commission. Many of these have been shown to be highly polluted (with high fecal coliform counts). According to the Health Department (Shipman 1977), the offending systems have been repaired and upgraded. Subsequent sampling in conjunction with the septic leachate detector survey, though, demonstrated that elevated fecal coliform counts in some drain pipes were still present.

Water quality sampling on other lakes has been limited in scope. In general, the analyses have centered on open water for the purpose of defining the trophic status of the lake. The results of these studies are presented in Section 3.1.3. Depending on the sampling time and the classification scheme utilized, most of the study area lakes are eutrophic to mesotrophic. Effluent from septic systems is typically implicated as a nutrient source, though to what extent it is a source is a rough approximation. Some specific water samples have been collected for the purpose of assessing whether public health problems exist. Where failed systems have been identified by sampling, most have been repaired.

Lush growth of macrophytes, algae, and zooplankton serve as indicators of nutrient enrichment. Landsat data prepared for the SMRPC shows qualitatively where the greatest enrichment has occurred. The limnological studies of Dewey Lake (Snow 1976) and Pipestone Lake (Banks 1977) identified heavy weed patches near shoreline areas. Mapping the aquatic biota provides a general indication of the level of nutrient availability, but numerous nutrient sources may contribute to productivity. Specific connections between the productive areas and septic tank effluent must be identified in order to determine the need for a project. None of the aquatic sampling programs have made those specific connections.

2.1.3.5. Indirect Evidence

Indirect evidence that correlates with known failures can be used as an initial screening device for locating areas where failures are probable. Site limitations that infer failures are:

- Seasonal or permanent high water table
- Lack of isolation distances for water wells (depending on well depth and presence or absence of hydraulically limiting layers)
- Documented groundwater flow from a soil absorption system to a water well
- Slowly permeable soils with percolation rates greater than 60 minutes per inch
- Bedrock proximity (within 3 feet of soil absorption system where bedrock is permeable)
- Rapidly permeable soil with percolation rates less than 0.1 minutes per inch
- Holding tanks, not in itself, but as evidence that site limitations prevent installation of soil absorption systems
- On-site treatment systems that do not conform to accepted practices or current sanitary codes including, but not limited to, cesspools, the "55 gallon drum" septic tank, and other inadequately sized components
- On-site systems in an area where local data indicate excessive failure rates or excessive maintenance costs.

These indirect evidences can be utilized to categorize residences as likely failures or likely to be operating properly. Because this project commenced before the Region V Guidance was developed, the needs documentation relies heavily upon the indirect evidences and replacement records for verification.

2.1.4. Identification of Problem Areas

Certain areas around the lakes exhibit a combination of site limitations, history of replacements, and documented water quality problems that appear to require off-site treatment. In general, these areas are characterized by a high water table, usually within 24 inches (61 centimeters) of the ground surface and soils of peat and marl interbedded with sand. These areas have narrow lakefront lots on which insufficient area is available for construction of raised drain beds (mound soil absorption systems). These areas (where the septic leachate detector survey was conducted) typically show several active, erupting plumes as evidence of failed systems and have higher percentages of replacement systems installed in the last 10 years according to the mailed questionnaire and the records of the health departments. Replacement systems usually do not meet code requirements for depth to groundwater and isolation distance from wells. These site conditions predominate around Pipestone Lake. Also a considerable number of drains that have high coliform counts and other water quality parameters characteristic of septic tank effluent were found around Pipestone Lake. None of the other lakes had drains discharging septic tank effluent.

Another type of area that appears to need off-site treatment are steeply sloping lots that front on the lake. Usually the lot is narrow, about 40 feet wide (12 meters) and the house and garage are constructed adjacent to the road right-of-way. The road elevation may be anywhere from 15 to 40 feet (4.5. to 12 meters) above the lake, and slopes of 18 to 40% between the house and lake are common. Houses are usually so close together that construction equipment cannot be moved between them. While soil material and depth to groundwater are adequate for dry wells near the road, frequently no room is available for the excavation. Placement of the dry well under the driveway has been a common "last resort" solution. According to the Indian Lake Sanitary Survey and replacement records of the county health departments, many of the systems

on these lots consist of a septic tank on the lake side of the house and a dry well or drain line at the base of the slope where the depth to the water table is inadequate. Numerous replacements have been constructed on these types of lots because the soil absorption system fails due to a high water table.

Nearly all of the problem areas that appear to need off-site treatment are characterized by one or the other condition or a combination of the two. Some lots, particularly in the Sister Lakes commercial area, are of such a size that no area for a replacement dry well is available.

In addition to those areas that appear to need off-site treatment, numerous on-site systems appear to need upgrading. Direct evidence of failures is minimal, but considerable indirect evidence is present. The aerial photographic interpretation analysis identified some possible failing on-site systems, but the field check of these revealed that further monitoring would be necessary to establish that they were indeed failing. The groundwater sampling results show that elevated nitrates are present in some wells, but the exact source of those nitrates has not been identified. On-site systems appear to be the most likely source in some locations. The septic leachate detector survey identified occasional erupting and dormant plumes in these areas that were verified by water quality analyses. The information received from the mailed questionnaire for Cass County shows that, irrespective of location, no lakeshore area is completely free of failure. The questionnaire, though, does not specifically identify locations of these failures.

The records of replacements and interviews with the county sanitarians show that systems fail primarily from inadequate construction. For example, numerous cement block trenches for disposal of effluent that were installed on the northwest side of Indian Lake are experiencing structural failure. Dry wells installed within the water table commonly fail. Some existing soil absorption systems consisting of one short run of draintile have experienced failure, particularly when usage patterns extend beyond the typical seasonal usage. The dry well soil absorption systems that predominate in Van Buren County are subject to frequent failure. The Health Department does not become involved in "restoning" the dry well when it no longer accepts effluent at a satisfactory rate. According to unconfirmed reports, many of the restoned dry wells are within the water table where they would likely fail quickly.

No lakeshore area has been identified where failures are not probable, based on records of replacements. The percentage of failures identified by the health department records is not large, in part because numerous repairs are not noted on permits. Elevated nitrate levels in some wells and the contribution of some nutrients to the lakes appear to be related to on-site systems that fail to perform as intended.

The available information on site limitations and the results of the various surveys are summarized in a generalized fashion in Table 2-4. Specific information that has been gathered was too voluminous for presentation. Generally, the problems indicated are limited to specific areas around certain lakes or are minimal. The contribution of on-site systems to lake eutrophication appears to be significant for some lakes, though, and may be the basis for further action.

The remainder of the study area away from the lakes was not studied in detail. Conversations with local officials and analysis of preliminary data indicate that the sewage treatment needs are too minimal to justify expending further efforts to quantify and to cost feasible alternatives that include the off-lake areas. Keeler Lake water quality data and shoreline surveys did not reveal any evidence to require including the lake in any further analyses. Subsequent analyses within this report, therefore, exclude these areas from further consideration for sewage treatment.

2.1.5. Septage Disposal Practices

Septic tanks are pumped when homeowners contract with a septage hauler for service. Numerous septage haulers operate in the area, some of which are based in Indiana (By telephone, Mr. Lee Maajer, Cass County Health Department, to WAPORA, Inc. 19 February 1982). The county health departments inspect the haulers' equipment for licensing. The State code for licensing is the basis for these actions.

The haulers dispose of septage either at sewage treatment plants or on land. Most haulers dispose of septage on land, although the Dowagiac wastewater treatment plant receives some of the septage. Land disposal sites in

Table 2-4. Description of site limitations and results of surveys pertinent to on-site systems for each district. Districts are shown on Figure 2-8.

		SPECIFIC USEPA CRITERIA FOR NEEDS DOCUMENTATION				ENVIRONMENTAL SITE LIMITATIONS			CONFORMANCE WITH CODES		PRESENCE OF OTHER ENVIRONMENTAL DEGRADATION	
		Discharges of Untreated Wastes	Surface Malfunctions	Contamination of Groundwater	Contamination of Surface Water	Soil Limitations[a]	Groundwater Levels	Topography[b]	Existing Systems	Rehabilitation Replacement Existing Systems	Near Shore Algae Growths	Trophic Status
	DATA SOURCES	Health Dept. & 'Septic Snooper'	Health Dept. & Aerial Photography	Health Dept. & Test Well Supplies	Health Dept. & 'Septic Snooper'	SCS; Health Dept. & Soils Investigations	SCS; Health Dept. & Soils Investigations	SCS; Health Dept. & Soils Investigations	Health Dept.	Health Dept.	Landsat 1973 & Other On-Site Investigations	Field Investigation Studies
INDIAN LAKE DISTRICTS	#1	none	4 suspected failures	2 wells elevated nitrates	7 erupting plumes (100% scan)	40% Sl 10% Mod 50% Sev	50% > 5' 50% < 5'	ABC slopes	Numerous block trenches, dry wells & drain beds in water table	24 upgrades	Some submerged macrophytes. Low densities of Cladophora.	Eutrophic
	#2	none	1 surface failure 6 suspected failures	none	1 dormant plume (30% scan)	25% Sl 35% Mod 40$ Sev	60% > 5' 40% < 5'	ABC slopes	Numerous dry wells & drain lines in water table, numerous old systems	11 upgrades	Some submerged macrophytes. Low densities of Cladophora.	Eutrophic
	#3	none	1 suspected failure	2 wells elevated nitrates	(0% scan)	25% Sl 15% Mod 60% Sev	60% > 5' 40% < 5'	ABCD slopes	Numerous drain beds in water table: Numerous dry wells in small areas.	18 upgrades	Some submerged macrophytes. Low densities-traces of Cladophora.	Eutrophic
SISTER LAKES DISTRICTS	#1	none	none	none	1 dormant plume (15% scan)	15% Sl 25% Mod 60% Sev	90% > 5' 10% < 5'	ABCDE slopes	Steep slopes & loamy soils limit systems; Oak Island Sub. has muck & small lots.	16 upgrades 1 holding tank	Some submerged & emergent macrophytes. Traces of Cladophora.	Mestrophic
	#2	none	2 suspected failures	none	3 polluted surface water inflows (100% scan)	100% Sev	100%< 5'	A slopes	3 drain beds have pipe drains into lake; Subcidence breaks systems	4 upgrades 1 holding tank (no permits required for upgrades)	30% surface area supported macrophyte growth (National Biocentric 1979)	Eutrophic

Table 2-4. Description of site limitations and results of surveys pertinent to on-site systems (continued).

	SPECIFIC USEPA CRITERIA FOR NEEDS DOCUMENTATION				ENVIRONMENTAL SITE LIMITATIONS			CONFORMANCE WITH CODES		PRESENCE OF OTHER ENVIRONMENTAL DEGRADATION	
	Discharges of Untreated Wastes	Surface Malfunctions	Contamination of Groundwater	Contamination of Surface Water	Soil Limitations[a]	Groundwater Levels	Topography[b]	Existing Systems	Rehabilitation Replacement Existing Systems	Near Shore Algae Growths	Trophic Status
DATA SOURCES	Health Dept. & 'Septic Snooper'	Health Dept. & Aerial Photography	Health Dept. & Test Well Supplies	Health Dept. & 'Septic Snooper'	SCS; Health Dept. & Soils Investigations	SCS; Health Dept. & Soils Investigations	SCS; Health Dept. & Soils Investigations	Health Dept.	Health Dept.	Landsat 1973 & Other On-Site Investigations	Field Investigation Studies
...SISTER LAKES DISTRICT (Cont'd)											
#3	2 partially treated flows	3 suspected failures	none	9 polluted surface water inflows 1 dormant surface water inflow 1 dormant plume (40% scan)	100% Sev	100% < 5'	A slopes	10 systems have pipe drains into lake. Subsidence breaks systems	(no permits required for upgrading)	Low densities of Cladophora.	Eutrophic
#4	none	2 suspected failures	none	1 erupting plume 2 dormant plumes (25% scan)	35% Sl 30% Mod 35% Sev	90% > 5' 10% < 5'	BCD slopes	Some dry wells in water table; some small lots	15 upgrades	Some submerged and emergent macrophytes present	Mesotrophic
#5	none	3 suspected failures	1 well elevated nitrate	1 erupting plume 7 dormant plumes (60% scan)	80% Mod 20% Sev	90% > 5' 10% < 5'	CDE slopes	Numerous small lots; some lots w/high water table	31 upgrades	Submerged & emergent macrophytes present	Mesotrophic
#6	none	4 suspected failures	2 wells elevated nitrate	4 erupting plumes 7 dormant plumes (70% scan)	40% Sl 20% Mod 40% Sev	85% > 5' 15% < 5'	BCD slopes	Numerous small shoreline lots w/steep slopes; some w/high water table	28 upgrades	Submerged & emergent macrophytes present	Mesotrophic-Eutrophic
#7	none	1 suspected failure	1 well elevated nitrate	no plumes (20% scan)	40% Sl 60% Mod	95% > 5' 5% < 5'	BC slopes	Some narrow lots w/steep slopes	11 upgrades	Submerged & emergent macrophytes present. Trace of Cladophora.	Mesotrophic-Eutrophic

Table 2-4. Description of site limitations and results of surveys pertinent to on-site systems (continued). .

	SPECIFIC USEPA CRITERIA FOR NEEDS DOCUMENTATION				ENVIRONMENTAL SITE LIMITATIONS			CONFORMANCE WITH CODES		PRESENCE OF OTHER ENVIRONMENTAL DEGRADATION	
	Discharges of Untreated Wastes	Surface Malfunctions	Contamination of Groundwater	Contamination of Surface Water	Soil Limitations[a]	Groundwater Levels	Topography[b]	Existing Systems	Rehabilitation Replacement Existing Systems	Near Shore Algae Growths	[illegible]
DATA SOURCES	Health Dept. & 'Septic Snooper'	Health Dept. & Aerial Photography	Health Dept. & Test Well Supplies	Health Dept. & 'Septic Snooper'	SCS; Health Dept. & Soils Investigations	SCS; Health Dept. & Soils Investigations	SCS; Health Dept. & Soils Investigations	Health Dept.	Health Dept.	Landsat 1973 & Other On-Site Investigations	Field Investigation Studies
#8	none	2 suspected failures	none	2 dormant plumes (70% scan)	60% Sl 30% Mod 10% Sev	90% > 5' 10% < 5'	ABCD slopes	Few small lots w/high water table	11 upgrades	Some emergent macrophytes	Mesotrophic
#9	none	4 suspected failures	1 well elevated nitrate	2 polluted surface water inflows 5 erupting plumes (80% scan)	30% Sl 40% Mod 30% Sev	85% > 5' 15% < 5'	ABCDE slopes	Numerous narrow lots w/steep slopes or high water table	23 upgrades	Submerged & emergent macrophytes present	Eutrophic
#10	none	7 suspected failures	1 well elevated nitrate	1 polluted surface water inflow 3 erupting plumes (50% scan)	25% Sl 5% Mod 70% Sev	55% > 5' 45% < 5'	ABCDE slopes	Numerous lots w/high water table; some narrow lots w/steep slopes	28 upgrades	Submerged & emergent macrophytes present	Eutrophic
#11	none	6 suspected failures	1 well elevated nitrate	3 erupting plumes (20% scan)	5% Sl 50% Mod 45% Sev	55% > 5' 45% < 5'	ABC slopes	Numerous narrow lots w/steep slopes; numerous lots w/high water table	28 upgrades	Submerged & emergent macrophytes present. Low to moderate densities of Cladophora.	Eutrophic
#12	none	4 suspected failures	none	7 dormant plumes (100% scan)	5% Sl 90% Mod 5% Sev	95% > 5' 5% < 5'	ABC slopes	Few lots w/steep slopes; few small lots w/high water table	5 upgrades	Submerged & emergent macrophytes present	Eutrophic

...SISTER LAKES DISTRICTS (Cont'd)

Table 2-4. Description of site limitations and results of surveys pertinent to on-site systems (concluded).

	SPECIFIC USEPA CRITERIA FOR NEEDS DOCUMENTATION				ENVIRONMENTAL SITE LIMITATIONS			CONFORMANCE WITH CODES		PRESENCE OF OTHER ENVIRONMENTAL DEGRADATION	
	Discharges of Untreated Wastes	Surface Malfunctions	Contamination of Groundwater	Contamination of Surface Water	Soil Limitations[a]	Groundwater Levels	Topography[b]	Existing Systems	Rehabilitation Replacement Existing Systems	Near Shore Algae Growths	Trophic State
DATA SOURCES	Health Dept. & 'Septic Snooper'	Health Dept. & Aerial Photography	Health Dept. & Test Well Supplies	Health Dept. & 'Septic Snooper'	SCS; Health Dept. & Soils Investigations	SCS; Health Dept. & Soils Investigations	SCS; Health Dept. & Soils Investigations	Health Dept.	Health Dept.	Landsat 1971 & Other On-Site Investigations	Field Investigation Studies
#13	none	9 suspected failures	none	6 erupting plumes 2 dormant plumes (50% scan)	15% Sl 80% Mod 5% Sev	95% > 5' 5% < 5'	ABC slopes	Numerous small lots; some lots w/high water table	8 upgrades	Submerged & emergent macrophytes present	Eutrophic
#14	none	none	none	none (60% scan)	5% Sl 90% Mod 5% Sev	95% > 5' 5% < 5'	ABCD slopes	Few lots w/steep slopes; few lots w/high water table	1 upgrade	Some emergent macrophytes	Mesotrophic
#15	none	3 suspected failures	none	3 dormant plumes (50% scan)	60% Sl 30% Mod 10% Sev	90% > 5' 10% < 5'	ABC slopes	Some small lots w/high water table or steep slopes	12 upgrades	Submerged & emergent macrophytes present. Low densities of Cladophora.	Eutrophic

SISTER LAKES DISTRICTS (Cont'd)

[a] SCS ratings: Sl-slight; Mod-moderate, and Sev-severe; soils with slight ratings may provide inadequate groundwater protection.

[b] SCS slope limits: A-0-2%; B-2-6%; C-6-12%; D-12-18%; E-18-45%.

Cass County must be approved by the sanitarians before septage can be applied. Approval of a particular site is contingent on whether nuisance conditions would likely result, either to surface waters or from odors. Most of the application areas are former agricultural land currently not under cultivation. Periodically, the hauler is responsible for discing or plowing the land so that nuisance conditions do not develop. There are no standards concerning how much septage can be applied to one area. Septage pumped in winter is also land-applied by certain haulers. It is applied on the snow where it freezes. As thaws occur the liquid from the septage will infiltrate the ground surface.

2.2. Identification of Wastewater Treatment System Options

2.2.1. Design Factors

Three categories of factors must be considered in the design of a wastewater treatment system: the present and projected wastewater flows in the study area, the effluent requirements established by Federal and State authorities, and economic cost criteria (duration of the planning period, interest rate, service factor, and service life of facilities and equipment). Each of these factors is discussed in the following sections.

2.2.1.1. Wastewater Load Factors

Wastewater flow projections for the Indian Lake and Sister Lakes proposed sewer service areas were developed based on a projected year 2000 design population (Section 3.2.1.3.), an average daily base flow (ADBF) of 65 gallons per capita per day (gpcd), and design infiltration of 10 gpcd. A determination of the design flow to the year 2000 is shown in Table 2-5.

The organic loads were projected on the basis of the accepted design values of 0.17 pounds of BOD_5 per capita per day and 0.20 pounds of suspended solids (SS) per capita per day. These values were applied to the projected year 2000 population. The BOD_5 and SS influent wastewater loading and influent wastewater concentrations are summarized in Table 2-5.

Table 2-5. Wastewater load factors projected for Sister Lakes and Indian Lake, Michigan, for the year 2000.

Parameters	Units	Value		
		Permanent	Seasonal	Total
Sister Lakes Service Area				
Design year population	--	3,415	3,470	6,885
Average daily base flow (ADBF)	gpcd	65	65	65
Design infiltration (based on maximum permissible infiltration rate of 200 gal/inch-diameter/mile/day)	gpcd	10	10	10
Average flow per capita per day	gal	75	75	75
Average daily design flow	mgd	0.256	0.262	0.52
Peak flow (based on a peaking factor of 3.25)	mgd	0.832	0.852	1.69
BOD_5 design loading (based on on 0.17 lb/c/d)	lb/d	583.6	589.7	1,173.3
BOD_5 influent concentration	mg/l	271	270	270
SS design loading (based on 0.20 (lb/c/d)	lb/d	686.6	694.0	1,380.6
SS influent concentration	mg/l	319	318	318
Indian Lake Service Area				
Design year population	--	1,031	760	1,791
Average flow per capita per day	gal	75	75	75
Average daily design flow	mgd	0.08	0.06	0.14
Peak flow (based on a peaking factor of 3.25)	mgd	0.26	0.20	0.46
BOD_5 design loading (based on 0.17 lb/c/d)	lb/d	176	129	305
BOD_5 influent concentration	mg/l	264	258	261
SS design loading (based on 0.20 lb/c/d)	lb/d	207	152	359
SS influent concentration	mg/l	310	304	307
Combined Sister Lakes - Indian Lake Service Area				
Design year population	--	4,446	4,230	8,676
Average flow per capita per day	gal	75	75	75
Average daily design flow	mgd	0.336	0.322	0.66
Peak flow	mgd	1.09	1.05	2.14
BOD_5 design loading	lb/d	759.6	718.9	1,478.5
BOD_5 influent concentration	mg/l	270	268	269
SS design loading	lb/d	893.6	846.0	1,739.6
SS influent concentration	mg/l	317	315	316

2.2.1.2. Effluent Requirements

On 26 February 1980 MDNR issued effluent limits for the Indian Lake-Sister Lakes study area in a letter to Gove Associates, Inc. (Appendix O). Effluent limits were issued for two discharge points to the surface water: at the Indian Lake outlet in the western half of Section 32 and at Silver Creek in Section 2. Both locations are in Silver Creek Township.

For the two discharge points, the first recommendation of the Engineering and Technical Services Section of the MDNR is land application. If this is not feasible, then the recommendation is as follows:

- For the Indian Lake outlet in the western half of Section 32, Township 5 South, Range 16 West, an annual discharge from 1 March to 15 May which will meet the following effluent limits is allowed:

Carbonaceous BOD_5	30 mg/l as a 30 day average 40 mg/l as a 7 day average
Total suspended solids	70 mg/l as a 30 day average 100 mg/l as a 7 day average
pH	6.0 to 9.0
Dissolved oxygen	5.0 mg/l daily minimum
Total phosphorus as P	At such time that technology provides an economically feasible means of removing phosphorus from stabilization lagoons, it shall be required at this facility.

During discharge, the ratio of wastewater flow to upstream flow shall be as follows: 1.0 from 1 March to 31 March; 0.4 from 1 April to 30 April; and 0.1 from 1 May to 15 May.

- For Silver Creek in Section 2 of Silver Creek Township, an annual discharge from 1 March to 15 May which will meet the following effluent limits is allowed:

Carbonaceous BOD_5	30 mg/l as a 30 day average 45 mg/l as a 7 day average
Total suspended solids	70 mg/l as a 30 day average 100 mg/l as a 7 day average
pH	6.0 to 9.0
Dissolved oxygen	5.0 mg/l daily minimum
Total phosphorus as P	At such time that technology provides an economically feasible means of removing phosphorus from stabilization lagoons, it shall be required of this facility.

  During discharge, the ratio of wastewater flow to upstream flow shall be as follows: 1.0 from 1 March to 31 March; 0.4 from 1 April to 30 April; and 0.1 from 1 May to 15 May.

It is assumed in the preparation of this EIS that at the present time there is no economically feasible means of removing phosphorus from stabilization lagoons. Therefore, phosphorus removal facilities are not proposed in any of the centralized wastewater treatment systems that have an annual discharge to the surface waters.

2.2.1.3. Economic Factors

The economic cost criteria consist of an amortization or planning period from the present to the year 2000, or approximately 20 years; an interest rate of 7.625%, and service lives of 20 years for treatment and pumping equipment, 40 years for structures, and 50 years for conveyance facilities. Salvage values were estimated using straight-line depreciation for items that could be used at the end of the 20-year planning period. An annual appreciation rate of 3% over the planning period was used to calculate the salvage value of the land. Operation and maintenance (O&M) costs include labor, materials, and utilities (power). Costs associated with the treatment works, pumping stations, solids handling and disposal processes, conveyance facilities, and

on-site systems are based on prevailing rates. Annual revenue-producing benefits, such as lease of land application sites for crop production, are subtracted from O&M costs.

Costs are based on the USEPA STP Construction Cost Index of 416.9, the USEPA Complete Urban Sewer System (CUSS) Construction Cost Index of 223, and the Engineering News Record (ENR) Construction Cost Index of 3,560 for the second quarter of 1981 (June 1981). The total capital cost includes the initial construction cost plus a service factor. The service factor includes costs for engineering, contingencies, legal and administrative, and financing. The service factors used for different alternative components are summarized in Table 2-6. The economic cost criteria are summarized in Table 2-7.

2.2.2. System Components

2.2.2.1. Flow and Waste Reduction

Economy in the construction and the operation of sewage collection, treatment, and disposal facilities, is, in many localities, achieveable by controlling waste flows or the amounts of impurities carried in the sewage. This economy is generally recognized in the short-term monetary savings that result from the reduced design capacities of facilities or from the long-term savings realized when facility expansion or replacement is unnecessary. Other savings can be achieved throughout the life of the facilities from reduced

Table 2-6. Service factor[a].

Item	Conventional Collection and Treatment System	Pressure Sewer, Cluster, and On-site Systems (%)
Contingencies	10	15
Engineering	10	13
Legal & Administrative	3	3
Financing	4	4
Total	27	35

[a] A service factor is applied to the construction cost to compute the capital cost. Interest during construction is not included.

Table 2-7. Economic cost criteria.

Item	Units	Value
Amortization period	years	20
Interest (discount) rate	%	7-5/8
STP construction cost index - Detroit, June 1981	-	416.9
Sewer (CUSS) construction cost index - Detroit, June 1981	-	223
ENR - construction cost index, June 1981	-	3,560
Service life		
Equipment	years	20
Structures	years	40
Conveyance facilities	years	50
Land	years	permanent
Salvage value		
Equipment	%	0
Structures	%	50
Conveyance structures	%	60
Land	%	103

operational costs. In addition, mitigation of some of the environmental impacts may be achieveable through waste reduction measures such as a reduction in the phosphorus content of laundry detergents.

Methods of flow and waste reduction considered for use in the study area include water conservation measures, waste segregation, and a detergent phosphorus ban.

2.2.2.1.1. Water Conservation Measures

Clean water has for many years often been regarded as one of the nation's bountiful free goods. Concerns over water supply and wastewater disposal and an increasing recognition of the benefits that may accrue through water conservation are serving to greatly stimulate the development and application of water conservation practices. The diverse array of water conservation prac-

tices may, in general, be divided into these major categories:

- Elimination of non-functional water use
- Water-saving devices, fixtures, and appliances
- Wastewater recycle/reuse system.

Elimination of Non-functional Water Use

Non-functional water use is typically the result of the following:

- Wasteful, water-use habits such as using a toilet flush to dispose of a cigarette butt, allowing the water to run while brushing teeth or shaving, or operating a clotheswasher or dishwasher with only a partial load
- Excessive water supply pressure - for most dwellings a water supply pressure of 40 pounds per square inch (psi) is adequate and a pressure in excess of this can result in unnecessary water use and wastewater generation, especially with wasteful water use habits
- Inadequate plumbing and appliance maintenance - unseen or apparently insignificant leaks from household fixtures and appliances can waste large volumes of water and generate similar quantities of wastewater. Most notable in this regard are leaking toilets and dripping faucets. For example, even a pinhole leak which may appear as a dripping faucet can waste up to 170 gallons per day at a pressure of 40 psi. More severe leaks can generate even more massive quantities of wastewater.

Water-Saving Devices, Fixtures, and Appliances

The quantity of water traditionally used by household fixtures or appliances often is considerably greater than actually needed. Typically, toilet flushing, bathing, and clotheswashing collectively account for more than more than 70% of the interior water use and waste flow volume of a household (Siegrist, Woltanski, and Waldorf 1978). Thus, efforts to accomplish major reductions in the wastewater flow volume, as well as its pollutant mass, have been directed toward the toilet flushing, bathing, and clotheswashing areas. Some selected water conservation/waste load reduction devices and

systems developed for these household activities include:

- Toilet devices and systems
  - Toilet tank inserts - such as water filled and weighted plastic bottles, flexible panels, and/or dams
  - Dual-flush toilet devices
  - Shallow-trap toilets
  - Very low volume flush toilets
  - Non-water carriage toilets

- Bathing devices and systems
  - Shower flow control devices
  - Reduced-flow shower fixtures

- Clotheswashing devices and systems
  - Waste flow reductions may be accomplished through use of a clotheswasher with a suds-saver attachment. The suds-saver feature is included as an optional cycle setting on several commercially made washers. The selection of suds-saver cycle when washing provides for storage of the washwater from the wash cycle for subsequent use as the wash water for the next wash load. The rinse cycle remains unchanged.

Wastewater Recycle/Reuse Systems

These systems provide for the collection and processing of all household wastewater or the fractions produced by certain activities for subsequent reuse. A system which has received a majority of development efforts includes the recycling of bathing and laundry wastewater for flushing water-carriage toilets and/or outside irrigation.

Other Water Conservation Measures

One possible method for reduction of sewage flow is the adjustment of the price of water to control consumption. This method normally is used to reduce water demand in areas with water shortages. It probably would not be effective in reducing sanitary sewer flows because much of its impact is usually on luxury water usage, such as lawn sprinkling or car washing. None of the luxury uses impose a load on a separated sewerage system and on on-site systems. Therefore, the use of price control probably would not be effective in significantly reducing wastewater flows.

Other measures include educational campaigns on water conservation in everyday living and the installation of pressure-reduction valves in areas where the water pressure is excessive (greater than 60 pounds per square inch). Educational campaigns usually take the form of spot television and radio commercials, and the distribution of leaflets with water and sewer bills. Water saving devices must continue to be used and maintained for flow reduction to be effective.

Results of Water Conservation Measures

Wastewater flows on the order of 15 to 30 gpcd can be achieved by installation of combinations of the following devices and systems:

- Replace standard toilets with dual cycle or other low volume toilets
- Reduce shower water use by installing thermostatic mixing valves and flow control shower heads. Use of showers should be encouraged rather than baths whenever possible
- Replace older clotheswashing machines with those equipped with water-level controls or with front-loading machines
- Eliminate water-carried toilet wastes by use of in-house composting toilets
- Use recycled bath and laundry wastewaters to sprinkle lawns in summer
- Recycle bath and laundry wastewaters for toilet flushing. Filtration and disinfection of bath and laundry wastes for this purpose has been shown to be feasible and aesthetically acceptable in pilot studies (Cohen and Wallman 1974; McLaughlin 1968). This is an alternative to in-house composting toilets that could achieve the same level of wastewater flow reduction
- Commercially available pressurized toilets and air-assisted shower heads using a common air compresser of small horsepower would reduce sewage volume from these two largest household sources up to 90%.

Impact of Water Conservation Measures on Wastewater Treatment Systems

Methods that reduce the flow or pollutant loads can provide the following benefits to a wastewater management program:

- Reduce the sizes and capital costs of new sewage collection and treatment facilities
- Delay the time when future expansion or replacement facilities will be needed
- Reduce the operational costs of pumping and treatment
- Mitigate the sludge and effluent disposal impacts
- May extend the life of the existing soil absorption system for an existing system functioning satisfactorily
- May reduce the wastewater load sufficiently to remedy a failing soil absorption system in which the effluent is surfacing or causing backups
- May reduce the size of the soil disposal field in the case of new on-site systems. However, the pretreatment process of the on-site systems should be maintained at full-size to provide the necessary capacity to treat and attenuate peak flows.

2.2.2.1.2. Waste Segregation

Various methods for the treatment and the disposal of domestic wastes involve separation of toilet wastes from other liquid waste. Several toilet systems can be used to provide for segregation and separate handling of human excreta (often referred to as blackwater), and, in some cases, garbage wastes. Removal of human excreta from the wastewater serves to eliminate significant quantities of pollutants, particularly suspended solids, nitrogen, and pathogenic organisms (USEPA 1980a).

Wastewaters generated by fixtures other than toilets are often referred to collectively as graywater. Characterization studies have demonstrated that typical graywater contains appreciable quantities of organic matter, suspended solids, phosphorus, and grease. The organic materials in graywater appear to degrade at a rate not significantly different from those in combined residential water. Microbiological studies have demonstrated that significant concentrations of indicator organisms such as total and fecal coliforms, are typically found in graywater (USEPA 1980a).

Although residential graywater does contain pollutants and must be properly managed, graywater may be simpler to manage than total residential wastewater due to a reduced flow volume. A number of potential strategies for management of segregated human excreta (blackwater) and graywater are presented in Figure 2-1 and Figure 2-2, respectively.

2.2.2.1.3. Michigan Ban on Phosphorus

Phosphorus is frequently the nutrient that controls algal growth in surface waters and is, therefore, an important influence on lake or stream eutrophication. Enrichment of the waters with nutrients encourages the growth of algae and other microscopic plant life. Decay of the plants increases biochemical oxygen demand and lowers the amount of dissolved oxygen in the water. The addition of nutrients encourages higher forms of plant life, thereby hastening the aging process by which a lake evolves into a bog or marsh. Normally, eutrophication is a natural process that proceeds slowly over thousands of years. However, human activity can greatly accelerate it. Phosphorus and other nutrients contributed to surface waters by human wastes, laundry detergents, and agricultural runoff often result in over-fertilization, over-productivity of plant matter, and "choking" of a body of water within a few years.

In 1971 the Michigan legislature limited the amount of phosphorus in laundry and cleaning supplies sold in Michigan to 8.7% (Michigan-Public Act 226, Cleaning Agent Act). To reduce phosphorus concentrations in wastewater further, the MDNR subsequently banned the use and sale of domestic laundry detergents containing more than 0.5% phosphorus by weight. The ban appears to have had a positive impact on surface water quality in the Great Lakes Basin, primarily by reducing phosphorus levels and algae in tributary and near-shore waters (Hartig and Horvath 1982). The preliminary assessment of the effects of the ban concluded that:

- Based on a survey of 58 major wastewater treatment plants in Michigan, influent and effluent total phosphorus concentrations decreased by 23% and 25%, respectively
- The phosphorus detergent ban resulted in a 20% reduction in total phosphorus loadings to the Great Lakes.

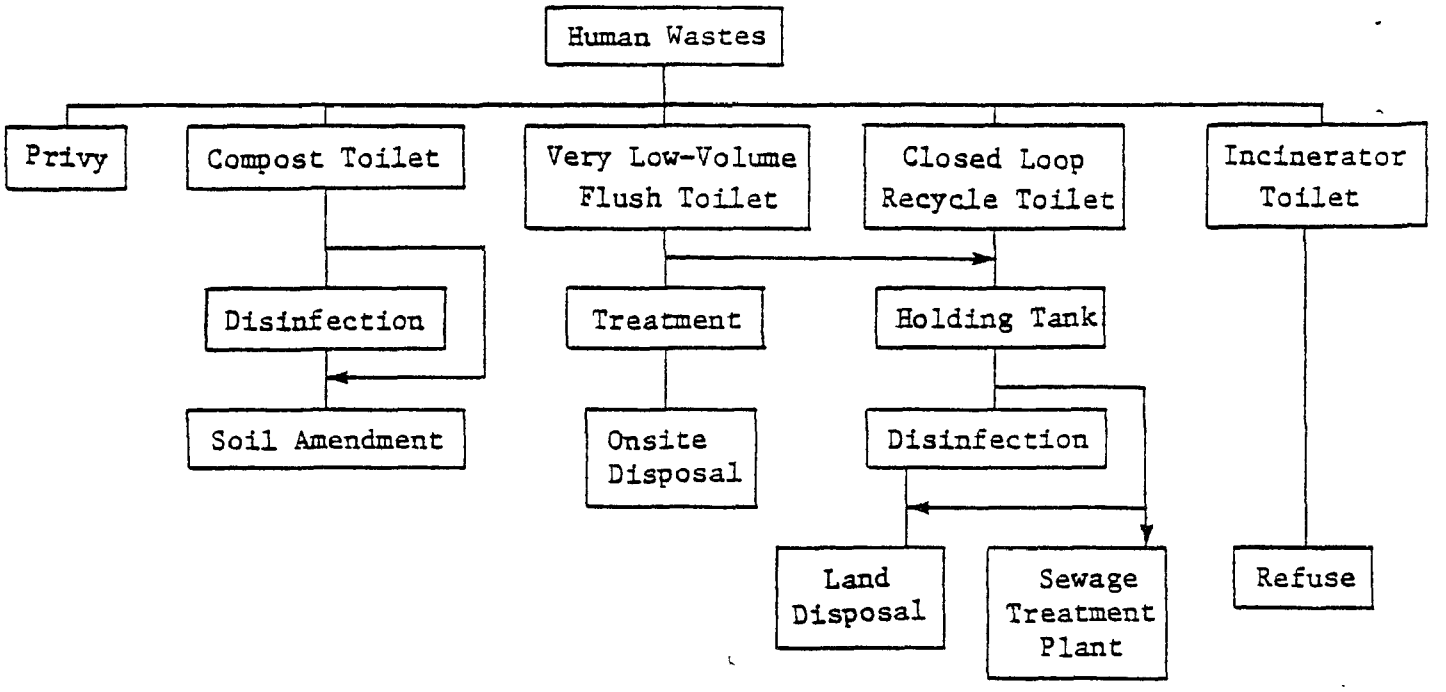


Figure 2-1. Example strategies for management of segregated human wastes.

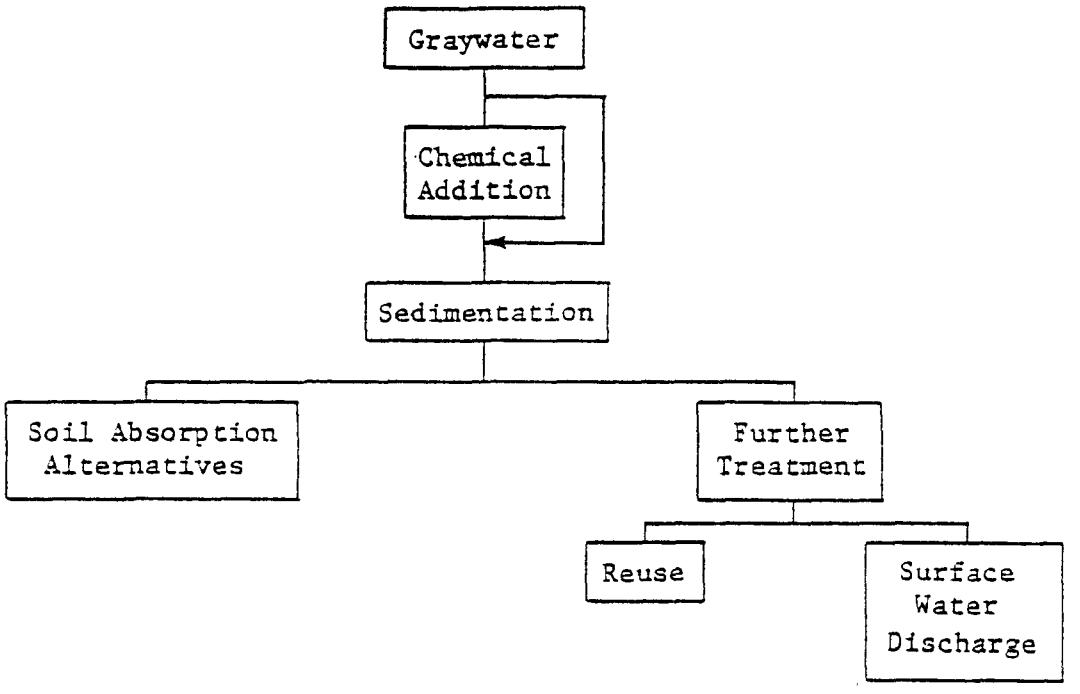


Figure 2-2. Example strategies for management of residential greywater.

There will be no cost savings or cost increases for on-site systems as a result of the phosphorus ban. It is possible, although not confirmed or quantified by previous research, that a reduction in phosphorus discharged to septic tank soil disposal systems will result in a considerable reduction in the amount of phosphorus transported by groundwater from the soil disposal system.

2.2.2.1.4. Summary

To reduce the waste loads (flow volume and/or pollutant contributions) generated by a typical household, an extensive array of techniques, devices, and systems are available. Because the per capita amount of water utilized (approximately 65 gpcd) in the study area for the centralized treatment alternatives is relatively small, water conservation measures would be marginally effective in reducing wastewater flows and, thus, are not necessary. Also, because the efficacy of water conservation is complex and must be determined on a case-by-case basis, a comprehensive water conservation alternative is not proposed in this document. However, on-site system alternatives (Alternatives 8A, 8B, and 9 described in Section 2.3) include separate treatment strategies for the graywater and blackwater. The proposed treatment for blackwater and graywater is described in Section 2.3.

2.2.2.2. Collection System

Two types of collection and conveyance sewer systems are proposed: a gravity sewer system and a pressure sewer system. Both types of collection systems are briefly described in the following sections.

2.2.2.2.1. Gravity Sewer System

The gravity sewer system generally consists of gravity sewers, pumping stations, and force mains. Usually it will also carry whatever industrial wastes are produced in the area that it serves. A gravity sanitary sewer carries wastewater by gravity (downslope) only.

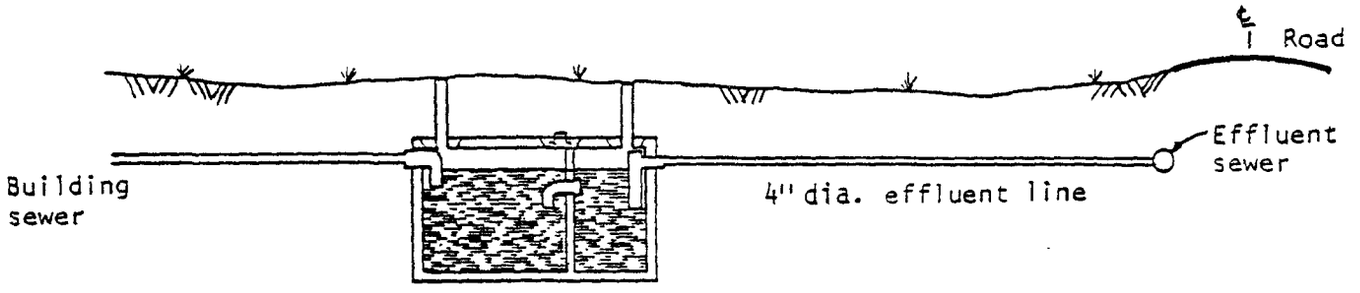
Apart from pumping facilities sometimes required at sewage treatment plants, the principal conditions and factors necessitating the use of pumping stations in the sewage collection system are as follows:

- The elevation of the area to be serviced is too low to be drained by gravity to existing or proposed trunk sewers
- Service is required for areas that are outside the natural drainage area, but within the sewage or drainage district
- Omission of pumping, although possible, would require excessive construction costs because of the deep cuts required for the installation of a trunk sewer to drain the area.

The pumping station pumps wastewater under pressure through a pipeline known as a force main. For the sake of economy, the force main profiles generally conform to existing ground elevations.

Gravity sewers that carry raw sewage are called, in this report, conventional gravity sewers. In these sewers, sewage should flow with sufficient velocity to prevent the settlement of solid matter. The usual practice is to design the sewers so that the slope is sufficient to ensure a minimum velocity of 2 feet per second (fps) with flow at one-half full or full depth. Pumping stations within the conventional gravity sewer system must be designed to handle the solids in raw sewage, either by grinding them or by screening larger material and passing smaller material through the pump. Force mains are generally designed with adequate velocity to prevent deposition of solids at minimum flow. Solids will not settle out at a velocity of 2.0 fps, but solids that settle out when no flow occurs (pumps are operating discontinuously) require a velocity of 3.5 fps to resuspend them.

Gravity sewers that carry septic tank effluent are called septic tank effluent gravity sewers in this report (Figure 2-3). Other terms commonly applied to them are Australian sewers and small diameter sewers. Because only clear effluent from septic tanks is carried, a minimum velocity of 1.5 fps can be designed. Also, a minimum pipe size of 4-inch diameter is sufficient. Cleanouts, rather than manholes, are recommended so that less dirt enters the pipes (Otis 1979). Pipes do not need to be laid at a constant slope nor in a straight line (Simmons and Newman 1979). Pumping equipment does not need



SEPTIC TANK EFFLUENT GRAVITY SEWER LAYOUT

Figure 2-3. Septic tank effluent gravity sewer layout.

solids handling equipment and force mains have no minimum velocity requirements. Because septic tank effluent is odorous, special measures must be taken to ensure that odors are properly handled and treated.

2.2.2.2.2. Pressure Sewer System

Essentially, a pressure sewer system is the reverse of a water distribution system. The latter employs a single inlet pressurization point and a number of user outlets, while the pressure sewer embodies a number of pressurizing inlet points and a single outlet, as shown in Figure 2-4. The pressure main follows a generally direct route to a treatment facility or to a gravity sewer, depending on the application. The primary purpose of this type of design is to minimize sewage retention time in the sewer.

There are two major types of pressure sewer systems: the grinder pump (GP) system and the septic tank effluent pump (STEP) system. As shown in Figure 2-5, the major differences between the alternative systems are in the on-site equipment and layout. There are also some subtle differences in the pressure main design methods and in the treatment systems required to reduce the pollutants in the collected wastewater to an environmentally acceptable level. Neither pressure sewer system alternative requires the modification of household plumbing, although neither precludes it if such modifications are deemed desirable.

The advantages of pressure sewers are primarily related to installation costs and inherent system characteristics. Because these systems use small-diameter plastic pipes buried just below the frost penetration depth, their installation costs can be quite low compared to conventional gravity systems in low-density areas. Other site conditions that enhance this cost differential include hilly terrain, rock outcropping, and high water tables. Because pressure sewers are sealed conduits, there should be no opportunity for infiltration. The sewers can be designed to handle only the domestic sewage generated in the houses serviced, which excludes the infiltration that occurs in most gravity systems. The high operation and maintenance costs for the use of mechanical equipment at each point of entry to the system is the major disadvantage of a pressure sewer system.

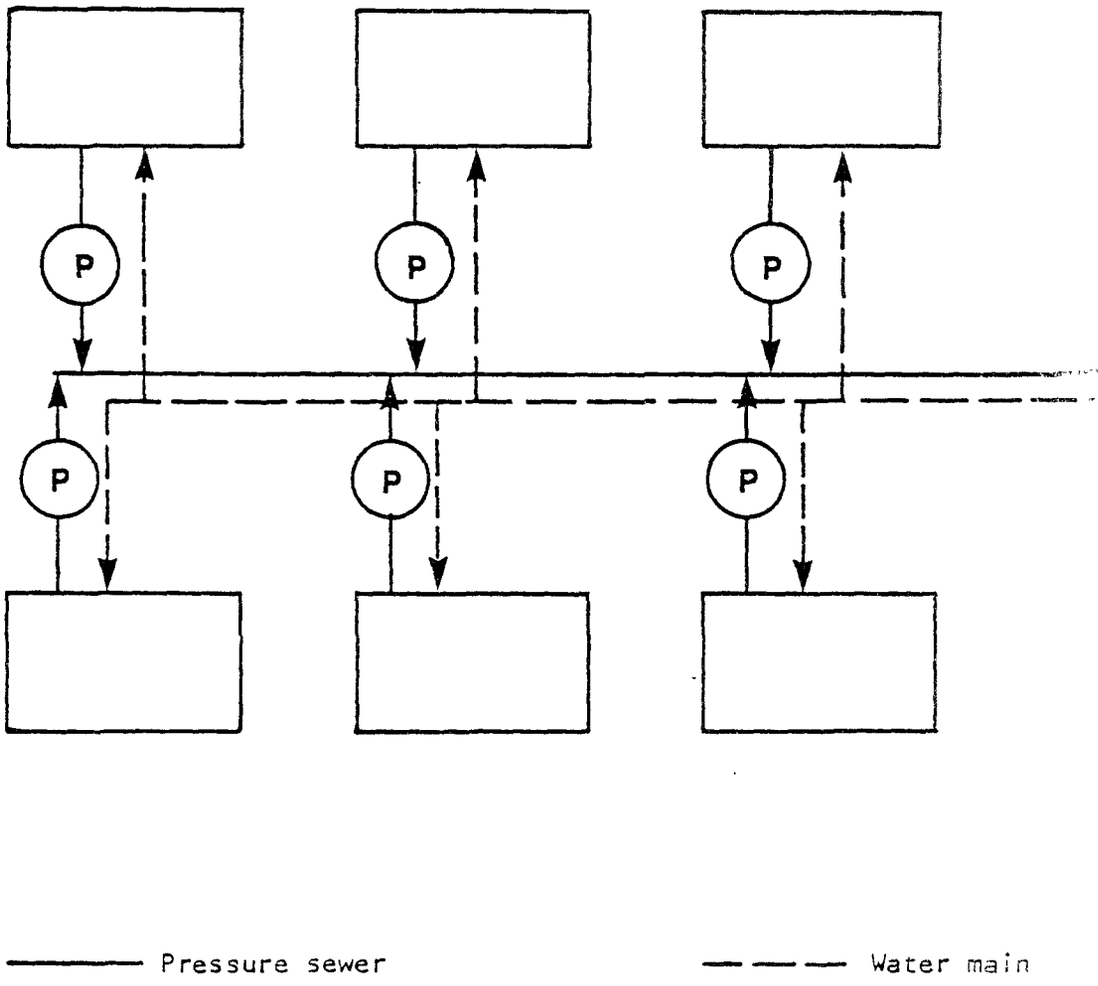
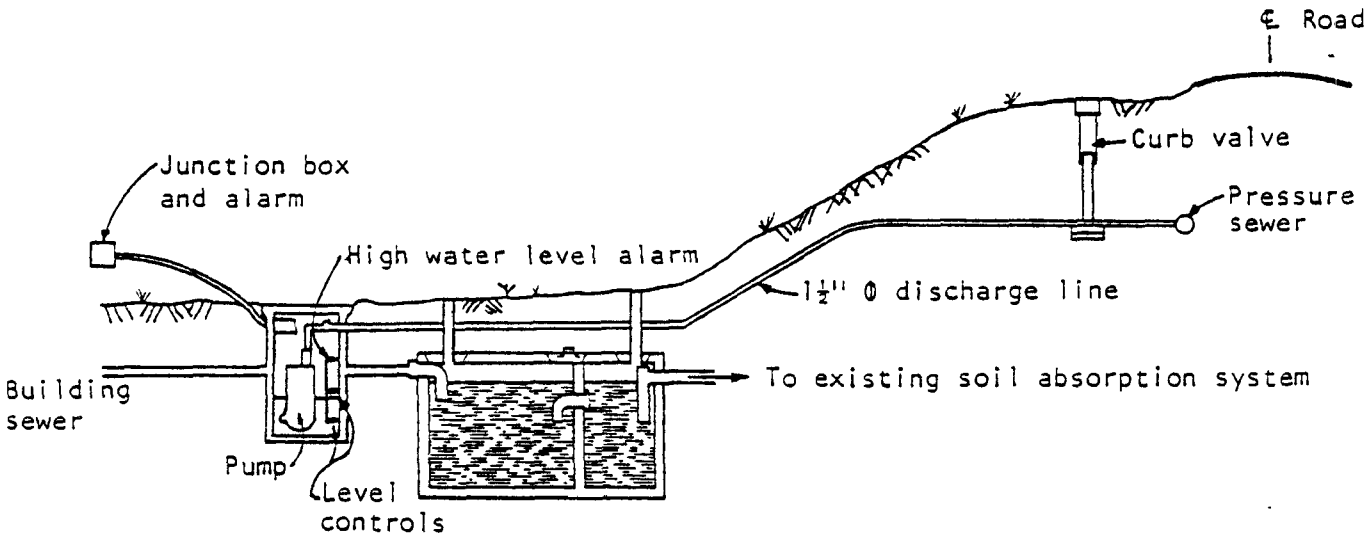
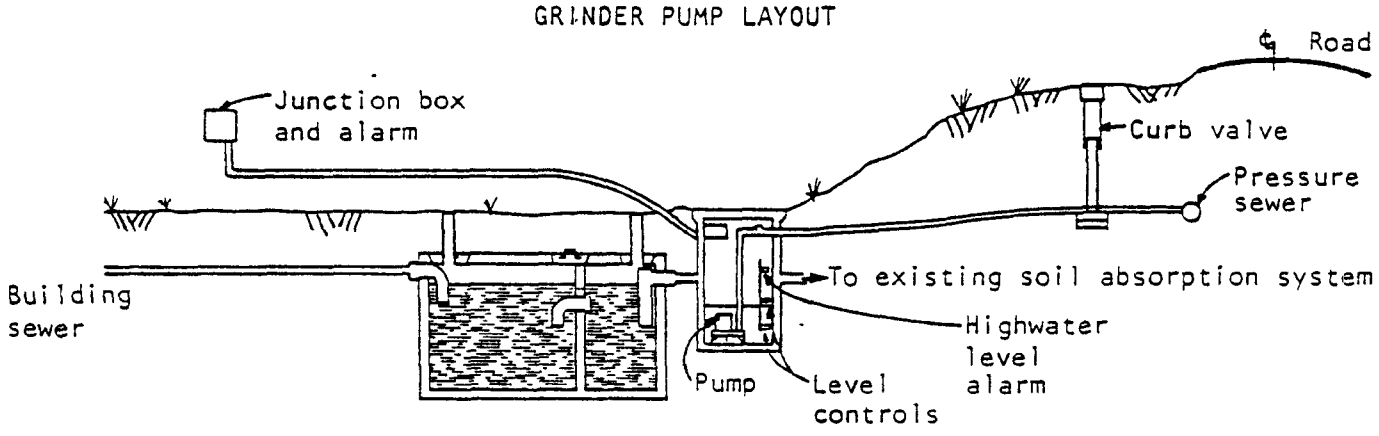


Figure 2-4. Pressure sewer vs. water main.



GRINDER PUMP LAYOUT



SEPTIC TANK EFFLUENT PUMP LAYOUT

Figure 2-5. Types of pressure sewer systems.

Most of the dwellings in the study area have existing septic tanks. Therefore, the septic tank effluent pump (STEP) system is proposed for the collection system alternatives described in this document.

2.2.2.3. Wastewater Treatment Processes

A variety of treatment options were considered in the facilities plan. In general, wastewater treatment options include conventional physical, biological, and chemical processes and land treatment. The conventional options utilize preliminary treatment, primary sedimentation, secondary treatment, and tertiary treatment (including chemical addition) for phosphorus removal. These unit processes are followed by disinfection prior to effluent disposal. Land treatment processes include lagoons, slow-rate infiltration or irrigation, overland flow, and rapid infiltration.

The degree of treatment required is dependent on the effluent disposal option selected (Section 2.2.2.4.). Where disposal of treated wastewater is by effluent discharge to surface waters, effluent quality limitations determined by MDNR establish the required level of treatment (Section 2.2.1.3.).

2.2.2.4. Effluent Disposal Methods

Three effluent disposal options are available: discharge to receiving waters, disposal on land, and reuse.

2.2.2.4.1. Stream Discharge

MDNR permits effluent discharge to the surface water at only two points: Indian Lake outlet in the western half of Section 32 and Silver Creek in Section 2, both in Silver Creek Township. A secondary treatment plant would be required to meet the effluent limitations (Section 2.2.1.2.) for discharge into Indian Lake outlet or Silver Creek. The discharge of the effluent at these two points is only permitted from 1 March to 15 May. Therefore, 9.5 months of effluent storage is provided for all the alternatives that recommend discharge to the surface waters at the two discharge points.

2.2.2.4.2. Land Application

Land application or land treatment of wastewater utilizes natural physical, chemical, and biological processes in vegetation, soils, and underlying formations to renovate and dispose of domestic wastewater. Land application methods have been practiced in the United States for more than 100 years and presently are being used by hundreds of communities throughout the nation (Pound and Crites 1973).

In addition to wastewater treatment, the benefits of land application may include nutrient recycling, timely water applications, groundwater recharge, and soil improvement. These benefits accrue to a greater extent in arid and semi-arid areas, but are also applicable to humid areas. Secondary benefits include preservation of open space and summer augmentation of streamflow.

The components of a land application system include a centralized collection and conveyance system, some level of primary treatment, possible secondary treatment, possible storage and disinfection, and the land application site and equipment. In addition, collection of the treated water may be included in the system design along with discharge or reuse of the collected water. The optional components may be necessary to meet state requirements or to make the system operate properly.

Land application of municipal wastewater for treatment encompasses a wide variety of possible processes or methods of application. The three principal processes utilized in land treatment of wastewater are:

- Overland flow
- Slow-rate or crop irrigation
- Rapid infiltration.

In the overland flow process, the wastewater is allowed to flow over a sloping surface and is collected at the bottom of the slope. This type of land application requires a stream for final disposal. Overland flow generally results in an effluent with an average phosphorus concentration of 4 mg/l. Phosphorus removals usually range from 30% to 60% on a concentration basis (USEPA 1977a).

In the slow-rate method partially treated wastewater is applied to the land to enhance the growth of vegetation. The vegetation performs a major role in removing nutrients through vegetative growth. Water is applied at rates that may range from 0.5 to 4.0 inches per week. The upper 2 to 4 feet of soil is where the major removals of organic matter, nutrients, and pathogens occur. Some processes involved are straining, chemical precipitation, and adsorption by the soil. The applied wastewater is either lost to the atmosphere by evapotranspiration or percolates to the water table. The water table must be naturally low or be maintained at a reasonable depth by wells or tile drainage. The surface soil must be kept aerobic for optimum conditions for removals to occur.

The rapid infiltration method involves high rates (4 to 120 inches per week) of application to rapidly permeable soils such as sands and loamy sands. Although vegetative cover may be present, it is not an integral part of the system. Cleansing of wastewater occurs within the first few feet of soil by filtering, adsorption, precipitation, and other geochemical reactions. In most cases, SS, BOD, and fecal coliform are removed almost completely. Phosphorus removal can range from 70% to 90%, depending on the physical and chemical properties of the soils. Nitrogen removal, however, generally is less significant, unless specific procedures are established to maximize denitrification (USEPA 1977a).

In rapid infiltration systems, there is little or no consumptive use of wastewater by plants, and only minor evaporation occurs. Because most of the wastewater infiltrates the soil, groundwater quality may be affected. To minimize the potential for groundwater contamination, the minimum depth to the water table should be 10 feet. Due to rapid rates of percolation, the permeability of the underlying aquifer must be high to insure that the water table will not mound significantly and limit the usefulness of the site.

Land Suitability

Land in the study area is generally suitable for slow-rate irrigation of effluent. Some areas may be suitable for rapid infiltration, although concern about non-degradation of groundwater, especially with the current State atti-

tude toward permits for discharging to groundwater, may make it difficult to implement. Overland flow treatment relies on surface flow for treatment and nearly all the soils of the area have infiltration rates such that the effluent would infiltrate.

The selection of a slow-rate irrigation area was based on criteria such as depth to water table greater that 15 feet, large expanse of nearly level to level soils, minimal orchards and woodlots, and proximity to the Sister Lakes area. The sections west and south of Dewey Lake (Section 7, 8, 16, and 17) best meet these criteria. Limited hydrogeological testing would be necessary in order to establish that these sites are indeed suitable and to design appropriate groundwater collection facilities, if necessary. MDNR requires a hydrogeological report approved by the groundwater section that shows that no degradation of any usable aquifer would result from application of wastewater effluent to the site. The "rule of thumb" for an acceptable application rate is approximately 2 inches per week, depending on the site and wastewater constituents (By telephone, Mr. Thomas Kampinnen, MDNR to WAPORA, Inc., 4 May 1982).

Treatment of Wastewater by Land Irrigation

Treatment of wastewater by the land irrigation process requires a considerable area of active cropland soils that have a moderately rapid permeability. Excellent removals of all pollutants, except highly soluble salts, can be expected (BOD_5 and SS, 99%; phosphorus 95% to 99%; and nitrogen 70% to 90%). Based on an application rate of 2.0 inches per week, an annual application period of 26 weeks, and a flow of 0.996 mgd, an irrigation area of 128.5 acres would be required. If irrigation were to be limited to compensation for deficiencies of soil moisture, considerably more land area would be required.

The principal soil characteristic required for an acceptable application site is a permeability that will allow reasonable drain tile spacing and still dewater the site. Under these conditions, farm equipment can be operated on the site within one day of irrigation without traction or compaction problems. In addition, it is essential that the application site does not have a slope

that will erode as a result of effluent applications. The acceptable slope varies according to the existing plant cover and the rate of infiltration. For example, cropland irrigation would be limited by slopes exceeding 6%, whereas forest irrigation would be feasible on slopes of up to 20% (Powers 1978).

Artificial drainage may be required on all sites unless the water table is naturally low. Artificial drainage can be advantageous because it allows control of the applied effluent. The outlet point can be designed to minimize any excess seepage.

During the winter it would be necessary to store the effluent. The storage pond should be located on naturally fine-textured material to minimize seepage. Soil surveys conducted in the area have not identified any soils that could function as a natural sealant. A pond constructed in this area would need to be artificially sealed.

2.2.2.4.3. Wetlands Discharge

Wetlands, which constitute approximately 3% of the land area of the continental US (USEPA 1977a), are hydrologically intermediate areas. Wetlands usually have too many plants and too little water to be called lakes, yet have enough water to prevent most agricultural or forestry uses. The use of wetlands to receive and satisfactorily treat wastewater effluent is a relatively new and experimental concept. In wetland application systems, wastewater is renovated by soil, plants, and microorganisms as it moves through and over the soil profile. Wetland systems are somewhat similar to overland flow systems in that most of the water flows over a relatively impermeable soil surface and the renovation action is more dependent on microbial and plant activity than on soil chemistry. The wetlands application option is not included in the alternatives considered herein because there are no suitable wetlands in the proximity of the proposed WWTP sites. Creating a wetlands area to treat wastewater would require a large amount of land and could be environmentally unacceptable.

2.2.2.4.4. Reuse

Wastewater management techniques included under the category of treated effluent reuse may be identified as:

- Public water supply
- Groundwater recharge
- Industrial process uses or cooling tower makeup
- Energy production
- Recreation and turf irrigation
- Fish and wildlife enhancement.

Reuse of treatment plant effluent as a public water supply or for groundwater recharge could present potential public health concerns. There are no major industries in the area that require cooling water. The availability of good quality surface water and groundwater and the abundant rainfall limit the demand for the use of treated wastewater for recreational and turf irrigation. Organic contamination and heavy metal concentrations also are potential problems. Direct reuse would require very costly advanced wastewater treatment (AWT), and a sufficient economic incentive is not available to justify the expense. Thus, the reuse of treated effluent currently is not a feasible management technique for the study area.

2.2.2.5 Sludge Treatment and Disposal

Some of the wastewater treatment processes considered will generate sludge. The amount of sludge generated will vary considerably, depending on the process. A typical sludge management program would involve interrelated processes for reducing the volume of the sludge (which is mostly water) and final disposal.

Volume reduction depends on the reduction of both the water and the organic content of the sludge. Organic material can be reduced through the use of digestion, incineration, or wet-oxidation processes. Moisture reduction is attainable through concentration, conditioning, dewatering, and/or drying processes. The mode of final disposal selected determines the processes that are required.

Sludge thickening, sludge digestion, dewatering and/or drying processes (including filter press, centrifuge, vacuum filtration, sludge drying beds, and sludge lagoons), and land disposal of liquid or dried sludge are some of the processes suitable for this project. Based on the processes proposed in the Facilities Plan, the sludge drying beds process was selected for further consideration with the secondary biological processes that require sludge dewatering. The dried sludge would be disposed of by land application on farm land. In the case of waste stabilization ponds, the sludge would collect in the bottom of the pond and would undergo anaerobic digestion. Inert solids that are not biologically decomposed would remain in the pond and may require cleanout and removal once every 10 to 20 years.

2.2.2.6. On-site Systems

The on-site systems proposed for use in the study area are those that are being utilized at the present time. Some modifications of the existing designs are suggested to improve the operation of on-site systems. The presently utilized systems are described in detail in Appendix B.

The septic tanks presently being installed in the area are considered adequate both in terms of construction and capacity. The continued use of 750-gallon tanks for small residences and 1,000- and 1,500-gallon tanks for larger residences are recommended. Septic tanks should have an exposed manhole or inspection port to monitor the contents of the tank. If, during pumpouts and inspections, certain septic tanks are found to be faulty or seriously undersized, these tanks would then be repaired or replaced. The number of these would be expected to be rather small because of the design code imposed on the tank manufacturers since to 1950.

The drain beds and drainfields (Figure 2-6) currently being installed in the area could have a greater than 20-year design life, if they are installed according to Code and maintained properly. The 400 square feet of drain bed should be adequate for most residences, unless the soil material contains greater than normal quantities of silt and clay. In these soil materials, the drain bed must be larger or the finer-textured soil material must be removed and replaced with sand. Similarly, in coarse-textured soils (coarse sand and

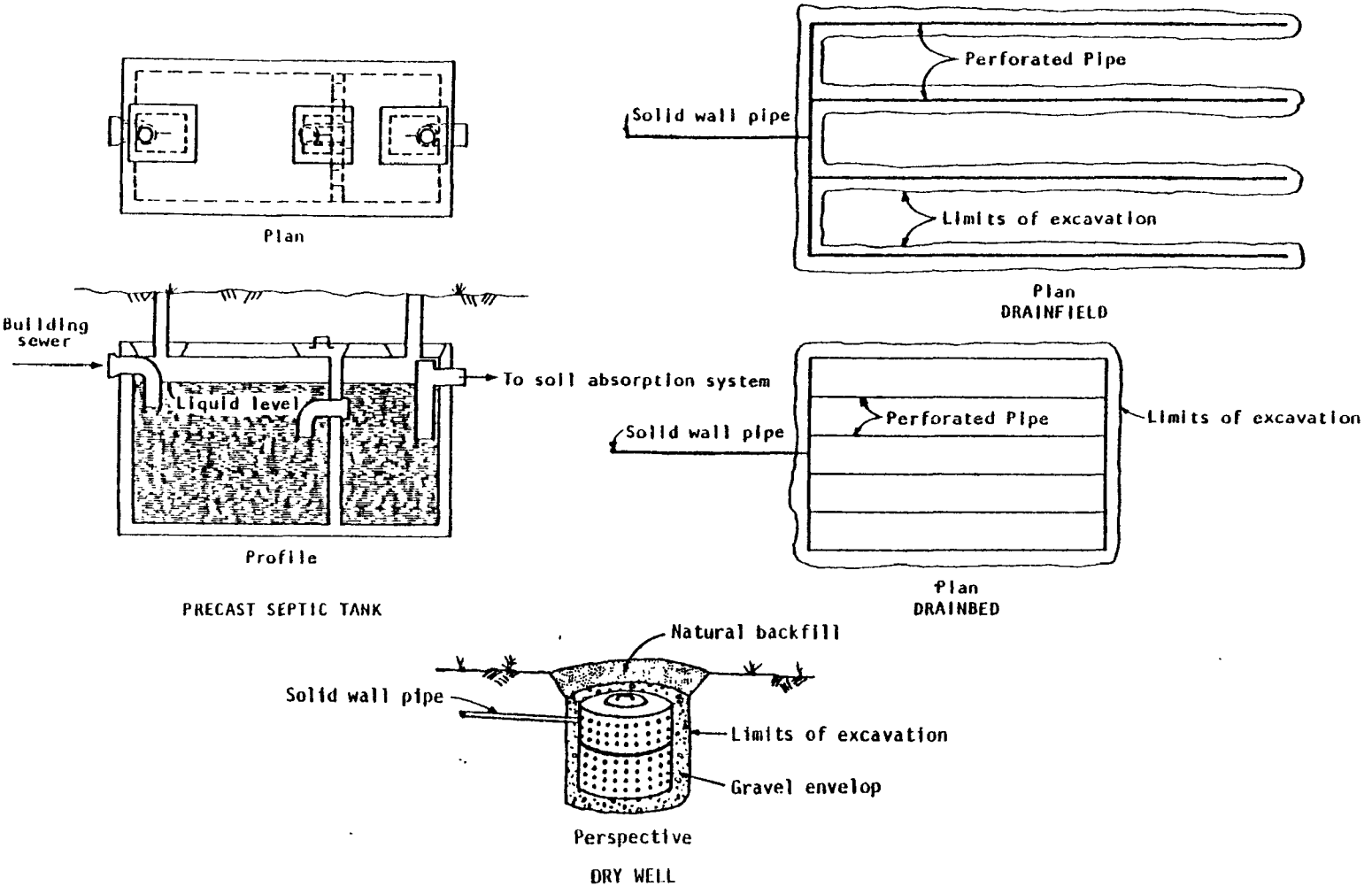


Figure 2-6. Septic tank - soil absorption systems.

gravel), the drain bed should be over-excavated and replaced with 18 inches of fine sand. Without the sand lining, the potential for groundwater pollution is high because of inadequate treatment.

The raised or elevated drain bed (Figure 2-7) is a variation of the so-called mound system. Mounds are constructed according to detailed design standards to overcome limitations of primarily limited soil permeability or shallow bedrock. The design for raised drain beds is essentially that of the standard drain bed elevated by fill to achieve the appropriate depth to groundwater. Thus, the elevation of the raised bed can be highly variable, from 6 inches to 3 feet. Some utilize gravity distribution systems while others use pumps and pressure distribution systems. In areas where the soils are peat and marl, the natural ground is first excavated and replaced with sand. Water-using appliances are usually kept to a minimum with these systems in order to keep the volume of sand fill to a minimum. It has been noted (By interview, Mr. Lee Maajers, Cass County Health Department, to WAPORA, Inc., 16 December 1981) that the use of proper materials and correct construction techniques is essential for these systems to operate satisfactorily.

The dry well soil absorption sytem (Figure 2-6) should be used only as a "last resort" treatment system for existing residences. The Van Buren County Health Department permits dry wells where the depth to the water table is adequate. Sufficient evidence has been accumulated to demonstrate that dry wells are more likely to pollute groundwater than drain beds. Dry wells consist of precast units, either cylinders or hand-laid blocks, that have perforated sidewalls. The dry well is placed in the ground and the annular space around it to natural ground is backfilled with clean stone. Stone is also placed on the bottom of the dry well. The top is covered with a precast lid and backfilled with topsoil. These units can be connected in series where necessary so that sufficient sidewall area can be provided.

Based strictly on a planning approach, no new soil absorption systems should be permitted on the soils that have a water table within 1 foot of the ground surface or that are formed in organic material. This would exclude the Adrian, Belleville, Boots (or Napoleon), Edwards, Gilford, Granby, Houghton, Marsh, Palms, Pella, Sebewa, and Tedrows soils. These soils have high water

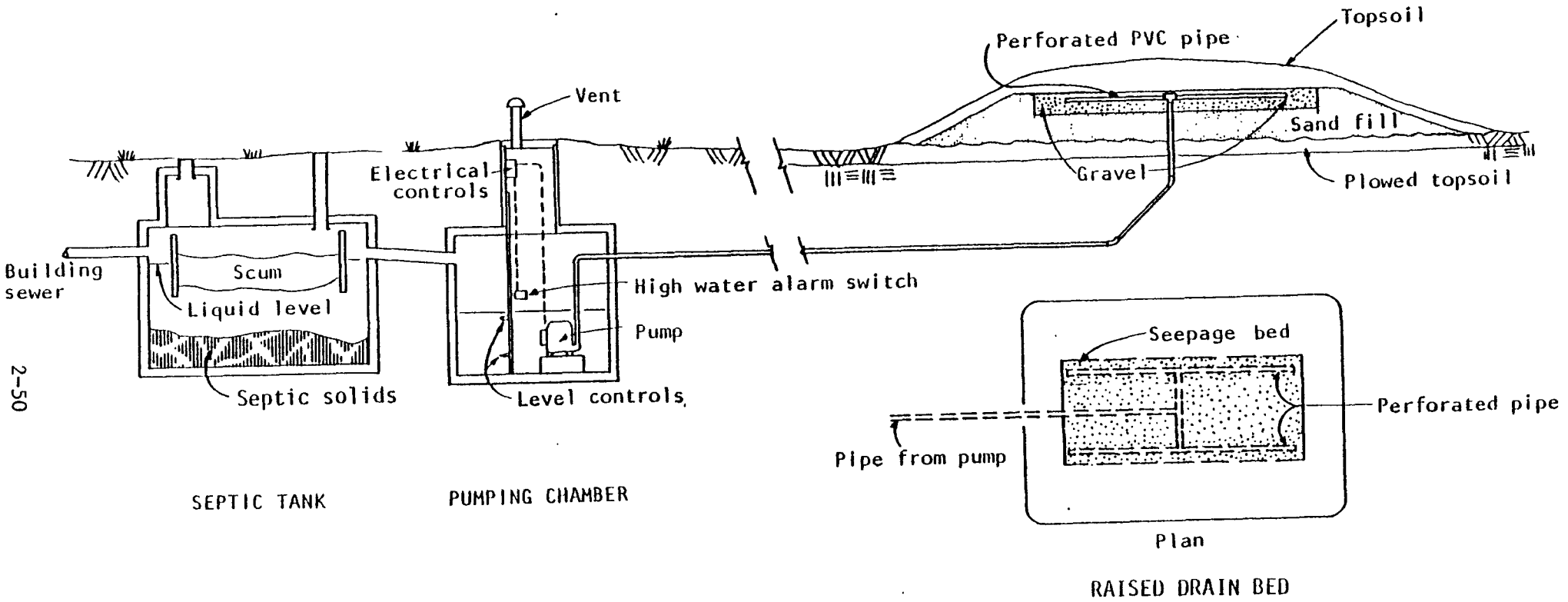


Figure 2-7. Septic tank - raised drain bed.

tables that are due to natural groundwater levels; therefore, they can be drained with extensive measures that lower the groundwater level of the area.

The soils that have a water table within 1 to 6 feet of the ground surface can have raised drain beds constructed on them. These soils are Brady, Bronson, Kibbie, Moracco, Selfridge, and Thetford.

Drain beds and drain fields are appropriate for the other soils where slopes allow construction activities. Dry wells are appropriate only where the depth to groundwater is adequate.

Blackwater holding tanks do not strictly constitute on-site treatment because the treatment of the wastes must occur away from the site. Components of the system include a low-flow toilet (2.5 gallons per flush or less), the holding tank for toilet wastes only, and the usual septic tank-soil absorption system for the remainder of the wastes. These systems are appropriate where an existing residence has a failing on-site system and no appropriate location for an upgraded system. When the toilet wastes are diverted from the septic tank-soil absorption system, that system has an opportunity to function properly and minimal pollution of groundwater and surface water would occur. Significant reductions of organic loads and 20 to 40% reductions in phosphorus loadings to the septic tank and soil absorption system occur when toilet wastes are excluded. The holding tank would have a 1,000 gallon capacity and be equipped with a high-level alarm. Nearly all residences that would require holding tanks are seasonally occupied, requiring approximately three pumpings annually. The blackwater holding tank systems are applicable where existing residences are on lots that have soils unsuitable or too small for raised drain beds or dry wells.

2.2.2.7. Cluster System

The cluster system designates a common soil absorption system and the treatment and collection facilities for a group of residences. The common soil absorption system is used because the individual lots are unsuitable for on-site soil absorption systems. An area of soils suitable for a common soil absorption system must be available in order to consider this option. In the

study area, only a small percentage of the area would be unsuitable for cluster drain fields. Thus, where off-site treatment is required, cluster drain fields are typically feasible.

It was assumed that the existing septic tanks, with some replacements, are adequate. Septic tank effluent could be conveyed by small-diameter gravity sewers or pressure sewers to the soil absorption system sites. A cost-effectiveness analysis could establish which collection system to use for a particular area. A dosing system is typically required on large drain fields in order to achieve good distribution in the field. Where the collection system uses pressure sewers, a separate accumulator tank and lift station is required. The wet well and lift station on the septic tank effluent gravity sewers can perform that function.

Cluster drain fields are usually designed as three drain fields. Two would be dosed on a daily basis in the summer and the third would be rested for an annual period. The drain fields must be designed according to the no degradation of any usable aquifer policy of MDNR. Preliminary design criteria indicate that 133 square feet of trench bottom per residence is required for each drain field. In order to satisfy the non-degradation policy, though, trench spacing may need to be much greater than the standard 6 feet.

Although the present soils information and topography indicate that cluster drain fields may be feasible, further field investigations would be needed before final designs could proceed. The depth of permeable material must be determined in order to show that groundwater mounding into the drainfield would not occur. Also, the characteristics of the proposed site soils must be examined sufficiently enough to verify the soil mapping of the SCS at a more detailed level than the present mapping.

The operation and maintenance requirements of the system are minimal. Periodic inspections of the lift stations and the drain fields are essentially all that is necessary. The septic tanks and the lift station wet wells would require occasional pumping. Maintenance of the collection piping is expected to be minimal (Otis 1979). Once a year the rested drain field would be rotated back into use and another one rested. Blockages of the collection

systems should occur only rarely because of the use of clear effluent. Lift stations are entirely dependent on a reliable power supply; thus, power outages will affect operation of the system. Since wastewater generation is also dependent on power for pumping well water, the potential for serious environmental effects are somewhat mitigated.

2.2.2.8. Septage Disposal

The use of a septic system requires periodic maintenance (3 to 5 years) that includes pumping out the accumulated scum and sludge, which is called septage. Approximately 65 to 70 gallons per capita per year of septage could accumulate in a properly functioning septic system used by permanent residents (USEPA 1977b). Septage is a highly variable anaerobic slurry that contains large quantities of grit and grease; a highly offensive odor; the ability to foam; poor settling and dewatering characteristics; high solids and organic content; and a minor accumulation of heavy metals.

Septage disposal regulations have been established mainly in states with areas that have a concentration of septic tanks. Many states, including Michigan, prohibit certain types of septage disposal, but do not prescribe acceptable disposal methods. The general methods of septage disposal are:

- Land disposal
- Biological and physical treatment
- Chemical treatment
- Treatment in a wastewater treatment plant.

Land Disposal

The two basic types of land disposal are:

- Methods which optimize nutrient recovery such as application of septage to cropland and pastures
- Methods of land application in which there is no concern for the recovery of nutrients in septage such as landfills.

Septage can be considered a form of fertilizer because of its nutrient value when applied to the soil. Nitrogen, phosphorus, and micronutrients are contained in septage. The septage application rate is usually dependent upon the amount of nitrogen available to the crop. The die-off of pathogens in septage which is surface spread is quicker than that of pathogens in septage injected into the soil. In septage incorporated into the top 3 inches of the soil, generally 99% of all pathogens will die off within one month (Brown and White 1977).

The advantages of direct cropland application of septage are: the recycling of nitrogen and phosphorus; the low technology, maintenance, and cost of the systems; and the hostile environment which the sun and soil create for pathogens and parasites.

The surface spreading of septage should occur only in isolated locations due to potential fly and odor problems. However, both problems can be minimized by applying the septage in a thin, uniform layer, or by soil incorporation. Septage should not be applied to land that is:

- Used for vegetable crops
- Frozen, snow covered, saturated, or located within a floodplain
- Located near dwellings, wells, springs, streams, bodies of water, or land adjacent to bodies of water where there is a chance of pollution due to runoff
- Steeper than 8%
- Sandy (due to pathogen transmission to groundwater).

The major problem with direct septage disposal on land is that the material cannot be applied at all times. Saturated soils generally restrict field access with disposal equipment. In addition to getting equipment stuck, soils are compacted and ruts are formed. Septage runoff is a problem if the waste is applied to frozen soils or steep slopes. Low temperatures and saturated soil moisture conditions will lengthen the die-off period of pathogens.

Biological and Physical Treatment

Septage may be treated biologically in anaerobic lagoons, aerobic lagoons, or digesters. Some advantages of aerobic treatment are that it reduces the offensive odor of the septage, produces a sludge with good dewatering characteristics, and produces a supernatant with a lower BOD_5 than anaerobic supernatants. The major disadvantage of aerobic treatment compared to anaerobic treatment is the higher operation and maintenance cost. Advantages of anaerobic treatment systems are that the waste undergoes stabilization of organic solids and they have relatively low operating and maintenance costs. A disadvantage of anaerobic treatment is the high BOD_5 of the effluent and the potential for odor nuisance.

Chemical Treatment

Treatment of septage involving the addition of a chemical is used to improve the dewaterability, reduce the odor, or kill the pathogens. Chemical treatment processes include addition of coagulants, rapid chemical oxidation, or lime stabilization.

Some of the advantages associated with the chemical treatment of septage are:

- Good reduction of the pollutant concentration can be achieved
- Dewaterability of septage is improved so the waste can be dewatered on sand beds
- Effective control of the pathogenic organisms is possible.

Disadvantages of chemical treatment of septage are:

- High costs are usually associated with chemical treatment and in many instances these alternatives are only feasible where relatively large quantities of septage are produced
- Large quantities of chemicals are needed
- Relatively high level of technology is needed.

Wastewater Treatment Plant

Septage can be adequately treated at a properly operated WWTP. Both the activated sludge or the fixed media type plants are used to treat septage.

Septage could be discharged into the liquid stream or sludge stream of a WWTP. If septage is handled as a slurry, the possible addition points at a WWTP are the upstream sewer, the bar screen, the grit chamber, the primary settling tank, or the aeration tank. Discharge into the upstream sewer allows solids to settle out in the sewer, particularly at periods of low flow.

The septage addition points in the sludge handling processes are the aerobic or anaerobic digester, the sludge conditioning process, or the sand drying beds. Septage added to a WWTP at 2% or less of the total flow will have little impact on the treatment processes.

The advantages of treating septage in a WWTP are that:

- Septage is diluted with wastewater and easily treated
- Few aesthetic problems are associated with this type of septage handling
- Skilled personnel are present at the plant site.

The disadvantages of septage disposal at a WWTP are that:

- A shock effect can occur in the unit processes of the WWTP if septage is not properly entered into the wastewater flow
- The waste should undergo separation, degritting, and equilization before treatment, hence requiring additional equipment and facilities.

Summary

A detailed cost-effectiveness analysis for septage and holding tank wastes treatment and disposal was not performed for this study. It is assumed that the septage would be pumped by commercial haulers under contract to the central management authority and would be disposed of in a manner consistent with present disposal practices (Section 2.1.5.). The cost of disposal is included in the operation and maintenance of the septic and holding tanks.

2.2.3. Centralized Collection System Alternatives

Three centralized collection system alternatives are considered in this document. They are:

- Alternative C1 - conventional gravity, pumping stations, and forcemains collection sewer system
- Alternative C2 - septic tank effluent pumps and pressure sewers with some gravity sewer system
- Alternative C3 - septic tank effluent small diameter gravity sewer system.

It is assumed in the case of collection system alternatives that Sister Lakes and Indian Lake areas would be served by separate WWTPs. The general layout of the sewer system outlined in the Facilities Plan (Gove Associates, Inc. 1980) was used. The design of the sewers is based on the year-2000 population (Section 3.2.1.3). The layout and sizes of the sewer system are shown in Figure 2-8 and Figure 2-9 for Alternatives C1 and C2, respectively. The layout of the sewer system for Alternative C3 is similar to Alternative C1.

A cost-effectiveness analysis was performed for the three centralized collection system alternatives. All cost data were based on June 1980 price levels. The detailed cost estimate for each alternative considered includes the costs for construction of the sewer system, the estimated salvage value after 20 years of use, and the estimated average annual operation and maintenance (O&M) costs. A detailed cost estimate for the various components of the three alternatives considered is presented in Appendix D. A cost comparison of the centralized collection sewer system alternatives is presented in Table 2-8. The total present worth was estimated to be $25,041,400 for Alternative C1, $19,995,900 for Alternative C2, and $24,321,400 for Alternative C3.

Based on the cost-effectiveness analysis presented in Table 2-8, it can be concluded that a collection sewer system with septic tank effluent pumps and pressure sewers with some gravity sewers is the most cost-effective alternative. Therefore, the septic tank effluent pumps and pressure sewers with some gravity sewers system alternative (Alternative C2) can be used in all

Table 2-8. Summary of all estimated costs of centralized collection system alternatives[a] (June 1980 costs, in thousands of dollars).

Alternative	Initial Cost		Present Worth[b]					
	Construction	O & M	Initial Capital	Future Connection	Initial O&M	Future O&M	Salvage	Total
C1 - Conventional gravity, station, and force mains collection sewer system	19,605.0	217.4	24,898.3	309.8	2,195.4	--	(2,362.1)	25,041.4
C2 - Septic tank effluent pumps and pressure sewers with some gravity sewer system	14,010.3	179.0	18,913.9	693.6	1,807.7	81.8	(1,501.1)	19,995.9
C3 - Septic tank effluent gravity sewer system	17,945.5	183.9	24,226.4	419.2	1,856.7	12.6	(2,193.5)	24,321.4

[a] All alternatives are based on separate WWTPS for Sister Lakes and Indian Lake areas.

[b] Present worth is computed for 20 years at 7-5/8% discount rate.

the system alternatives except Alternative 5B. Alternative 5B includes the conventional gravity, pumping station, and force mains collection sewer system (Alternative C1), so that this alternative is similar to the recommended alternative in the Facilities Plan (Gove Associates, Inc. 1980).

2.2.4. Centralized Wastewater Treatment Plant Alternatives

Different types of wastewater treatment plant alternatives were considered in the Facilities Plan (Gove Associates, Inc. 1980). The cost-effectiveness analysis included in the Facilities Plan showed that in most of the cases studied (regional and/or subregional WWTP) the three most cost-effective treatment system alternatives are:

- Waste stabilization ponds
- Aerated lagoons with storage ponds
- Oxidation ditch and sludge drying beds with storage ponds.

A screening analysis for these three alternatives was performed for this study. These three alternatives were compared for three sets of conditions. They are:

- A separate WWTP for the Indian Lake area
- A separate WWTP for the Sister Lakes area
- A regional WWTP for combined Indian Lake and Sister Lakes area.

The design factors and effluent requirements used in the analysis are given in Section 2.2.1.

A cost-effectiveness analysis was performed among the three treatment system alternatives for the three sets of conditions mentioned above. All cost data were based on June 1980 price levels. A detailed cost estimate for the various components of the three alternatives considered for the three sets of conditions is presented in Appendix D. A cost comparison of the centralized WWTP alternatives is presented in Table 2-9. Based on the present worth analysis, it can be concluded that the waste stabilization ponds WWTP is the

Table 2-9. Summary of all estimated costs of centralized wastewater treatment plant (WWTP) alternatives (June 1980 costs, in thousands of dollars).

Alternative	Construction Cost	O&M Cost	Present Worth[a] Capital Cost	O&M Cost	Salvage Value	Total
Inidan Lake Area						
Waste stabilization ponds WWTP	800.7	23.5	1,016.9	237.3	(102.4)	1,151.8
Aerated lagoons with storage ponds WWTP	757.1	37.0	961.5	373.6	(83.8)	1,251.3
Oxidation ditch with storage ponds WWTP	1,052.7	64.7	1,336.9	653.4	(113.8)	1,876.5
Sister Lakes Area						
Waste stabilization ponds WWTP	1,742.2	41.3	2,212.6	417.1	(248.6)	2,381.1
Aerated lagoons with storage ponds WWTP	1,834.3	71.8	2,329.6	725.0	(231.9)	2,822.7
Oxidation ditch with storage ponds WWTP	2,359.2	107.9	2,996.2	1,089.6	(288.2)	3,797.6
Regional Plant (combined Indian Lake/Sister Lakes areas)						
Waste stabilization ponds WWTP	2,061.4	49.5	2,618.0	499.9	(298.2)	2,819.7
Aerated lagoons with storage ponds WWTP	2,149.1	87.1	2,729.3	879.6	(276.3)	3,332.6
Oxidation ditch with storage ponds WWTP	2,787.2	127.7	3,539.7	1,289.5	(347.4)	4,481.8

[a]Present worth is computed for 20 years at 7-5/8% discount rate.

most cost-effective treatment alternatives under all three sets of conditions. Therefore, waste stabilization ponds WWTP is used in the system alternatives described in Section 2.3.

2.3. System Alternatives

Feasible and compatible sets of component options were combined into system alternatives. The system alternatives represent combinations of conveyance options for various wastewater flows, different treatment processes, siting options, effluent disposal options, sludge processing and disposal options, and on-site system options. The alternatives include no action, independent treatment systems for Indian Lake and Sister Lakes, regional treatment systems serving both Indian Lake and Sister Lakes, treatment at the existing Dowagiac WWTP, and on-site systems. Nine potential wastewater treatment alternatives were developed and evaluated for technical feasibility, cost-effectiveness, and environmental concerns. These alternatives, including the No Action Alternative, and costs associated with each one are described in the following sections. All cost data are based on June 1981 price levels.

2.3.1. Alternative 1 - No Action Alternative

The EIS process must evaluate the consequences of not taking action. The No Action Alternative implies that neither USEPA nor FmHA would provide funds to build, upgrade, or expand existing wastewater treatment systems. Wastewater would be treated in existing on-site systems and no new facility would be built except to replace obviously failed systems. This report assumes, however, that the county health departments would assume responsibility for upgrading existing systems that fail.

The need for improved wastewater management around Indian Lake and Sister Lakes is not well documented. The number of on-site systems experiencing serious or recurrent malfunctions is small. The impacts of individual on-site systems on the water quality of lakes are variable, but, taken together, the systems have not been shown to adversely affect the lakes.

With the No Action Alternative, health authorities will continue to have inadequate information with which to design on-site system repairs appropriate to the problems and their causes. They are unlikely to have the time, personnel, or monitoring capabilities to be able to specify innovative attempts to solve the problems. The result will be increasing numbers of holding tanks on small lots and on lots with high groundwater.

If a No Action Alternative is implemented, existing on-site systems in the study area would continue to be used in their present conditions. Also, failure to correct the present situation would represent a disregard of not only the natural environment, but of the spirit and intent of Public Law 92-500.

2.3.2. Alternative 2 - Pressure Collection Sewers and Separate WWTPs for the Sister Lakes and Indian Lake Areas with Discharge to Surface Waters

This alternative consists of a centralized collection sewer system and separate WWTPs for the Sister Lakes and Indian Lake areas. The cost-effective collection system alternative (Alternative C2, Section 2.2.3.) that includes pressure sewers with some gravity sewers is incorporated into this alternative (Figure 2-9).

Both the WWTPs would include waste stabilization ponds with storage lagoons. A storage capacity of 9.5 months at design flow is provided at both WWTPs. The WWTP for the Sister Lakes area would be located in Section 11 of Silver Creek Township with discharge to Silver Creek. The WWTP for the Indian Lake area would be in Sections 29 and 32 of Silver Creek Township with discharge to the Indian Lake Outlet. The approximate locations of the conveyance sewers (interceptor sewer), WWTPs, and the outfall sewers for the both proposed systems are shown in Figure 2-10.

This alternative has estimated present worth costs of $19,995,900 for the collection systems, $1,905,400 for conveyance systems, and $3,532,900 for treatment plants. The total present worth for this alternative was estimated to be $25,434,200. The detailed cost estimates for the collection sewer systems, conveyance sewers, and the WWTPs are presented in Appendix D.

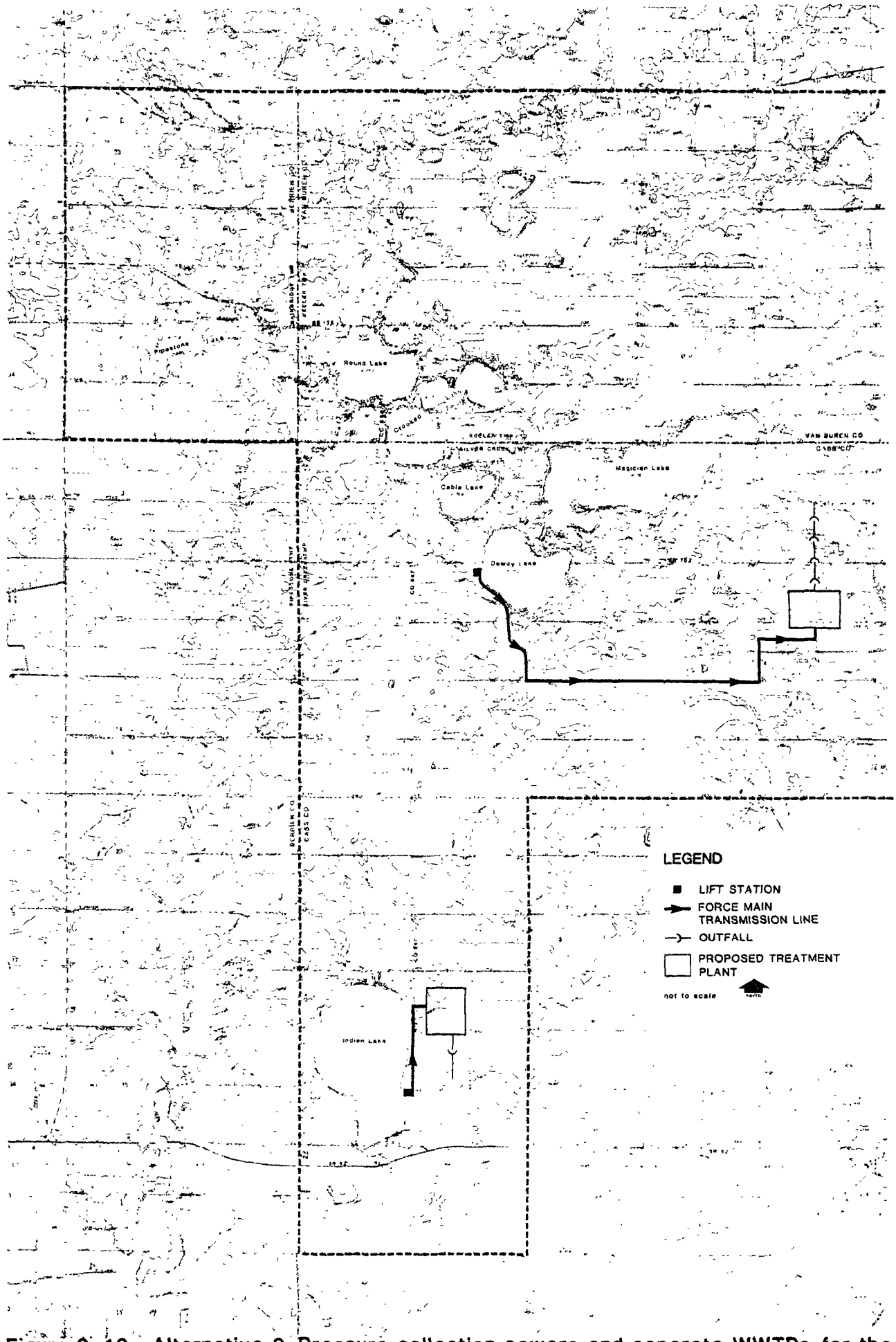


Figure 2-10. Alternative 2-Pressure collection sewers and separate WWTPs for the Sister Lakes and indian Lake areas with discharge to surface waters.

2.3.3. Alternative 3 - Pressure Collection Sewers and Regional Treatment and Land Treatment System

This alternative consists of a centralized collection sewer system with a regional pretreatment facility and land application site located in Section 8 of Silver Creek Township that would serve both the Indian Lake and Sister Lakes areas (Figure 2-11). The centralized collection sewer system consists of pressure sewers with some gravity sewers (Alternative C2, Section 2.2.3), as shown in Figure 2-9. The wastewater from both the Indian Lake and the Sister Lakes areas would be pumped through conveyance sewers to the pretreatment facilities. A waste stabilization pond system would be used for pretreatment.

The effluent from the waste stabilization ponds would be sprayed on the land with center pivot systems. At an application rate of 2.0 inches per week and a 6 months per year application period, approximately 130 acres of land would be required for the land application site. A total of 255 acres would be needed for the land application site, the waste stabilization ponds, roadways, and a buffer zone. It was assumed that the land application site would be leased for crop production during the growing season.

The alternative has an estimated present worth cost of $19,995,900 for the collection systems, $1,667,500 for the conveyance systems, and $3,703,200 for a regional treatment and land application system. The total present worth for this alternative was estimated to be $25,366,600. The detailed cost estimates for different components of this alternative are presented in Appendix D.

2.3.4. Alternative 4 - Presure Collection Sewers and Regional WWTP located in Section 11

This alternative consists of a centralized collection sewer system and a regional WWTP serving both the Indian Lake and Sister Lakes area. The centralized collection sewer system consists of pressure sewers with some gravity sewers (Alternative C2, Section 2.2.3.), as shown in Figure 2-9. The regional WWTP would include biological treatment using waste stabilization ponds. The stabilization ponds and the additional storage lagoons would provide storage capacity for 2.5 months. The regional WWTP would be located in Section 11 of the Silver Creek Township. The treated wastewater would be discharged to

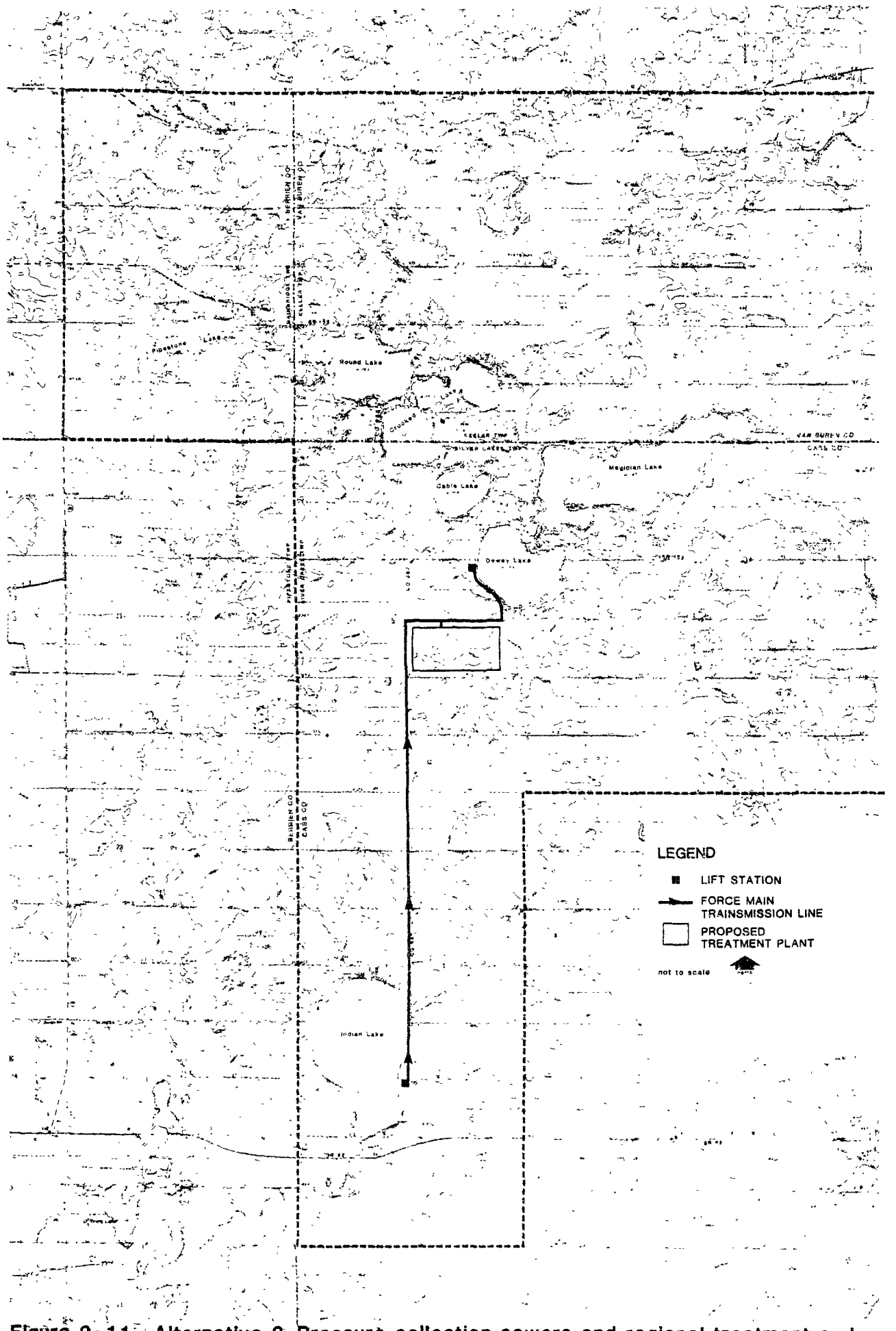


Figure 2-11. Alternative 3-Pressure collection sewers and regional treatment and land treatment system.

Silver Creek from 1 March through 15 May of each year. The approximate location of the conveyance sewers, regional WWTP, and the outfall sewer to Silver Creek is shown in Figure 2-12.

This alternative would have an estimated present worth cost of $19,995,900 for the collection sewer systems, $2,963,800 for the conveyance systems, and $2,819,700 for a regional WWTP. The total present worth for this alternative was estimated to be $25,779,400. The detailed cost estimates for the collection sewer systems, conveyance sewers, and the regional WWTP are presented in Appendix D.

2.3.5. Alternative 5A - Pressure Collection Sewers and a Regional WWTP Located in Sections 29 and 32

This alternative is similiar to Alternative 4 except the regional WWTP would be located in Sections 29 and 32 of Silver Creek Township and the treated wastewater would be discharged to the Indian Lake Outlet from 1 March through 15 May of every year. The approximate locations of the conveyance sewers, regional WWTP, and the outfall sewer to the Indian Lake Outlet are shown in Figure 2-13.

This alternative would have an estimated present worth cost of $19,995,900 for the collection sewer systems, $2,018,500 for the conveyance systems, and $2,819,700 for a regional WWTP. The total present worth for this alternative was estimated to be $24,834,100. The detailed cost estimates for the components of this alternative are presented in Appendix D.

2.3.6. Alternative 5B - Gravity Collection Sewers and a Regional WWTP Located in Sections 29 and 32

This alternative is similar to Alternative 5A except that a conventional gravity collection sewer system (Alternative C1 Section 2.2.3.) replaces the pressure collection sewer system (Alternative C2, Section 2.2.3.). This alternative resembles the alternative proposed in the Facilities Plan (Gove Associates, Inc. 1980). The layout of the collection sewer system included in

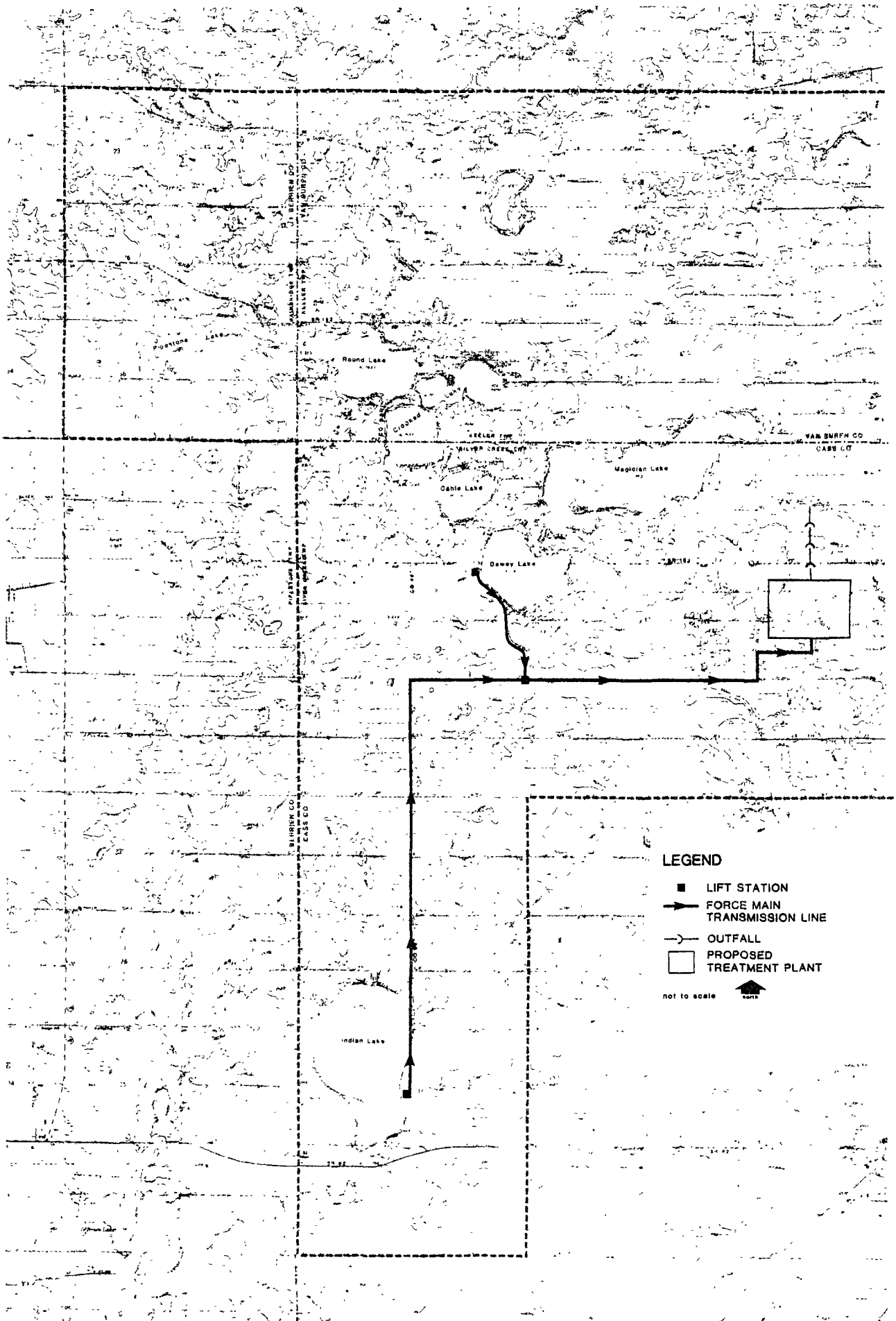


Figure 2-12. Alternative 4-Pressure collection sewers and regional WWTP located in Section 11.

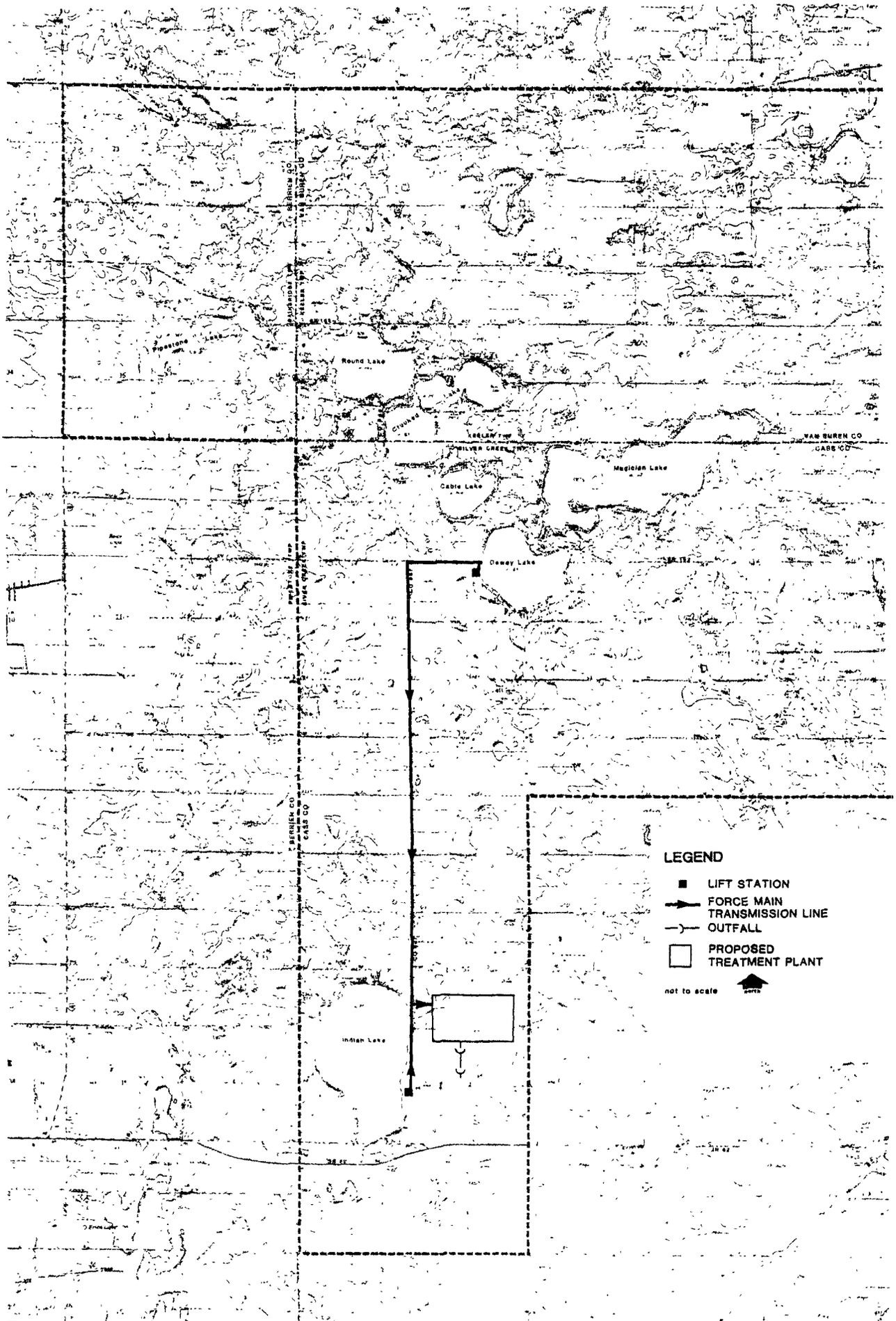


Figure 2-13. Alternative 5A-Pressure collection sewers and Alternative 5B-Gravity collection sewers and regional WWTP located in Sections 29 and 32.

this alternative is shown in Figure 2-8. The approximate locations of the conveyance sewers, regional WWTP, and the outfall sewer to the Indian Lake Outlet are shown in Figure 2-13.

This alternative would have an estimated present worth cost of $26,342,600 for the collection sewer systems, $2,018,500 for the conveyance systems, and $2,819,700 for a regional WWTP. The total present worth for this alternative was estimated to be $31,180,800. The detailed cost estimates for the collection sewer systems, conveyance sewers, and the WWTPs are presented in Appendix D.

2.3.7. Alternative 6 - Pressure Collection Sewers and Existing Dowagiac WWTP for Indian Lake and new WWTP for Sister Lakes

This alternative consists of centralized collection sewer systems, construction of a WWTP for the Sister Lakes area in Section 11 of Silver Creek Township, and treatment of wastewater from Indian Lake area at the existing Dowagiac WWTP. The centralized collection sewer system consists of pressure sewers with some gravity sewers (Alternative C2, Section 2.2.3.) as shown in Figure 2-9. The approximate layout of the conveyance sewers, WWTP for Sister Lakes and the location of the existing Dowagiac WWTP is shown in Figure 2-14.

The new WWTP in Silver Creek Township would include waste stabilization ponds, with additional storage lagoons. A total storage capacity of 9.5 months is provided at design flow. The treated effluent would be discharged to Silver Creek from 1 March to 15 May of each year.

The wastewater from Indian Lake area would be pumped through conveyance sewers for treatment at the existing Dowagiac WWTP. The user charges and the other fees for hook ups to the existing Dowagiac WWTP were provided by the City of Dowagiac in a letter dated 19 January 1982 (Appendix E).

This alternative would have an estimated present worth cost of $19,995,900 for the collection sewer systems, $2,259,000 for the conveyance systems, and $2,949,300 for the treatment systems. The total present worth for this alternative was estimated to be $25,204,200. The detailed cost estimates for the components of this alternative are presented in Appendix D.

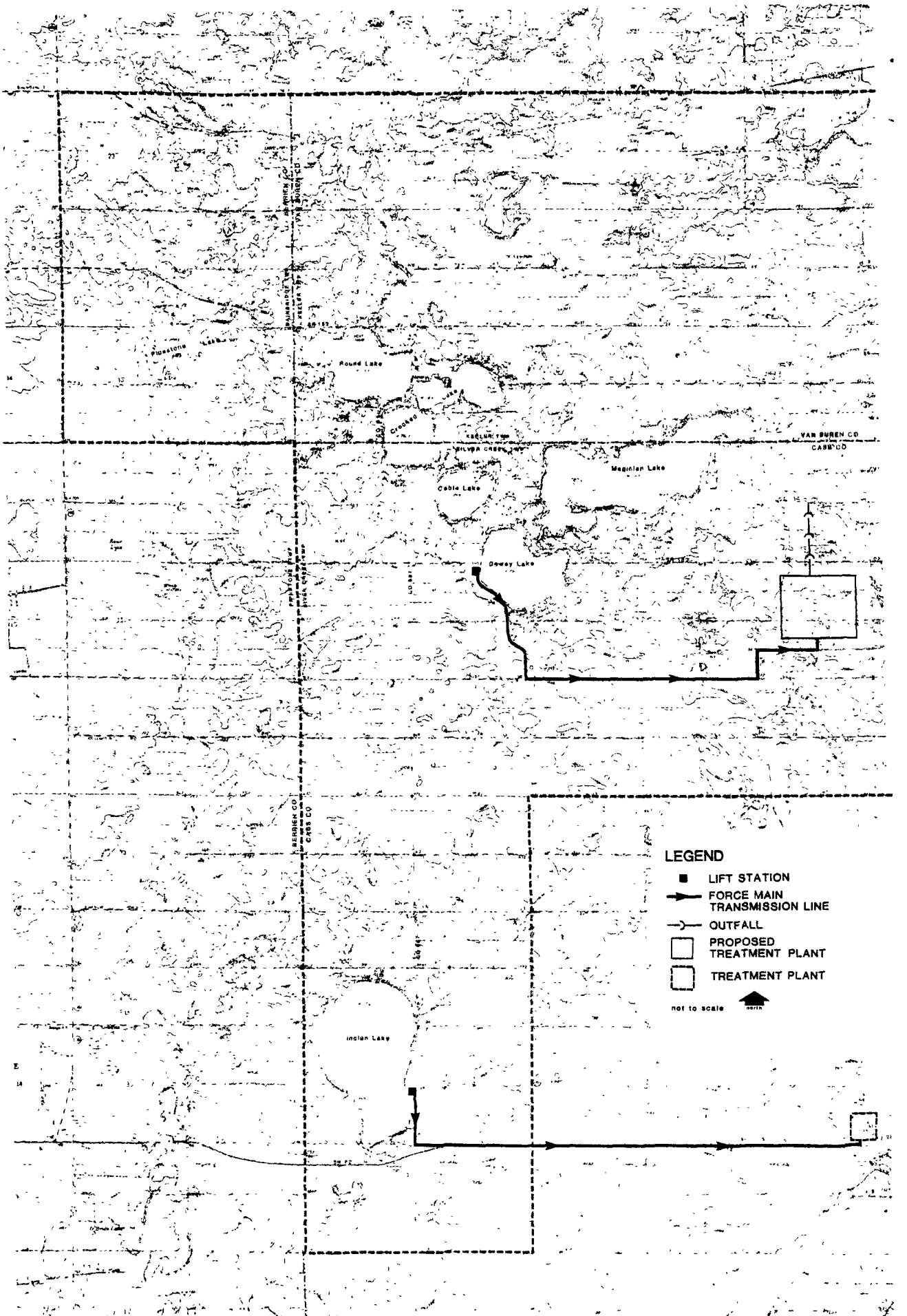


Figure 2-14. Alternative 6-Pressure collection sewers and existing Dowagiac WWTP for Indian Lake and a new WWTP for Sister Lakes.

2.3.8. Alternative 7 - Pressure Collection Sewers and Existing Dowagiac WWTP

This alternative is similar to Alternative 6 except that wastewater from both the Indian Lake and the Sister Lakes areas would be treated at the existing Dowagiac WWTP. The layout of the collection system is shown in Figure 2-9. The approximate layout of the conveyance sewers from the Sister Lakes area to the Indian Lake area and the Indian Lake area to the existing Dowagiac WWTP and the location of the existing Dowagiac WWTP are shown in Figure 2-15.

This alternative would have an estimated present worth cost of $19,995,900 for the collection sewer systems, $3,449,600 for the conveyance system, and $2,676,500 for the treatment system. The total present worth for this alternative was estimated to be $26,122,000. The detailed cost estimates for the components of this alternative are presented in Appendix D.

2.3.9. Alternative 8A - On-site Systems Upgrading and Critical Areas Septic Tank Effluent Collected by Pressure Sewers and Conveyed to Cluster Drain Fields

Under this alternative collection of septic tank effluent would be collected from the critical areas by pressure sewers for treatment in cluster drain fields. All other residences would continue to rely on septic tanks and soil absorption systems, many of which would be upgraded. The layout of the collection sewers and the tentative locations of the cluster drain fields are shown in Figure 2-16. The critical areas that are presumed to need off-site treatment are subject to redefinition during further field investigations. The number and type of upgraded on-site systems estimated for this alternative and the conceptual approach by which they were estimated are presented in Appendix C.

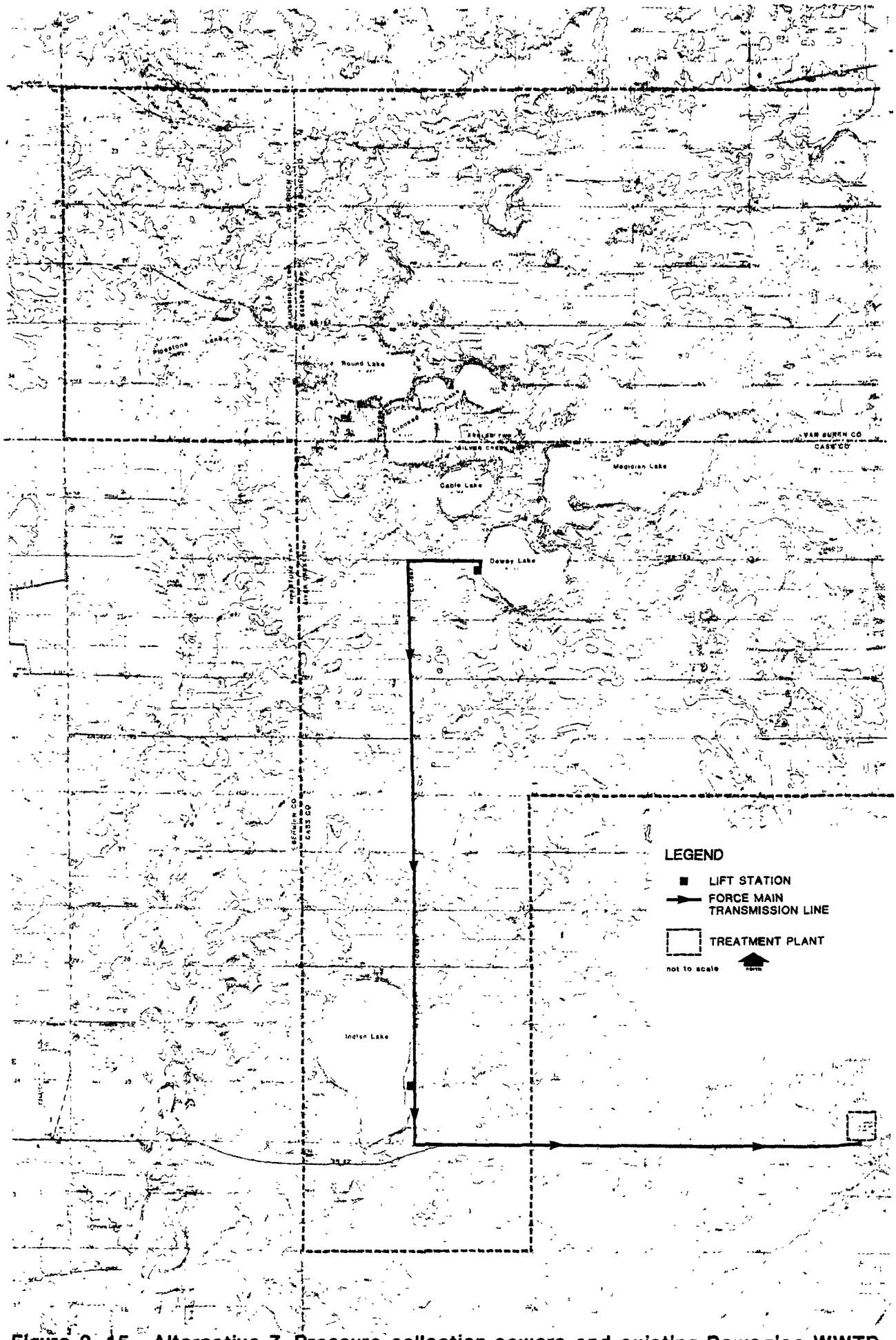


Figure 2-15. Alternative 7-Pressure collection sewers and existing Dowagiac WWTP.

The cluster systems would consist of septic tank effluent pumps and pressure sewers for collection, a dosing pump station (at all but the small cluster drain fields), and three alternating fields at the cluster drain field site. Two fields could be used alternately during any one year; the other field would be rested for a year.

This alternative has an estimated present worth cost of $11,685,000 for the upgrading of existing on-site systems, future on-site systems, collection and conveyance of wastewater for critical areas with treatment provided at cluster drain fields, and $1,075,000 for administration and laboratory analyses. The total present worth for this alternative was estimated to be $12,760,000. The detailed cost estimates for the components of this alternative are presented in Appendix D.

2.3.10. Alternative 8B - On-site Systems Upgrading and Critical Areas Septic Tank Effluent Collected by Small Diameter Gravity Sewers and Conveyed to Cluster Drain Fields

Under this alternative septic tank effluent would be collected by small-diameter gravity sewers from the critical areas that are identified in Alternative 8A and treated in cluster drain fields. All other residences would continue to rely on existing and upgraded septic tanks and soil absorption systems (Appendix C) identical to the systems estimated in Alternative 8A. The layout of the collection sewers and the tentative locations of the cluster drain fields are similar to those shown in Figure 2-16. The gravity sewers require the use of pump stations at the low points in the area served and force mains to the cluster drain field sites. The critical areas are subject to change upon further information.

The cluster systems would consist of septic tank effluent gravity sewers, pump stations and force mains for collection, and alternating valves and three alternating fields at the cluster drain field site. One field would be rested for a year while the other two would be used on an alternate basis.

This alternative has an estimated present worth cost of $11,307,500 for upgrading existing on-site systems, future on-site systems, collection and conveyance of wastewater from critical areas with treatment provided at clus-

ter drain fields and $1,075,000 for administration and laboratory analyses. The total present worth for this alternative was estimated to be $12,382,500. The detailed cost estimates for the components of this alternative are presented in Appendix D.

2.3.11. Alternative 9 - On-site Systems Upgrading and Blackwater Holding Tanks

This alternative consists of selectively upgrading the existing on-site systems and future on-site systems. For residences where the on-site system cannot be upgraded because of site limitations, the graywater and blackwater will be separated. Graywater would continue to be treated in the existing septic tank and soil absorption system that may be upgraded. The blackwater components would include a new low-flow toilet and a holding tank. Quantities and type of initial and future systems to be upgraded are included in Appendix C. In addition, the conceptual approach by which the systems were estimated is presented in Appendix C. The numbers and types of upgraded systems are subject to redefinition after further field investigations.

This alternative has an estimated present worth cost of $5,497,900 for upgrading of existing on-site systems, future on-site systems, and blackwater holding tanks, and $1,075,000 for administration and laboratory analyses. The total present worth for this alternative was estimated to be $6,572,900. The detailed cost estimates for the components of this alternative are presented in Appendix D.

2.4. Flexibility and Reliability of System Alternatives

2.4.1. Flexibility

Flexibility measures the ability of a system to accommodate future growth and depends on the ease with which an existing system can be upgraded or modified. The majority of the system alternatives considered in this report include centralized collection sewer systems, wastewater treatment plant, the "cluster" systems, and various on-site systems. Since most of the components are found in a majority of the alternatives, the following evaluation is generally applicable to most of the alternatives unless otherwise stated in the discussion.

For gravity and pressure sewer systems, the flexibility to handle future increases in flows greater than the original design flow is generally low. The interceptor sewers are generally designed for capacity beyond the planning period. The increase in capacity of collector sewers is a somewhat expensive process. Also, the layout of the system depends upon the location of the treatment facility. The expansion of a sewer system is generally easy with the addition of new sewers, but is expensive.

The ability to expand a conventional WWTP depends largely upon the processes being used, the layout of the facilities, and the availability of additional land for expansion. The expansion or upgrading of most of the treatment processes considered in the proposed WWTPs is relatively easy. With proper design of process components of the treatment plant and proper planning of the facility layout, the cost and effort required for expansion may be relatively small. Most conventional treatment processes also have good operational flexibility because operators can, to some extent, vary treatment parameters.

On-site systems are flexible in that they are generally designed for each user. As long as spatial and environmental parameters are met, the type of system can be chosen according to individual requirements. Existing septic systems can be expanded by adding tank and drain field capacity, if suitable land is available. Flow can then be distributed to an added system with little disturbance of the existing one. In the case of raised drain bed systems, the future expansion may be difficult or impossible. Cluster systems treat wastewater from more than one house. The flexibility for design and expansion of such a system is somewhat less than for a standard septic system.

Based on the above discussion, it can be concluded that the majority of the alternatives considered in this report generally have similar flexibility for future growth and/or planning.

2.4.2. Reliability

Reliability measures the ability of a system or system components to operate without failure at its designed level of efficiency. It is parti-

cularly important to have dependable operation in situations where adverse environmental or economic impacts may result from failure of the system.

The gravity sewer is highly reliable when designed properly. Such systems require little maintenance, consume no energy, and have no mechanical components to malfunction. Gravity sewer problems can include clogged pipes that result in sewer backups; infiltration/inflow which increases the volume of flow beyond the design level; and broken or misaligned pipes. Major contributors to these problems are improperly jointed pipes and damage to manholes, especially where they are not located in paved roads. Where large sewers are used in order to achieve lower pipe slopes, problems with solids deposition can mean that frequent flushing with large volumes of water will be necessary.

Pump stations and force mains increase operation and maintenance requirements and decrease the system reliability. Backup pumps are installed in order to provide service in case one pump fails and a backup power source is usually provided, either dual power lines, or stationary or portable emergency generators. Force mains are generally reliable; excessive solids deposition and burst pipes occur rarely. Leaking joints occur more frequently and can cause environmental damage.

Septic tank effluent pumps and pressure sewers generally are reliable means of conveying effluent to treatment. Because the solids have been removed in the septic tank, problems associated with solids deposition are avoided. The pump units themselves have been shown to be reliable; when failure or power outages do occur, storage of approximately 1.5 day's sewage volume in the pump chamber and septic tank permits replacements to be made before backups occur. The pressure sewers themselves should be even more reliable than force mains because the pumped liquid is clear.

Federal Guidelines for Design, Operation, and Maintenance of Wastewater Treatment Facilities (Federal Water Quality Administration 1970) require that:

> All water pollution control facilities should be planned and designed so as to provide for maximum reliability at all times. The facilities should be capable of operating satisfactorily during power failures, flooding, peak loads, equipment failure, and maintenance shutdowns.

The wastewater control system design for the study area will consider the following types of factors to insure system reliability:

- Duplicate sources of electric power
- Standby power for essential plant elements
- Multiple units and equipment to provide maximum flexibility in operation
- Replacement parts readily available
- Holding tanks or basins to provide for emergency storage of overflow and adequate pump-back facilities
- Flexibility of piping and pumping facilities to permit rerouting of flows under emergency conditions
- Provision for emergency storage or disposal of sludge
- Dual chlorination units
- Automatic controls to regulate and record chlorine residuals
- Automatic alarm systems to warn of high water, power failure, or equipment malfunction
- No treatment plant bypasses or upstream bypasses
- Design of interceptor sewers to permit emergency storage without causing backups
- Enforcement of pretreatment regulations to avoid industrial waste-induced treatment upsets
- Floodproofing of treatment plant
- Plant Operations and Maintenance Manual to have a section on emergency operation procedures
- Use of qualified plant operators.

The wastewater treatment portion of the centralized collection and treatment alternatives (Alternatives 2-7) would be highly reliable if these measures were incorporated. The collection systems are less reliable because so many pump stations are required. If dual power lines from separate substations can be extended to every pump station (an expensive proposition), a reasonable level of reliability can be attained. Supplying auxiliary power units for each pump station is not feasible. A failure of a pump station

would likely result in raw sewage or septic tank effluent being discharged into one of the lakes. Because as many as nine pump stations must operate in series, a failure of one would likely result in spillage into a lake.

The on-site systems are generally a reliable means of treating and disposing of wastewater. Except with certain systems, they operate with no power inputs and little attention. When failures do occur, the impact to the environment is small and diffuse. Total failures rarely occur in which no treatment at all takes place.

Septic tanks provide reliable treatment when they are properly designed and maintained. The principal maintenance requirement is periodic pumping of the tank, usually every 3 to 5 years. The treatment process can be harmed if large quantities of strong chemicals are flushed into the tank.

Soil absorption systems generally provide excellent treatment if the design and installation are accomplished properly and the soil conditions are suitable. Other key factors in the successful operation of soil absorption systems are proper functioning of the septic tank or other treatment unit and observance of reasonable water conservation practices consistent with the design flows. Soil absorption systems can malfunction when extended wet weather results in saturation of the soil, when solids carryover plugs the drain bed, and when compaction of the soil surface results in restricted permeability. Raised drain bed soil absorption systems are more reliable than drain bed systems where water tables are high because the potential groundwater problems are minimized. They do require an effluent pump, though, and rely on a dependable power supply. The septic tank and pump chamber generally can hold approximately 1.5 days of storage, which is probably longer than the average power outage. A malfunctioning pump can be replaced readily if the units are standardized. The cost of a raised drain bed system is about two times that of a drain bed system; thus, it would be utilized only where a drain bed system has failed or has little chance of operating properly. The average design life of soil absorption systems is greater than 20 years; some could be expected to fail earlier. Some soil absorption systems could be expected to last indefinitely, as long as the system is not overloaded with water or solids.

Cluster systems serve a group of houses with components similar to a septic tank-soil absorption system. The individual septic tanks would operate at similar levels of reliability. The septic tank effluent sewers are exposed to hazards of breakage and to plugging due to cleanout failure similar to gravity sewers. Sewage solid accumulations in the sewers does not occur when the septic tanks are maintained properly. The pump station that doses the drain fields may not operate properly due to mechanical failure or power interruption. An effluent spill may occur at that time. The soil absorption system should be sited on permeable soils that have a water table always greater than six-foot depth. The operation of the drain field should be more reliable than an individual on-site soil absorption system because of pressure distribution by dosing and because of the optimum location.

2.5. Comparison of Alternatives and Selection of the Recommended Action

The selection of the most cost-effective, environmentally acceptable, and implementable alternative(s) through the EIS process involved the consideration of technical feasibility, reliability, costs, environmental effects, public desirability, and the ability to comply with the applicable design and effluent discharge standards for the State of Michigan. Selection of the most cost-effective alternative also required identification of trade-offs between costs and other relevant criteria.

2.5.1. Comparison of Alternatives

2.5.1.1. Project Costs

Project costs were categorized into capital expenses, operative and maintenance (O&M) expenses, and salvage values for the equipment and structures for each alternative. The costs for the collection, conveyance, and treatment systems for each alternative were estimated separately. A summary of the estimated costs of project alternatives are displayed in Table 2-10. Appendix D contains a description of the methodology and assumptions used in the analyses as well as the detailed costs for each alternative. The capital cost for the selected alternative would be shared by the Federal government through the Federal Construction Grant Program (75% of conventional

Table 2-10. Summary of all estimated costs of alternatives (June 1981 costs, in thousands of dollars).

Alternative Number and Title	Present Worth				Average Annual Equivalent Cost	Ranking
	Collection	Conveyance	Treatment	Total		
1. No Action	-	-	-	-	-	NA
2. Pressure collection sewers and separate WWTPs for Sister Lakes and Indian Lake areas with discharges to surface water	19,995.9	1,905.4	3,532.9	25,434.2	2,517.9	8
3. Pressure collection sewers and regional treatment and land disposal system located in Section 8 in Silver Creek Township	19,995.9	1,667.5	3,703.2	25,366.6	2,511.3	6
4. Pressure collection sewers and regional WWTP located in Section 11 with discharge to Silver Creek	19,995.9	2,963.8	2,819.7	25,779.4	2,552.2	7
5A. Pressure collection sewers and regional WWTP located in Sections 29 and 32 with discharge to Indian Lake outlet	19,995.9	2,018.5	2,819.7	24,834.1	2,458.6	4
5B. Gravity collection sewers and regional WWTP located in Sections 29 and 32 with discharge to Indian Lake outlet	26,342.6	2,018.5	2,819.7	31,180.8	3,086.9	10
6. Pressure collection sewers and existing Dowagiac WWTP for Indian Lake and WWTP for Sister Lakes located in Section 11 with discharge to Silver Creek	19,995.9	2,259.0	2,949.3	25,204.2	2,495.2	5
7. Pressure collection sewers and existing Dowagiac WWTP	19,995.9	3,449.6	2,676.5	26,122.0	2,586.0	9
8A. On-site systems upgrading and critical area septic tank effluent collected by pressure sewers and conveyed to cluster drainfields	11,685.0[a]	--	1,075.0[b]	12,760.0	1,263.2	3
8B. On-site systems upgrading and critical areas septic tank effluent collected by small diameter gravity sewers and conveyed to cluster drainfields	11,307.5[a]	--	1,075.0[b]	12,382.5	1,225.9	2
9. On-site systems upgradings and holding tanks	5,497.9[c]	--	1,075.0[b]	6,572.9	650.7	1

a. Includes costs for upgrading of existing on-site systems, future on-site systems, collection and conveyance of wastewater for some areas with treatment provided at cluster systems.
b. Includes administrative and laboratory costs.
c Includes cost for upgrading of existing on-site systems, future on-site systems, and blackwater holding tanks.

NA Not Applicable

systems or 85% of innovative and alternative wastewater collection and treatment systems) and by local participants. Annual O&M costs would be financed entirely by the local users of the system.

The system alternatives are grouped into four categories -- centralized collection and treatment systems that will discharge to surface water (Alternatives 2, 4, 5A, 5B, 6, and 7), centralized collection and treatment system with land disposal system (Alternative 3); upgraded on-site systems and service of certain critical areas with off-site treatment systems (Alternatives 8A and 8B); and upgraded on-site systems and blackwater holding tanks (Alternative 9). Based on total present worth cost, upgraded on-site systems and blackwater holding tanks (Alternative 9) is the lowest cost alternative. Alternatives 8A and 8B which include upgraded on-site systems and service of certain critical areas with off-site treatment systems, are ranked third and second respectively, on the basis of total present worth. The other alternatives, including the centralized collection and treatment systems, are ranked fourth through tenth as shown in Table 2-10. Based on total present worth cost, Alternative 5B which is similar to the recommended alternative of the Facilities Plan, is the most expensive (tenth ranking). The total present worth cost ranges from approximately $6.6 million for Alternative 9 to approximately $31.2 million for Alternative 5B.

2.5.1.2. Environmental Impacts

The No Action Alternative, would entail almost no construction impacts. Construction of any of the "build" alternatives, however, will have primarily short-term impacts on the local environment (Section 4.1.1.). The implementation of Alternative 9 would have impacts on those lots where upgraded on-site systems are necessary. These impacts may be considerable on some lots but overall they would be of limited extent. The two alternatives (8A and 8B) that have critical area collection systems and cluster drain fields would involve construction in some right-of-ways and on the drain field sites in addition to on-site upgrading. The combined environmental impacts of these alternatives are not significantly greater than those that would occur under Alternative 9.

The centralized collection and treatment alternatives would have considerable impacts on the rights-of-way where sewage facilities are necessary. Many rights-of-way are narrow and tree-lined, which makes construction within them difficult. Dewatering for deep sewer excavations and pump stations could affect wells in the vicinity. The treatment plant sites for waste stabilization lagoons, proposed for all centralized treatment alternatives except Alternative 7, would have a significant effect on the particular site. All three sites, located in Sections 8, 11, or 29, are presently agricultural land; Section 29 is mostly prime agricultural land that would be converted irretrievably to treatment plant use.

The operation of the facilities proposed in the alternatives would produce some significant long-term impacts at least for some of the lakes (Section 4.1.2.). Water quality impacts in the lakes would be greatest under the No Action Alternative because increasing phosphorus loads would increase the extent and density of nuisance algal blooms. Excessive nitrates in wells may also increase as a problem. Local perceptions concerning water quality, especially at Indian Lake and Pipestone Lake, are that current problems warrant a "build" alternative and that these problems will be exacerbated unless remedial action is taken. The operation of the three alternatives that rely primarily on existing and upgraded on-site systems (8A, 8B, and 9) would somewhat improve the water quality within the lakes. Some degradation of groundwater quality below the cluster drain field can be anticipated, but the groundwater is expected to meet the drinking water quality standard.

The centralized collection and treatment alternatives would improve water quality in the lakes, although the improvements may not be noticeable. Spills of septic tank effluent or of raw sewage at pump stations could occur if a malfunction or power failure were to occur. The nutrient load from one spill could easily equal the average annual nutrient load. Proper maintenance of the pumps and backup power sources for all the pump stations would reduce the potential for such an impact. The treatment facilities for the centralized alternatives would be capable of meeting the discharge requirements established by MDNR. Water quality in the receiving streams would be altered, but not seriously degraded during the discharge period. The land application alternative should result in minimal operating impacts because the infiltrated

water should be of comparatively high quality. The alternatives that include sewage treatment in the Dowagiac WWTP would reduce the capacity for future growth in Dowagiac.

2.5.1.3. Implementability

How a wastewater management plan is implemented depends upon whether the selected alternative relies primarily upon centralized or decentralized components. Because most sanitary districts have in the past been designed around centralized collection and treatment of wastewater, there is a great deal of information about the implementation of such systems. Decentralized collection and treatment, however, is relatively new and there is little management experience on which to draw.

Decentralized systems may include on-site systems, small cluster systems with subsurface disposal, and other small-scale technologies. They can be managed by a wide variety of public or private entities or a combination of these entities. Public entities may include state, regional, or local agencies and nonprofit organizations; private entities may include private homeowner associations and private contractors.

In this section the term "management agency" refers to the authority responsible for managing the systems. A management agency need not be an autonomous organization devoted solely to the management of these systems. It may in fact be charged with other duties, and may share systems management responsibility through agreements with other agencies.

The value of small waste flows systems as a long-term rather than short-term alternative to centralized collection treatment began to be recognized in the 1970s. As a result, communities preparing facilities plans after 30 September 1978 were required to provide an analysis of the use of innovative and alternative wastewater processes and techniques that could solve a community's wastewater needs (PRM 78-9; USEPA 1978a). Included as alternative processes are individual and other on-site treatment systems with subsurface disposal units (drain fields).

The 1977 Clean Water Act amendments recognized the need for continual supervision of the operation and maintenance of on-site systems. USEPA Construction Grant Regulations (USEPA 1978a; USEPA 1979b) which implement that act require an applicant to meet a number of preconditions before a construction grant for private wastewater systems may be made. They include:

- Certifying that a public body will be responsible for the proper installation, operation, and maintenance of the funded systems
- Establishing a comprehensive program for the regulation and inspection of on-site systems that will include periodic testing of existing potable water wells and, where a substantial number of on-site systems exists, more extensive monitoring of aquifers
- Obtaining assurance of unlimited access to each individual system at all reasonable times for inspection, monitoring, construction, maintenance, rehabilitation, and replacement.

PRM 79-8 extends these requirements to grants for publicly owned systems.

Regardless of whether the selected alternative is primarily centralized or decentralized, four aspects of the implementation program must be addressed:

- There must be legal authority for a managing agency to exist and financial authority for it to operate
- The agency must manage construction, ownership, and operation of the sanitary district
- A choice must be made between the several types of long-term financing that are generally required in paying for capital expenditures associated with the project
- A system of user charges to retire capital debts, to cover expenditures for operation and maintenance, and to provide a reserve for contingencies must be established.

In the following sections, these requirements are examined first with respect to centralized systems and then with respect to decentralized systems.

Centralized Systems

The Indian Lake-Sister Lakes Facility Plan identified the Cass County Board of Commissioners as the legal authority for implementing the Plan's Proposed Action. The Cass County Department of Public Works (CCDPW) would be the operating division that would construct, operate and maintain the centralized wastewater management system. Under Act 185 of the Michigan Public Acts of 1957 as amended, the county has the authority to implement this system and to contract with the villages and townships for services. Cass County also would have to contract with Berrien County and Van Buren County for services to the parts of these counties which are included in the study area.

As the management agency, the CCDPW would construct, maintain, and operate the centralized sewerage facilities proposed in the Alternatives 2-7, except those parts of Alternatives 6 and 7 that propose utilizing the Dowagiac WWTP that is operated and maintained by the City of Dowagiac. The managerial capacity of the CCDPW can be readily expanded to provide managerial services for the proposed gravity sewers and the WWTPs including the land disposal site in Alternatives 2-7. There are several options for septic tank effluent pumps connected to pressure sewers:

- The station may be designed to agency specifications, with the responsibility for purchase, maintenance, and ownership residing with the homeowner
- The station may be specified and purchased by the agency, with the homeowner repurchasing and maintaining it
- The station may be specified and owned by the agency, but purchased by the homeowner
- The station may be specified, purchased, and owned by the agency.

Regardless, however, of the option selected, all residences are treated equally.

Capital expenses associated with a project may be financed by several techniques which are discussed in detail in Section 4.1.3. User charges are set at a level that will provide for repayment of long-term debt and cover

operation and maintenance expenses. The user charges for the different alternatives are discussed in Section 4.1.3. In addition, prudent management agencies frequently add an extra charge to provide a contingency fund for extraordinary expenses and equipment replacement.

Decentralized Systems

Regulation of on-site sewage systems has evolved to the point where most new facilities are designed, permitted, and inspected by local health departments or other agencies. After installation, the local agency has no further responsibility for these systems until malfunctions become evident. In such cases the local agency may inspect and issue permits for repair of the systems. The sole basis for governmental regulation in this field has been its obligation to protect public health.

Rarely have governmental obligations been interpreted more broadly to include monitoring and control of other effects of on-site system use or misuse. The general absence of information concerning septic system impacts on groundwater and surface water quality has been coupled with a lack of knowledge of the operation of on-site systems.

Michigan presently has no legislation which explicitly authorizes governmental entities to manage wastewater facilities other than those connected to conventional collection systems. However, Michigan Statutes Sections 123.241 et seq. and 232.37 et seq. have been interpreted as providing counties, townships, villages, and cities with sufficient powers to manage decentralized facilities (Otis and Stewart 1976).

The purpose of a decentralized systems district is to balance the costs of management with the needs of public health and environmental quality. Management of such a district implies formation of a management agency and formulation of policies. The concept of such an agency is new. Community obligations for management of private wastewater systems and six community management models are presented in the Draft-Generic Rural Lake Projects EIS (USEPA 1981a).

The cluster systems (Alternative 8A and 8B) could be managed by one of several agencies. The CCDPW probably is best equipped at this point to assume responsibility for these systems. While the technologies involved may be unusual for the CCDPW, no components are involved that are difficult to manage. The possibilities for management include different authorization for the health department, a township board, another division of county government, a special district, or a public utility commission (USEPA 1979b). The system itself should be simple to manage. The residential pumping units use electrical power; thus, power interruptions may result in operational or environmental problems. Maintenance and repair activities are more critical for this system than for gravity sewers. Regular cleaning of the septic tanks is essential for the system to operate properly. The operation of the drain field must be carefully monitored so that the treatment aspect of the soil is not abrogated. The billing of the user charge could be similar to the charge system set up for the conventional gravity sewers and treatment plant.

The management of on-site systems (Alternatives 8A, 8B and 9) can be accomplished in many ways (USEPA 1979b; USEPA 1979a). The management structure will depend primarily on State law and local preference. The USEPA requires a public agency to serve as grantee and to provide assurances that the systems be constructed properly and that maintenance be performed to insure that the environmental laws are not violated. Many different agencies are presently responsible for on-site systems: health departments, sanitary districts, homeowners associations, on-site management districts, private companies, and county government. Management responsibilities range from a detailed permit process to complete ownership of all facilities. There are certain advantages with each type of management and ownership option. Complete control by the agency comes closest to guaranteeing that the systems will be operating at optimal levels, but represents the most costly approach. The least costly approach would be to keep the homeowner responsible for all maintenance activities and costs. The homeowner then would be more inclined to utilize water-saving measures and other methods to minimize maintenance costs. However, as is currently the case, environmental protection suffers when the homeowner is responsible for maintenance. Other factors also should be considered. Systems for residences constructed after 27 December 1977 are not eligible for Federal grants. Having the homeowner pay for installation

constitutes a considerable expense for new residences that the community may wish to employ as a means of discouraging future on-site systems. The USEPA requires the grantee to certify that public ownership is not implementable, a policy that may be difficult to show.

The agencies with the most experience with on-site systems in the study area are the county health departments. They have had no experience in writing and implementing contracts, because their primary role is issuing permits and inspecting construction. The CCDPW has the experience with contracts and management of maintenance activities, although it does not have experience with on-site systems. Experience with on-site systems is crucial for the personnel responsible for the design, construction, and inspection of on-site systems. Thus, the consolidation of contracting and billing functions with the CCDPW would result in an efficient operation. It is anticipated that the most cost-effective managerial system would be implemented; health department personnel will be responsible for the systems and the CCDPW will provide contractural and billing expertise. The local costs for the construction of new systems and rehabilitation of existing systems can be assessed to each user equally by a variety of means or assigned to the respective homeowner. Operation and maintenance costs also can be handled in the same way, based on public or private ownership. The billing could be similar to the billing uses for the centralized system.

2.5.2. Conclusions

The least cost alternative from both an economic and environmental perspective is Alternative 9 -- on-site system upgrading and blackwater holding tanks for some critical areas. There is one exception to this alternative as stated in Section 2.1. regarding needs documentation. MDNR requires that the site-specific environmental and engineering data base be developed as part of a Step 1 grant (By telephone, Dan Pearson, MDNR, to WAPORA, Inc. 5 May 1982). USEPA Region V Needs Guidance requires that, at most, a representative sampling (15% to 30%) of site-specific data base need be developed in Step 1. The remaining sampling should be done in Step 2. Based on the information presented in Section 2.1., USEPA Region V has decided that additional studies will be conducted during the period between publication of the Draft EIS and

the Final EIS. These studies may include:

- A sanitary survey for 30% of the residences in the study area
- A septic leachate detector scan of drinking water samples obtained from each house visited in the sanitary survey for traces of wastewater effluent
- A near-shore hydrology study to determine the direction of groundwater flow.

Based on the available information and the results of the data collected from additional studies, a more precisely defined wastewater management system for the study area will be recommended in the Final EIS.

This draft EIS clearly shows that some kind of on-site wastewater management system is the most cost-effective alternative for the Indian Lake-Sister Lakes study area. If the local grantee and the State of Michigan concur in the selection of an on-site system alternative, the following activities should be undertaken before implementing the proposed alternative:

- Plan an operation and maintenance program established to meet local, State, and Federal requirements
- Obtain assurance of unlimited access to each individual system at all reasonable times for such purposes as inspections, monitoring, construction, maintenance, operations, rehabilitation, and replacement
- Plan for a comprehensive program of regulation and inspection for individual systems
- Develop a site-specific environmental and engineering data base
- Design the management organization.

3.0. AFFECTED ENVIRONMENT

3.1. Natural Environment

3.1.1. Atmosphere

Elements of the atmospheric environment that are relevent to the consideration of the proposed wastewater treatment alternatives include temperature, precipitation, wind, odor, and noise levels. Other than the consideration of potential odor and noise generated by specific treatment processes, air quality is not expected to be affected significantly and, therefore, is described briefly.

3.1.1.1. Climate

Meteorological data representative of the Indian Lake-Sister Lakes study area have been collected at the Michiana Regional Airport, located approximately 25 miles south of the study area at South Bend, Indiana (National Oceanic and Atmospheric Administration [NOAA] 1977). The temperature and precipitation data for this location do not vary significantly from similar data available for Benton Harbor, Michigan, located 10 miles from the study area.

The study area has a continental-type climate that is modified by Lake Michigan. This modification is reflected by moderate average daily temperatures resulting in a low number of days with temperatures above 90° fahrenheit (F) or 32° centigrade (C) in the summer and below 0°F (-17.7°C) in the winter. Approximately 43% of the annual precipitation occurs during the 5 months of the growing season (May through September). The average annual mean precipitation in the study area is approximately 36 inches (92.0 centimeters). The average length of the growing season is 165 days. The latest spring freeze recorded is 30 May and the earliest freeze recorded in autumn is 18 September. Snow generally falls from November through March, although snowfall has been recorded in October and April. During the months of March and April the mean wind direction is north by northwest; during December, January, and February it is southwest; and during May through November it is south by southwest. High winds, excessive precipitation, and electrical storms occur occasionally

in the area. Additional climatological data are presented in Appendix F, Table F-1.

Upper air data for the study area indicate the occurrence of elevated inversions. The mean afternoon mixing heights in the study area range from approximately 2,400 feet (730 meters) in the winter to 5,217 feet (1,590 meters) in the summer. The mean annual afternoon mixing height is 4,003 feet (1,220 meters). After calculating the pollution dispersion factor (Edwards and Wheat 1978), the pollution dispersion conditions for the Indian Lake-Sister Lakes area generally are good.

3.1.1.2. Air Quality

The Indian Lake-Sister Lakes study area is located in the USEPA South Bend-Benton Harbor Interstate Air Quality Control Region (AQCR) and is regulated by the Air Quality Division (AQD) of the Michigan Department of Natural Resources (MDNR). The air quality standards applicable to the study area are the Michigan Ambient Air Quality Standards. These standards are identical to the National Ambient Air Quality Standards (NAAQS) (Appendix F, Table F-2). The Michigan Air Sampling Network has an air quality monitoring site in Cass County, located at the Central Fire Station in Dowagiac. The monitoring site is approximately 3 miles (4.8 kilometers) southwest of the study area.

Concentrations of total suspended particulates (TSP) in Cass County were in compliance with both annual and maximum 24-hour primary (health-related) NAAQS from 1971 through 1976. Although violations of the maximum 24-hour secondary (welfare-related) NAAQS did occur (MDNR 1977a), the maximum 24-hour TSP value recorded during the 6-year monitoring period was 181 ug/m^3, well below the primary standard of 260 ug/m^3 (Appendix F, Table F-3).

Although hydrocarbons and carbon monoxide levels were not monitored in the study area, concentrations probably are low. Only one significant point source, an asphalt plant in Silver Creek Township operated by the Klett Construction Company, exists in the study area. The plant emits both particulates (5.4 metric tons per year) and sulfur dioxide (3.6 metric tons per year) (USEPA 1978a). No significant line sources such as interstate highways exist in the area. Nitrogen oxide and sulfur oxide concentrations also were

not monitored in the study area, but are expected to be low. The lack of monitoring stations in Berrien and Van Buren counties indicates that they are presumed to be in compliance with air quality standards, with the exception of oxidants (MDNR 1977a).

Photochemical oxidants, especially ozone, are pollutant problems over much of the US because of the long-distance transport of hydrocarbons and nitrogen oxides. Although no information on ozone levels is available for the study area, it is likely that ozone standards are exceeded, particularily because of the close proximity of large metropolitan centers. The Lower Peninsula of Michigan has been designated as a non-attainment area for photochemical oxidants (MDNR 1977a).

3.1.1.3. Noise

There are no known major noise sources in the study area. Noise generated by typical automobile and recreational boat traffic and gravel quarry operations within the study area may affect people who live near these noise sources.

3.1.1.4. Odor

The Air Quality Division of MDNR has not recieved any complaints of odors in the study area (By telephone, Mr. Dick Vandebunt, MDNR, to WAPORA, Inc., 16 November 1978). It is presumed that there are no significant odor problems in the study area. However, there is an asphalt plant located in Silver Creek Township which may affect people residing near the plant.

3.1.2. Land

3.1.2.1. Geology

3.1.2.1.1. Topography and Physiography

The landscape of the Indian Lake-Sister Lakes study area is characterized by hummocky, morainic terrain in the northwestern and southwestern parts and by nearly-level to gently-sloping outwash plains in the central and eastern parts. Elevations range from 880 feet (268 meters) above mean sea level (msl) southwest of Round Lake to less than 720 feet (219 meters) msl in the far western part of the study area (Figure 3-1). Numerous lakes occur within the

study area. Although most of the major lakes are concentrated in the central part of the study area, at least a dozen smaller lakes occur in the study area. The largest lakes include the Sister Lakes (Cable Lake, Crooked Lake, Dewey Lake, Magician Lake, Pipestone Lake and Round Lake), Keeler Lake, and Indian Lake. Many vegetated wetlands also occur adjacent to these lakes and in numerous depressions throughout the study area.

Most of the surface waters of the study area drain into the Dowagiac River through the Osborn Drain, Silver Creek, an unnamed creek that collects excess water from Indian Lake, and a few intermittent streams. A small part of the study area, near Pipestone Lake, drains to the southwest into the St. Joseph River through Pipestone Creek.

3.1.2.1.2. Bedrock and Surficial Geology

The study area is located in the western portion of a large structural feature called the Michigan Basin. The bedrock geology is characterized by a sequence of northeasterly-dipping Paleozoic strata that overlie a Precambrian basement of crystalline rocks. The Coldwater Formation (Mississippian) forms the bedrock surface throughout most of the study area. Underlying the Coldwater Formation is the Ellsworth Formation (Mississippian).

The bedrock surface in the study area and in surrounding areas is highly irregular and contains numerous bedrock valleys. Due to preglacial and glacial erosion, the thickness of the Coldwater Formation is extremely variable. Exploratory oil well logs indicate that while the Coldwater Formation may be absent in bedrock valleys, it can attain thicknesses of up to 105 feet (32 meters) in bedrock uplands. The thicknesses of the Ellsworth Formation ranges from 282 to 410 feet (86 to 125 meters).

Overlying the bedrock surface are unconsolidated sediments that were deposited during the Pleistocene Epoch by glaciers and by glacial meltwaters. The landforms and the surficial deposits of the study area were formed during the Cary substage of the Wisconsinan stage of glaciation and are associated with the Lake Michigan lobe of the Wisconsinan glacier (Terwilliger 1954).

The surficial geology of the study area is shown in Figure 3-2. The regions outlined in this map are generalized and reflect only the glacial deposits that exist at the surface. The underlying glacial drift may be very different. Well records (Michigan Department of Conservation n.d.), topographic maps (US Geological Survey [USGS] nd), and a report by Terwilliger (1954) constitute the data used in the construction of this map. The surficial glacial deposits of the study area consist predominantly of terminal moraines, outwash plains, and glacial lakebed deposits. The glacial till of these terminal moraines contains unsorted mixtures of gravel, sand, silt, and clay.

The northwestern section of the study area is part of the Valparaiso Moraine (Terwilliger 1954). Well records, topographic information, and soils data suggest that the glacial geology in the vicinity of Indian Lake also is characteristic of terminal moraines. However, the morainic system of this area is not known. The glacial till of these deposits appears to contain large amounts of sand and gravel and may be very permeable in places. The stratigraphic and hydrologic characteristics, however, are complex and can change drastically within a short distance.

Numerous kames (isolated or clustered mounds of sand and gravel) are associated with the terminal moraines in the study area. These formations constitute valuable sand and gravel resources.

The lakes in the study area most likely developed from depressions or kettles that were formed when isolated blocks of ice were buried by glacial drift. When the ice blocks melted, a depression remained which subsequently filled with water. Lakes of this derivation usually are classified as kettle lakes. In the study area, terminal moraines, kettles, and kames often occur in association with each other, producing a hummocky topography.

The majority of the study area has been identified as an outwash plain. These outwash deposits consist of beds and lenses of gravel, sand, silt, and some clay. Since the retreat of the last glacier, the surficial geology of the area has been modified by subsequent erosion and deposition. Glacial deposits throughout most of the area are overlain by a mantle of loess (wind blown deposits of silt and fine sand). Recent deposits also include alluvium and lacustrine sediments. Undrained depressions, marshes, and lake bottoms within the area commonly contain muck or peat.

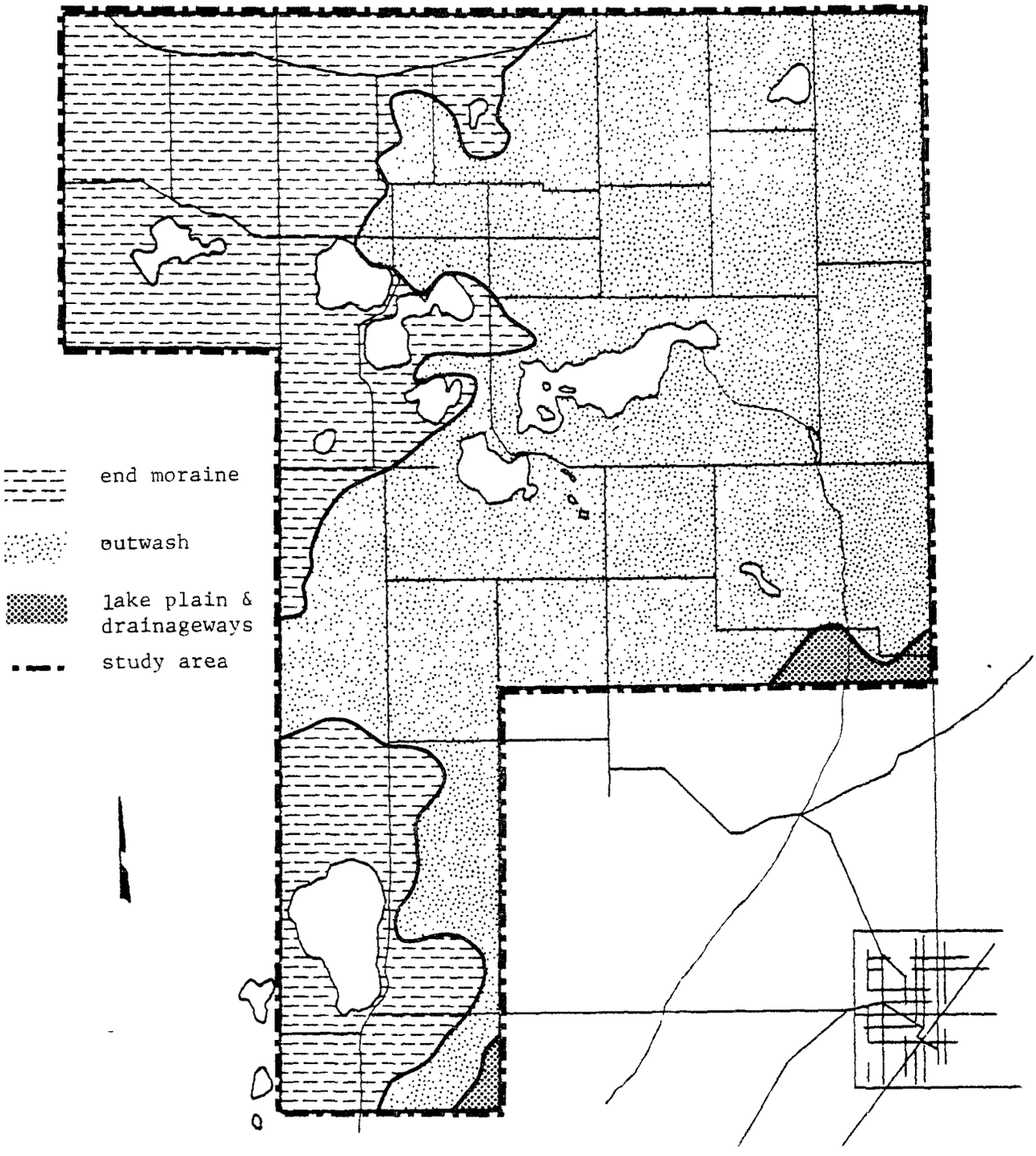


Figure 3-2. Surficial geology of the study area.

3.1.2.2. Soils

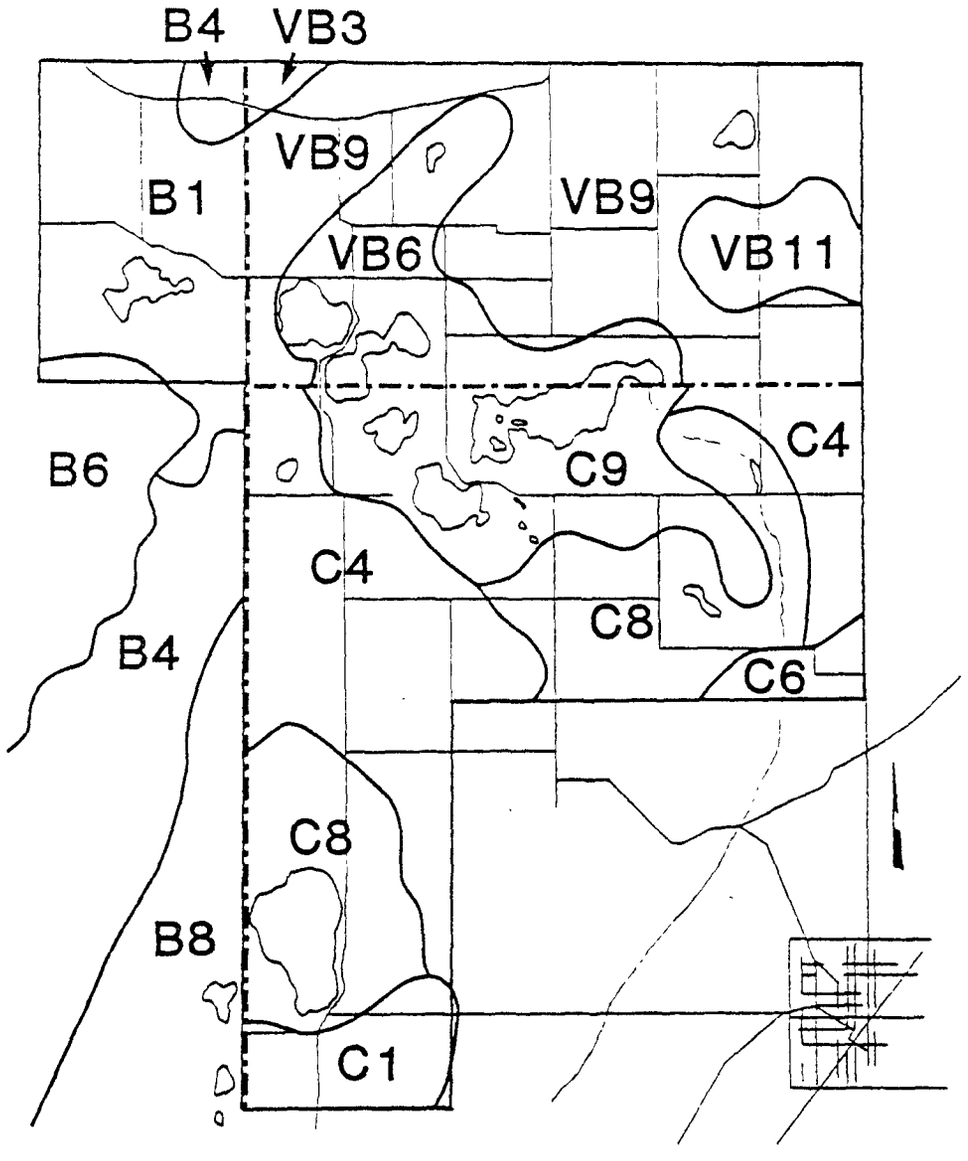
Sewage disposal in rural areas most often depends on soil-based systems. Whether they function properly or not depends on proper design and construction of the system and a careful selection of proper design criteria. One approach to selection of design criteria is to generalize soils into similar groupings based on pertinent physical characteristics.

The USDA Soil Conservation Service (SCS) in cooperation with the Michigan Agricultural Experiment Station recently completed this task in Berrien County and has published the Soil Survey (SCS 1980b) according to current standards. Advance field sheets for a soil survey of Van Buren County also were available and certain areas of Cass County were mapped as part of this EIS. The soils mapping of both Van Buren County and Cass County was prepared in a manner consistent with the Soil Survey of Berrien County.

The soils of the Indian Lake-Sister Lakes area will be described first on an association basis. "Each map unit, or association, on the general soil map is a unique natural landscape. Typically, an association consists of one or more major soils and some minor soils. It is named for the major soils." (SCS 1980b). The general soil or association map (Figure 3-3) is to be used for a general picture of soils of the area; the soils of a specific parcel must be seen on the detailed soil maps. The associations map of Berrien County was prepared from the recent soil mapping. The associations maps of Van Buren County and Cass County were prepared from old reconnaissance soil maps and have not been updated based on the recent soil mapping.

General and detailed soil maps are useful as a guide to planning needs documentation efforts. They do not by themselves document need. Soil associations can be used for preliminary determinations of the potential suitability of on-site systems on a community-wide basis. Soil interpretation data should be used in planning site specific field investigations of on-site system suitability.

The predominant soil association within the Cass County section of the study area is the Oshtemo-Kalamazoo. It is composed of deep, well-drained, level to undulating soils found on outwash plains. The texture of these soils is moderately coarse to coarse. On-site systems on coarse textured soils



B1 - Spinks, Oakville, Oshtemo
B4 - Riddles, Ockley, Oshtemo
B6 - Pella, Kibbie, Lenawee
B8 - Ockley, Oshtemo

VB3 - Riddles, Ockley, Oshtemo
VB6 - Kalamazoo, Oshtemo
VB9 - Spinks, Oakville, Oshtemo
VB11 - Houghton, Adrian, Palms

C1 - Kalamazoo
C4 - Oshtemo, Kalamazc
C6 - Brady, Gilford, Matherton, Sebewa
C8 - Ockley, Oshtemo
C9 - Kalamazoo, Oshten Hillsdale

Figure 3-3. Soil associations in the study area.

within this association may, because of poor filter characteristics, result in degradation of groundwater quality.

The Kalamazoo-Oshtemo-Hillsdale soil association surrounds the Sister Lakes in Cass County. This association is characterized by deep, well-drained, undulating to rolling soils found on outwash plains and moraines. These soils are moderately coarse to coarse in texture. Some of the undulating areas are covered by croplands and orchards, but most of the rolling areas are covered by permanent pasturelands and forests. Soil absorption systems can be designed and constructed on the major soils within this association, except where steep slopes prohibit construction, although there is a hazard of groundwater degradation because of poor filter characteristics.

The Oshtemo-Spinks-Oakville soil association is located southeast of the Sister Lakes area and surrounds the Indian Lake area. This association is composed of deep, well-drained, undulating to rolling soils found on outwash plains and moraines. These soils have moderately coarse to coarse textures. Land cover is about equally divided between orchards, croplands, and woodlands. Soil-based treatment systems on the major soils of the association may, because of poor filter characteristics, result in groundwater degradation.

The Kalamazoo asociation, located south of Indian Lake, is composed of deep, well-drained, level to undulating soils found on outwash plains. The soils are moderately fine-textured in the upper part and coarse-textured in the lower part. Most of this area is covered by croplands, with some orchards and woodlands. Soil-based treatment systems must be designed and installed with care because the moderately fine textured surface soil limits downward percolation. Soil-based treatment systems installed in the coarse-textured lower part may result in degradation of the groundwater.

The predominant soil association in the Van Buren County section of the study area is the Oshtemo-Chelsea-Spinks. This association is located on the uplands west and north of the lakes area. It abuts the Oshtemo-Kalamazoo association of Cass County. The soils are deep, well-drained, nearly level, pitted, and are found on outwash plains. The soil texture is coarse to very coarse. Most of the area of the association is utilized for orchards, with

smaller areas utilized for croplands. Woodlands and permanent pasturelands are located on pitted areas. Steep-sided pitted areas limit construction activities and require somewhat specialized designs for soil absorption systems. On-site systems in the coarser-textured soil material may degrade groundwater quality because of poor filter characteristics.

The Kalamazoo-Oshtemo association occurs in the area immediately around and north of the Sister Lakes in Van Buren County . The adjacent association in Cass County is the Kalamazoo-Oshtemo-Hillsdale association. The soils of the Kalamazoo-Oshtemo association are deep, well-drained, and rolling to hilly. They are located on moraines, outwash plains, and till plains. The soil textures are moderately coarse. Most of this association is in woodlands and wetlands, although some is utilized for orchards and croplands. Soil absorption systems on the major soils of the association may result in degradation of groundwater quality because of poor filter characteristics. Some moderately fine textured soils require somewhat specialized designs for successful operation. Steep slopes limit construction activities in some areas.

The Houghton-Adrian-Palms association is located in the area around the Osborn Drain, near the northeastern corner of the study area. This association is characterized by deep to shallow, very poorly drained, nearly level, organic soils formed in old lake beds, depressions, and floodplains. This area is covered by marshes, wetlands and woodlands. This association is not suitable for soil-based on-site systems except for highly specialized designs.

The Metamora-Metea association occupies a small part of the northwestern corner of the study area in Van Buren County. The association has deep, well-drained to poorly drained, level to rolling soils on outwash over till plains. The predominant soil textures are medium to coarse. Woodlands, wetlands, and orchards are the predominant land use/cover types on these soils. Some areas are suitable for soil absorption systems while most of the association is unsuitable because high water table, somewhat poor permeability, and steep slopes preclude installation of soil absorption systems.

The Riddles-Ockley-Oshtemo soil association occurs at the north end of the study area in Berrien County. It is bordered by the Metamora-Metea association in Van Buren County. This association also occurs further south in Berrien County, where it is bordered by the Oshtemo-Kalamazoo association in Cass County. These soils are well-drained, nearly level to very steep, and were formed in outwash plains, moraines, and till plains. The predominant soil textures are loam, sandy clay loam, and sandy loam. Orchards, croplands, woodlands, and wetlands are the predominant land use/cover types that occur on this association. Most of the association is satisfactory for soil-based treatment systems, although somewhat fine soil textures in some areas require specialized designs. Steep slopes in some areas of the major soils preclude construction activities.

The Spinks-Oakville-Oshtemo soil association occurs in the vicinity of Pipestone Lake. It is bordered by the Oshtemo-Chelsea-Spinks association in Van Buren County. The well-drained, nearly level to steep soils were formed on moraines, till plains, outwash plains, and beach ridges. The subsoil is sandy or loamy, and overlies sand and gravelly sand parent material. All of the soils have rapid permeability and are droughty. Orchards are the predominant land use/cover type occurring on this association, although wetlands and woodlands also are common. The lakeshore area consists of minor soils within the association that are unsuitable for soil absorption systems. Soil absorption systems on the major soils within the association may cause degradation of groundwater quality.

The Pella-Kibbie-Lenawee soil association is located southwest of Pipestone Lake. It occupies only a small portion of the study area. The soils, formed in glacial lake deposits, are poorly drained and nearly level to very gently sloping. The subsoil has a loamy or clayey texture, and the underlying material ranges from loamy sand to silty clay layers. Wetlands and croplands are the predominant land use/cover types occurring on this association. The association is generally unsuitable for soil absorption systems because high water tables and somewhat fine soil textures preclude design of soil absorption systems.

The Ockley-Oshtemo association is located in Berrien County adjacent to Indian Lake. The Oshtemo-Spinks-Oakville and Kalamazoo associations are adjacent to it in Cass County. These are well-drained, nearly level to steep soils on outwash plains and moraines. Loessial and loamy drift or sandy subsoils underlain by sand and gravel predominate. Specialty fruit crops occur over most of this association in the study area, with croplands and woodlands occurring over smaller areas. Soil-based treatment systems can be designed and installed on the major soils of the association, except where steep slopes limit construction activities, although some hazard of groundwater degradation exists when soil absorption systems are installed in the coarse-textured soil material.

The individual soil series are mapped on a scale of 4 inches = 1 mile in Berrien County and Van Buren County and 1 inch = 1,000 feet in Cass County. The smallest area mapped is approximately 2.5 acres (1.1 hectares). This scale is useful for identifying the soil characteristics in a field-sized unit, but is of limited usefulness for a residential lot on the lakeshore. Detailed soil maps are not presented in this report, but are available for inspection in the respective SCS offices.

Each series represents soils that have similar characteristics, but by no means are uniform. Thus, considerable variation may be present within one mapping unit on the detailed soil maps. For example, the depth to the water table may vary from zero to greater than 6 feet and slope may vary from zero to 18%. The characteristics of the major soil series that relate to soil-based sewage disposal are presented in Table 3-1. The SCS has given the soils of the majority of the watershed area a severe rating for soil absorption systems.

The primary limitation is "poor filter", that is, coarse textured soil material. The soils may vary between fine to medium sands, that have no limitations, and coarse gravels, that have poor filter characteristics. Where gravels are encountered, the drainbed area can be overexcavated and backfilled with sand prior to construction of the gravel bed. Existing soil absorption systems in coarse textured soils are difficult to evaluate with respect to the capability of the soil to treat pollutants from the septic tank effluent. Groundwater pollutants cannot be traced back to a particular on-site system except with detailed groundwater testing.

Table 3-1. Soil series characteristics and ratings for soil absorption systems (SCS 1980b).

SCS Soil Name	Mapping Symbol: Cass and Van Buren	Mapping Symbol: Berrien	Slope range (percent)	Soil Texture[1]: Surface	Soil Texture[1]: Underlying Material	Depth to Water Table (feet)	Permeability to 60" (in/hr)	Ratings for Soil Absorption Systems[2]
Adrian	27	6	0-2	muck	sand	+1-1.0	0.2-6.0 (26") 6.0-20	Sev= p
Belleville	60	30	0-2	lfs	cl,sicl	+1-1.0	6.0-20 (30") 0.2-0.6	Sev= p
Boots (or Napoleon)	38		0-2	mucky peat	peat	0-1.0	6-20	Sev= p
Brady	25A	19A	0-2	sl	ls, s&gr	1.0-3.0	2.0-6.0 (35") 2.0-20 (48") > 20	Sev= pf, wetness
Bronson	24A		0-3	sl	s,ls	2.0-3.5	2.0-6.0 (40") 6.0-20	Sev= pf, wetness
Edwards	11	55	0-2	muck	marl	+1-0.5	0.2-6.0 (22") variable	Sev= p,sp
Gilford	26	20	0-2	sl	ls,s	0.5-1.0	2.0-6.0 (33") 6.0-20	Sev= p,pf
Granby	5	37	0-2	lfs	s,fs	+1-1.0	6.0-20	Sev= p,pf
Houghton	28	5	0-2	muck	muck	+1-1.0	0.2-6.0	Sev= p,sp
Kalamazoo	22A		0-2	l	ls,s,grs	6.0	0.6-2.0 (35") 6.0-20	Sev= pf
	22B		2-6	l	ls,s,grs	6.0	0.6-2.0 (35") 6.0-20	Sev= pf
	22C		6-12	l	ls,s,grs	6.0	0.6-2.0 (35") 6.0-20	Sev= pf,sl
	22D		12-18	l	ls,s,grs	6.0	0.6-2.0 (35") 6.0-20	Sev= pf,sl
	22E		18-35	l	ls,s,grs	6.0	0.6-2.0 (35") 6.0-20	Sev= pf,sl
Kibbie	31A	31A	0-3	l	sicl,fs	1.0-2.0	0.6-2.0	Sev= wetness
Marsh	10					+1-0.5		Sev= p
Martinsville		56B	2-6	fsl	s,scl	6.0	0.6-2.0	Sl
		56C	6-12	fsl	s,scl	6.0	0.6-2.0	Mod= sl
Metea		63B	1-6	ls	cl,scl,sicl	6.0	>20 (36") 0.6-2.0 (41") 0.2-2.0	Sev= sp
		63C	6-12	ls	cl,scl,sicl	6.0	>20 (36") 0.6-2.0 (41") 0.2-2.0	Sev= sp
Morocco		42A	0-2	ls	fs,s	1.0-3.0	6.0-20	Sev= pf, wetness
Ockley		12A	0-2	l	ls,grs	6.0	0.6-2.0 (45") > 20	Sl
		12B	2-6	l	ls,grs	6.0	0.6-2.0 (45") > 20	Sl
		12C	6-12	l	ls,grs	6.0	0.6-2.0 (45") > 20	Mod= sl
		12D	12-18	l	ls,grs	6.0	0.6-2.0 (45") > 20	Sev= sl
Oshtemo	6A		0-2	sl	s&gr	6.0	2.0-6.0 (33") 6.0-20 (41") > 20	Sev= pf
	6B	11B	2-6	sl	s&gr	6.0	2.0-6.0 (33") 6.0-20 (41") > 20	Sev= pf
	6C	11C	6-12	sl	s&gr	6.0	2.0-6.0 (33") 6.0-20 (41") > 20	Sev= pf
	6D	11D	12-18	sl	s&gr	6.0	2.0-6.0 (33") 6.0-20 (41") > 20	Sev= pf,sl
	6E	11E	18-35	sl	s&gr	6.0	2.0-6.0 (33") 6.0-20 (41") > 20	Sev= pf,sl
Palms	54	7	0-2	muck	cl,sicl,fsl	+1-1.0	0.2-6.0 (40") 0.2-2.0	Sev= p, subsides
Pella		16B	0-2	sil	ls,sicl	+1-2.0	0.6-2.0	Sev= p
Riddles	52B	14B	2-6	l	cl,sl,l	6.0	0.6-2.0	Sl
	52C	14C	6-12	l	cl,sl,l	6.0	0.6-2.0	Mod= sl
	52D	14D	12-18	l	cl,sl,l	6.0	0.6-2.0	Sev= sl
		14E	18-45	l	cl,sl,l	6.0	0.6-2.0	Sev= sl
Sebewa	40		0-2	l	s&gr	+1-1.0	0.6-2.0 (29") 6.0-20	Sev= pf,p
Selfridge		64A	0-3	ls	cl,l,sicl	1.0-2.0	6.0-20 (35") 0.2-2.0	Sev= sp, wetness
Spinks	20A		0-2	ls	s,lfs	6.0	6.0-20 (10") 2.0-20	Sev= pf
	20B	13B	2-6	ls or lfs	s,lfs	6.0	6.0-20 (10") 2.0-20	Sev= pf
	20C	13C	6-12	ls or lfs	s,lfs	6.0	6.0-20 (10") 2.0-20	Sev= pf
	20D	13D	12-18	ls or lfs	s,lfs	6.0	6.0-20 (10") 2.0-20	Sev= pf,sl

Table 3-1. Soil series characteristics and ratings (concluded).

SCS Soil Name	Mapping Symbol: Cass and Van Buren	Mapping Symbol: Berrien	Slope range (percent)	Soil Texture [1]: Surface	Soil Texture [1]: Underlying Material	Depth to Water Table (feet)	Permeability to 60" (in/hr)	Ratings for Soil [2] Absorption Systems
Spinks-Oshtemo complex	12A		0-2			6.0		Sev= pf
(See Spinks and Oshtemo)	12B		2-6			6.0		Sev= pf
	12C		6-12			6.0		Sev= pf
	12D		12-18			6.0		Sev= pf,sl
	12E		18-35			6.0		Sev= pf,sl
Tedrow	8A		0-2	ls	s,fs	0.5-1.5	6.0-20	Sev= pf, wetness
Thetford	37A	57A	0-2	ls	lfs,sl,fs	1.0-2.0	2.0-6.0	Sev= pf, wetness

1 Soil texture abbreviations are: sic-silty clay, si-silt, cl-clay loam, sicl-silty clay loam, scl-sandy clay loam, grcl-gravelly clay loam, sil-silt loam, l-loam, fsl-fine sandy loam, lfs-loamy fine sand, fs-fine sand, ls-loamy sand, s-sand, grs-gravelly sand, s&gr-sand and gravel.

2 Ratings abbreviations for soil absorption systems are: Sl-slight, Mod-moderate, Sev-severe, and fl-flooding, p-ponding, sp-slow permeability, sl-slope.

The county sanitarians have identified fine-textured soils as a reason for the failure of standard design soil absorption systems on certain lots. These soils were not identified through soil mapping because these areas were smaller than the standard mapping unit. Soil absorption systems in these areas require designs somewhat different than the standard design.

Steep slopes are identified as a limitation for soil absorption systems. Within the mapping units, considerable variation in slope is likely. Building sites with steep slopes generally have adequate depths to the water table so that a drywell absorption system can be installed. Construction difficulties on slopes greater than 18% prevent soil absorption systems from being installed.

High water table and flooding or ponding are identified as reasons for severe ratings for soil absorption systems. The high water table is characteristic of some lakeshore areas and is frequently associated with organic soils. Many soil absorption systems in these areas have been constructed within or slightly above the water table. Soil absorption systems that are within the water table are more likely to fail because the organics in the septic tank effluent decompose slowly, resulting in clogs in the system and surface breakout or backups.

These ratings indicate the general difficulties in designing, constructing, and maintaining soil absorption systems. The poor filter, slope, wetness, and slow permeability limitations can generally be overcome and operational systems installed, but the design solutions may be complicated and expensive. The on-site systems presently installed are described in detail in Section 2.1.1.

3.1.3. Water Resources

3.1.3.1. Rivers and Lakes in the Study Area

The study area, situated within the St. Joseph River Drainage Basin, contains eleven lakes, one river, two creeks, and numerous wetlands. With the exception of Indian Lake, the lakes are located in the northern section of the study area. The lakes that are particularly significant to this discussion are Cable Lake, Crooked Lake, Dewey Lake, Indian Lake, Magician Lake, Pipe-

stone Lake, Keeler Lake and Round Lake. (Brown Lake, Grabemeyer Lake, and Priest Lake are relatively small and are not discussed herein.)

The flow in the rivers and streams of the study area is determined by overland runoff from precipitation, by groundwater flow, and, in some cases, by wastewater discharged to the streams. Stream flow usually is highest during the late winter and spring because of increased runoff from meltwaters, and lowest during the late summer and fall when there is little precipitation.

3.1.3.1.1. Dowagiac River

The Dowagiac River, a tributary of the St. Joseph River, flows in a southwesterly direction along the eastern and southern borders of the study area. The USGS (1978) measured the flow of the Dowagiac River at Sumnerville, approximately 4.5 miles (7.2 kilometers) south of the study area. The maximum flow during the 19-year period of record at the station was 1,267 cubic feet per second (cfs; 36.2 cubic meters per second [m^3/s]), recorded on 26 June 1968, and the minimum flow was 84 cfs (2.4 m^3/s), recorded on 10 September 1964. During the period from October 1976 to September 1977, the maximum, minimum, and mean flows were 637 cfs (18.2 m^3/s), 112 cfs (3.2 m^3/s), and 245 cfs (7.0 m^3/s), respectively.

3.1.3.1.2. Dowagiac Creek

Dowagiac Creek is not within the boundaries of the study area. However, a description of the Creek is included because it is the receiving body for the effluent discharged from the Dowagiac sewage treatment plant (STP). Dowagiac Creek is the outlet from Mill Pond, located in Cass County. The Creek flows in a westerly direction through the City of Dowagiac and past the existing STP, located west of the City. Approximately 1.9 miles (3 kilometers) past the STP, the Dowagiac Creek flows into the Dowagiac River. The maximum and minimum flows recorded in Dowagiac Creek at State Highway M-62 during a 6-year period from 1969 through 1974 were 137 cfs (3.9 m^3/s) and 46.6 cfs (1.33 m^3/s) respectively. The mean flow during this period was 66.6 cfs (1.9m^3/s) (MDNR 1978c).

3.1.3.1.3. Silver Creek

Silver Creek is the outlet for Magician Lake. The Creek originates at the northeastern end of Magician Lake and flows south to southeast through the Dowagiac Swamp, where it enters the Dowagiac River.

3.1.3.1.4. Pipestone Creek

Pipestone Creek is the outlet for Pipestone Lake. This creek flows south to southwest to its confluence with the St. Joseph River, approximately 8 miles (12.9 kilometers) west of the study area.

3.1.3.1.5. Inland Lakes

Physical characteristics for each of the seven major lakes in the study are presented in Table 3-2. Indian Lake, located in the southern part of the study area, has the greatest surface area (481.5 acres or 195 hectares), the largest watershed (4,148.5 acres or 1,679 hectares) and one of the higher watershed to lake surface ratios (8.6:1). Dewey Lake has the highest watershed to surface area ratio (9.9:1). Crooked Lake has the greatest recorded depth (62 feet or 18.8 meters) and the lowest watershed to surface area ratio (3.1:1). Although Magician Lake has a lake surface area similar in size to Indian Lake, Magician Lake has nearly twice the shoreline length compared to Indian Lake.

3.1.3.2. Water Quality of the Major Rivers and Lakes in the Study Area

The Michigan Water Resources Commission of the MDNR has been designated as the water pollution control agency for the State (Act No. 245 of the Public Acts of 1929). The applicable standards for the study area and proposed revisions are shown in Table 3-3. The proposed amendments include raising the minimum dissolved oxygen level from 4 mg/l to 5 mg/l for protection of warm water fish and the addition of a standard for concentrations of toxic organic and inorganic substances. The State water quality standards are applied selectively, according to the type of use that has been designated for a particular body of water. Designations include domestic and industrial water supply, total or partial body contact recreation, fish, wildlife and other aquatic life, agricultural, and navigation.

Table 3-2. Physical characteristics of major lakes in the Indian Lake-Sister Lakes study area (Marsh and Borton 1974).

	Cable Lake	Crooked Lake	Dewey Lake	Indian Lake	Magician Lake	Pipestone Lake	Round Lake
County	Cass	Van Buren, Cass	Cass	Cass	Van Buren, Cass	Berrien	Van Buren
Township, Section	Silver Creek 5	Keeler 31, 32 Silver Creek 5, 6	Silver Creek 4, 5, 8, 9	Silver Creek 30, 31	Keeler 34 Silver Creek 3, 4	Bainbridge 25, 26, 35, 36	Keeler 31, 32
Surface area (acres)	91.2	226.8	189.4	481.5	468.7	106.0	198.7
Maximum depth (m)	12.5	18.8	13.7	10.6	18.2	9.1	10.6
Length of shoreline (km)	3.7	6.1	4.5	6.1	11.3	5.8	3.7
Watershed area (acres)	681.2	695.1	1,869.5	4,148.5	2,049.7	2,801.6	681.2

Table 3-3. Existing and proposed water quality standards for State of Michigan (Act 245, Public Acts 1929, Part 4 and Michigan Department of Natural Rseources 1981).

Parameter	Existing Standards (1973)	Proposed Standards (1981)
Temperature	Rivers, streams, and impoundments naturally capable of supporting coldwater fish shall not receive a heat which would: a) increase the temperature more than 2°F above the existing natural water temperature or b) increase the temperature of the receiving waters at the edge of the mixing zone to temperatures greater than the following maximum monthly temperatures (in °F): J F M A M J J A S O N D 38 38 43 54 65 68 68 68 63 56 48 40	Rivers, streams, and impoundments naturally capable of supporting coldwater fish shall not receive a heat load which would increase the temperature of the receiving waters at the edge of the mixing zone, on a monthly basis, above the following weekly average temperature (in °F): J F M A M J J A S O N D 38 38 43 54 65 68 68 68 63 56 48 40
	Rivers and streams naturally capable of supporting warmwater fish shall not receive a heat load which would: a) warm the receiving water at the edge of the mixing zone more than 5°F above the existing natural water temperature or b) increase the temperature of the receiving waters at the edge of the mixing zone to temperatures greater than the following maximum monthly temperatures (in °F): J F M A M J J A S O N D 41 40 50 63 76 84 85 85 79 68 55 43	Rivers and streams naturally capable of supporting warmwater fish shall not receive a heat load which would increase the temperature of the receiving waters at the edge of the mixing zone to temperatures greater than the following maximum monthly temperatures (in °F): J F M A M J J A S O N D 41 40 50 63 76 83 83 83 79 68 55 43
	Inland lakes shall not receive a heat load which would: a) increase the temperature of the receiving waters at the edge of the mixing zone more than 3°F above the existing natural water temperature or b) increase the temperature of the mixing zone to temperatures greater than the following monthly maximum temperature (in °F): J F M A M J J A S O N D 45 45 50 60 70 75 80 85 80 70 60 50	Inland lakes shall not receive a heat load which would increase the temperature of the receiving waters at the edge of the mixing zone, on a monthly basis above the following weekly average temperatures nor exceed the maximum temperatures indicated by an asterisk (in °F): J F M A M J J A S O N D 45 45 50 60 70 75 80 83* 80 70 60 50
pH (standard units)	6.7 to 8.8	6.7 to 9.0
Dissolved Oxygen	Coldwater streams: a minimum of 6 mg/l Inland lakes: in general, 5 mg/l to 6 mg/l, depending on the type of aquatic life and the structure of the lake Other waters: a minimum of 5 mg/l - daily average and no single values less than 4 mg/l in waters naturally capable of supporting warmwater fish	Coldwater streams: a minimum of 7 mg/l Inland lakes: in general, 5 mg/l to 7 mg/l, depending on the type of aquatic life and the structure of the lake Other waters: a minimum of 5 mg/l
Dissolved Solids	Shall not exceed concentrations that are injurious and no more than 750 mg/l at any time as a result of controllable sources	Shall not exceed concentrations that are or may become hazardous to any designated use and shall not exceed 750 mg/l at any time as a result of controllable sources

Table 3-3. Existing and proposed water quality standards (concluded).

Parameter	Existing Standards (1973)	Proposed Standards (1981)
Chloride (Cl^-)	Shall not exceed 125 mg/l, monthly average	Shall not exceed 125 mg/l, monthly average
Total Phosphorus (Total P)	1 mg/l, monthly average	Nutrients shall be limited to prevent the excessive growth of aquatic plants, fungi, or bacteria that be injurious to the designated uses
Fecal Coliforms	Total body contact recreation: no more than 200 fecal coliforms/100 ml geometric average Other waters: no more than 1,000 fecal coliforms/ 100 ml, geometric average	No more than 200 fecal coliforms/100 ml for total body contact recreation, 31 May to 31 October. Other areas: no more than 1,000 fecal coliforms/ 100 ml, 31 May to 31 October
Filtrable Iron	No greater than 0.3 mg/l	No proposed standard
Inorganic/organic Chemicals	Shall not exceed standards set in USDOI, Water Quality Criteria (1968) or standards promultaged by the USEPA	Arsenic 50.0 ug/l Barium 1,000.0 ug/l Cadmium 10.0 ug/l Chlorophenoxys 2, 4-D 100.0 ug/l 2, 4, 5-TP 10.0 ug/l Chromium (total) 50.0 ug/l Endrin 0.2 ug/l Fluoride 2,400.0 ug/l Lead 50.0 ug/l Lindane 4.0 ug/l Methoxychlor 100.0 ug/l Mercury 2.0 ug/l Nitrate 10,000.0 ug/l Selenium 10.0 ug/l Silver 50.0 ug/l Toxaphene 5.0 ug/l

3.1.3.2.1. Dowagiac River and Tributaries

Based on the preceding classification the Dowagiac River has been designated for agricultural use, navigation, industrial water supplies, and other aquatic and terrestrial wildlife. In general, the following uses have been designated for the Dowagiac River by the MDNR Water Resources Commission (1976):

- Total body contact recreation and support of cold-water fish populations (from the headwaters to just above its mouth)
- Partial body contact recreation and support of cold-water fish populations (from just above the mouth of the River to the confluence with the St. Joseph River).

The Pipestone Creek, Dowagiac Creek, and Osborn Drain have been designated as trout streams (MDNR 1975).

Selected water quality data for the Dowagiac River, Dowagiac Creek, and Pipestone Creek (tributary to the St. Joseph River) are compared to state standards (MDNR 1973) in Table 3-4. Additional physical and chemical characteristics for the three streams are contained in Appendix H, Tables H-1, H-2, and H-3.

Table 3-4. Selected water quality parameters for the rivers in the study area (MDNR 1973).

Parameter	State Standard	Dowagiac River	Dowagiac Creek	Pipestone Creek
Fecal Coliform (MPN/100 ml)	200 (total body contact in recreational waters) 1000 (all other waters)	1066	2394	574
Dissolved Oxygen (mg/l)	6 (minimum for streams and inland lakes protected for cold water fish) 5 (minimum for all other streams and inland lakes)	7.9	7.2	9.0
pH	6.7-8.8	8.1	8.1	8.3

The average dissolved oxygen levels in the Dowagiac Creek and River, and the Pipestone Creek were above the state standard of 5.0 mg/l. The pH of the three streams fell within the range set by the state standard. Concentrations of fecal coliform bacteria, however, were higher than the level permitted for total body recreation. Bacterial contamination of the waters in these streams is indicated by the fecal coliform data.

3.1.3.2.2. Inland Lakes

All lakes within the study area were designated for total body contact recreation and were classified, from a fisheries perspective, as warm water lakes (By telephone, Mr. Don Reynolds, MDNR, Fisheries Division, to WAPORA, Inc., 18 May 1979). Warm water lakes are typically shallow lakes and do not become stratified.

A sampling program was implemented to qualitatively characterize the water quality and trophic status of lakes in the study area. The survey was completed in two phases to compare early summer conditions with those of late summer when algal pulses, or blooms, are often evident. Phytoplankton collections were conducted during the periods of 4-6 June 1979 and 4-6 September 1979. Between five and ten sampling stations were distributed evenly around each lake. The actual number depended upon the size of the lake. The sampling station locations are shown in Appendix I, Figure I-1. The phytoplankton analyses including computer printouts summarizing the density, the percent occurrence of major groups and individual taxa, the number of taxa, and the Shannon-Wiener Diversity Index for each sample also are shown in Appendix I. In addition, dissolved oxygen levels, temperature, and Secchi disc depths were measured at each station on 4-7 September 1979 (Appendix I, Table I-2).

In general terms Chrysophyta (yellow-green or golden-brown algae), followed by Chlorophyta (green algae), were the most abundant algae in most of the lakes during the June sampling period. During the September sampling period, Cyanophyta (blue-green algae) was generally the most abundant algae present. Cable, Crooked, Indian, and Keeler lakes exhibited the greatest algal density in June.

During the September sampling period, surface dissolved oxygen concentrations were greater than 8.0 parts per million (ppm) in all of the lakes. The bottom dissolved oxygen levels, however, were less than 2.0 ppm at one or more stations on Cable, Crooked, Dewey, Magician, Pipestone, and Round lakes. The bottom dissolved oxygen levels for Indian and Keeler lakes were similar to the surface levels (Table 3-5). All of the measurements of surface temperature for the sampling stations on each lake were greater than 68°F (20°C) during both sample periods.

The Secchi disc readings obtained in September were greater than 6.6 feet (2 meters) and often greater than 9.8 feet (3 meters) for most of the sampling stations. Pipestone Lake, with readings of 3.3 feet (1 meter) was the exception. Algal concentrations visible to the naked eye were greatest at Indian Lake in June and at Crooked, Dewey, and Round lakes in September.

Following the collection and the analysis of the samples, general indices were utilized to determine the trophic status of each lake. Nygaard's Trophic Status Indices (Table 3-6) are based on ratios of selected taxa present in the water. The various genera present are rated according to their water pollution tolerance by Palmer's Organic Pollution Indices (Table 3-7) . The numerical values assigned to each genus are summed to yield a score that can be compared with values associated with high or low organic pollution.

The results of the various indices indicate that the lakes of the area are either in an advanced mesotrophic state or in an eutrophic state. This conclusion was substantiated further by the existence of moderate to heavy aquatic vascular plant growth in the lakes and the dissolved oxygen readings of less than 2.0 ppm in the deeper sections of six of the lakes. The reduced Secchi disc transparency readings for Pipestone Lake also indicate greater algal productivity (biomass) and turbidity compared to the other lakes.

Other research on the lakes in this area supports Nygaard's Trophic Status classification. The remainder of this section will describe the lakes individually and incorporate results found by other investigators.

Table 3-5. Water quality data collected from Indian Lake and the Sister Lakes on 4-6 September 1979.

Lake	Station No.	Date	Depth of Lake (ft)	Water Temperature (°C) Surface	Water Temperature (°C) Bottom	Dissolved Oxygen (ppm) Surface	Dissolved Oxygen (ppm) Bottom	Secchi Disc Depth (ft)	General Wind Direction	General Wind Speed (mph)
Pipestone	1	4 Sep 79	15	25.0	17.0	10.4	0.0	3.0	NE	0-2
"	2	"	22	24.9	12.2	10.6	0.0	3.5	NE	0-2
"	3	"	14	25.0	18.3	10.6	0.0	3.5	NE	0-2
"	4	"	23	24.5	9.7	11.9	0.0	3.5	NE	0-2
"	5	"	21	25.0	8.8	12.8	0.0	3.5	NE	0-2
Round	6	5 Sep 79	7	24.8	23.5	8.3	8.7	7.0*	E	0-2
"	7	"	7	23.7	23.5	8.2	8.2	7.0*	E	0-2
"	8	"	8	23.4	23.2	8.1	7.3	8.0*	E	0-2
"	9	"	9	23.8	23.4	8.7	8.3	9.0*	E	0-2
"	10	"	17	23.7	22.1	8.3	1.6	9.5	E	0-2
"	11	"	10	23.5	23.2	8.1	4.9	9.0	E	0-2
"	12	"	12	23.8	23.0	8.1	7.3	10.0	E	0-2
"	13	"	14	23.7	23.0	8.3	7.9	9.5	E	0-2
Crooked	14	5 Sep 79	12	24.5	23.0	9.0	9.7	10.0	N	0-2
"	15	"	9	24.0	23.2	8.8	9.4	9.0	N	0-2
"	16	"	>41	23.8	7.2	9.1	0.0	11.0	N	0-2
"	17	"	9	24.0	23.1	8.9	10.6	9.0*	N	0-2
"	18	"	11	24.0	23.0	8.8	9.3	10.5	N	0-2
"	19	"	17	24.0	21.3	8.6	0.0	10.0	N	0-2
"	20	"	22	24.3	19.1	8.9	0.0	9.5	N	0-2
"	21	"	18	23.0	21.3	8.9	0.8	9.5	N	0-2
"	22	"	34	24.0	7.9	8.9	0.0	9.0	N	0-2
"	23	"	7	24.0	23.5	9.0	9.9	7.0*	N	0-2
Cable	24	6 Sep 79	8	24.0	23.5	8.5	8.7	8.0*	NW	3-8
"	25	"	15	24.5	22.2	8.4	9.3	13.0	NW	3-8
"	26	"	16	24.5	8.7	8.9	2.0	16.0	NW	3-8
"	27	"	29	25.0	10.0	8.8	1.6	15.5	NW	3-8
"	28	"	26	24.3	10.2	8.6	1.8	17.5	NW	3-8
Dewey	29	6 Sep 79	7	24.7	24.0	9.2	9.8	7.0*	NW	3-8
"	30	"	6	25.0	24.3	9.6	10.4	6.0*	NW	3-8
"	31	"	4	24.8	24.9	9.1	9.2	4.0*	NW	3-8
"	32	"	16	24.8	21.7	8.8	2.8	8.5	NW	3-8
"	33	"	13	24.2	23.9	9.1	10.5	8.5	NW	3-8
"	34	"	17	24.9	22.0	8.8	0.7	10.0	NW	3-8
"	35	"	9	24.8	24.8	9.5	9.9	9.0	NW	3-8

Table 3-5. Water quality data collected from Indian Lake and the Sister Lakes (concluded).

Lake	Station No.	Date	Depth of Lake (ft)	Water Temperature (°C) Surface	Bottom	Dissolved Oxygen (ppm) Surface	Bottom	Secchi Disc Depth (ft)	General Wind Direction	General Wind Speed (mph)
Magician	36	4 Sep 79	32	24.3	9.9	8.6	0.0	7.5	NE	0-2
"	37	"	30	24.5	9.1	8.7	0.0	7.0	NE	0-2
"	38	"	4	24.5	24.5	8.3	9.4	4.0*	NE	0-2
"	39	"	13	24.5	21.6	8.8	2.4	5.5	NE	0-2
"	40	"	4	25.0	24.0	8.7	9.5	4.0*	NE	0-2
"	41	"	18	25.4	22.5	9.3	7.7	6.5	NE	0-2
"	42	"	5	25.2	24.5	9.4	9.0	5.0*	NE	0-2
"	43	"	6	25.0	24.8	9.5	9.7	6.0*	NE	0-2
"	44	"	9	24.6	24.0	8.9	8.4	7.0	NE	0-2
"	45	"	27	25.0	9.0	9.2	0.0	7.0	NE	0-2
Keeler	46	5 Sep 79	7	27.0	24.9	8.4	10.2	7.0*	E	0-2
"	47	"	6	25.2	25.0	8.8	11.8	6.0*	E	0-2
"	48	"	11	25.9	24.2	8.5	9.0	9.5	E	0-2
"	49	"	8	27.0	24.7	8.5	9.0	8.0*	E	0-2
"	50	"	8	26.0	24.2	8.9	10.2	8.0*	E	0-2
Indian	51	6 Sep 79	4	24.1	24.0	8.9	9.8	4.0*	NW	3-8
"	52	"	7	24.0	24.0	8.7	8.9	7.0*	NW	3-8
"	53	"	4	24.5	24.5	10.3	10.9	4.0*	NW	3-8
"	54	"	10	24.0	24.0	9.5	10.0	5.5	NW	3-8
"	55	"	15	24.1	23.2	9.8	9.9	6.5	NW	3-8
"	56	"	4	24.5	24.3	8.9	10.0	4.0*	NW	3-8
"	57	"	10	24.8	24.3	9.2	10.9	5.5	NW	3-8
"	58	"	9	24.5	24.5	8.9	8.9	6.0	NW	3-8
"	59	"	13	24.6	23.5	10.2	10.2	6.0	NW	3-8

*Secchi Disc visible on bottom

Table 3-6. Nygaard's Trophic Status (NTS)[a] for lakes in the Indian Lake-Sister Lakes study area (E = eutrophic, O = oligotrophic).

	June 1979		September 1979	
Lake	Myxophycean[b]	Diatom[c]	Myxophycean[b]	Diatom[c]
Cable	-[d]	-	-	-
Crooked	1.5(E)	0.375(E)	4.0(E)	0.67(E)
Dewey	1.0(E)	-	1.0(E)	1.0(E)
Indian	0.75(E)	0.429(E)	1.5(E)	0.75(E)
Keeler	1.33(E)	-	1.0(E)	-
Magician	1.0(E)	0.4(E)	4.0(E)	0.5(E)
Pipestone	1.0(E)	2.0(E)	2.0(E)	0.5(E)
Round	1.5(E)	0.4(E)	1.0(E)	0.25(O)

[a] Morris et al 1977

[b] Myxophycean = Myxophyceae / Desmideae — 0.0-.4 Oligotrophic; 0.1-3.0 Eutrophic

[c] Diatom = Centric Diatoms / Pennate Diatoms — 0.-0-0.3 Oligotrophic; 0.0-1.75 Eutrophic

[d] Dashes indicate that taxa necessary to calculate the ratio were not present.

Table 3-7. Palmer's Organic Pollution Indices for lakes in the Indian Lake-Sister Lakes study area.[a]

Lake	June 1979	September 1979
Cable	15	21
Crooked	14	30
Dewey	16	21
Indian	25	21
Keeler	19	19
Magician	11	25
Pipestone	13	25
Round	15	24

[a] The indices are based on genus. A numerical score of 20 or more is evidence of high organic pollution. A numerical score of 15-19 is probable evidence of high organic pollution (Morris and others 1977).

Pipestone Lake

A limnological study of Pipestone Lake conducted in 1978 (Snow 1978) classified the lake as mesotrophic to eutrophic on the basis of Bortleson's water quality index, summer chlorophyll a concentrations, and mean Secchi disc depth (Appendix H, Table H-4).

The spring survey (April) data indicated the lake was well-mixed while the late summer (August) survey found the lake to be strongly stratified (Snow 1978). Clinograde dissolved oxygen-temperature profiles, typical of an eutrophic lake, were exhibited in the lake with a maximum oxygen concentration in the epilimnion due to wind mixing and algal photosynthesis and a minimum in the hypolimnion due to stratification coupled with bacterial metabolism. A near shore fecal coliform survey conducted in June 1978 indicated that one sample out of three exceeded the standard for total body contact. This sample was taken near the mouth of the Dakin-Peter Drain. A lake survey conducted by Banks (1977) also found elevated levels of fecal coliform (1185 MPN/100 ml) and total phosphorus (0.173 mg/l) in the sample collected from the Dakin-Peter Drain.

Round Lake

Water quality data for Round Lake, which was monitored during 1977 and 1978 (MDNR 1978c), are summarized in Appendix H, Table H-5. The dissolved oxygen and temperature measurements of June 1978 to a depth of 24 feet (7.3 meters) show clinograde dissolved oxygen - temperature profiles, that are typical of eutrophic lakes. The temperature varied from 75°F (24°C) at a depth of 2 feet (0.6 meters) to 59°F (15°C) at a depth of 24 feet. Dissolved oxygen at the same depths varied from 9 mg/l to 0.2 mg/l. Limited water clarity (about 4 feet, Secchi disc depth) and chlorophyll a concentrations also indicated that eutrophic conditions were present during the sampling period.

Crooked Lake

Water quality data for Crooked Lake, monitored during 1978 (MDNR 1978c), are summarized in Appendix H, Table H-6. The dissolved oxygen and temperature measurements of 21 June 1978, taken at 2- to 46-foot (0.6- to 14- meter)

depths show clinograde profiles that are typical of eutrophic lakes. The temperature varied from 75°F (24°C) at a 2-foot depth to 45°F (7°C) at a 46-foot depth. Dissolved oxygen at the same depths varied from 9.4 mg/1 to 0.1 mg/1. Similar dissolved oxygen and temperature trends were monitored by WAPORA during September 1979 (Table 3-5). The temperature and dissolved oxygen monitored at the surface and at a depth of approximately 41 feet (12 meters) varied from 74.8°F (23.8°C) to 45°F (7°C) and 9.1 mg/1 to 0.0 mg/1, respectively.

Cable Lake

For the September 1979 sampling date, Cable Lake had a clinograde temperature-oxygen curve at three of the five sampling stations (Table 3-5). These conditions, found only at stations with a depth of 16 feet (4.8 meters) or greater, indicated that Cable Lake stratifies in the deeper regions. Cable Lake had the highest Secchi disc average (15.5 feet) of the eight lakes sampled in September 1979. Blue-green algae densities during June and September 1979 were low compared to Pipestone Lake. Between the June and September sampling dates, there was a dramatic decline in the density of green algae and a moderate increase in concentration of blue-green algae. This type of algal succession is typical in temperate North American lakes.

Dewey Lake

Dewey Lake was classified as eutrophic (MDNR 1977b, 1978b, 1979) on the basis of Secchi depth and chlorophyll a measurements collected through the Inland Lake Self-Help Program (Appendix H, Table H-7). A limnological study (Snow 1976) conducted during 1976 measured the seasonal temperature profiles for the surface water to a 50-foot (15.2-meter) depth. The results indicated that a large region of the lake remained isothermal and well-mixed until colder temperatures were reached in the autumn; at that time, the entire lake was isothermal. A portion of the lake stratified during the summer months with the hypolimnion developing below 20 feet (6.1 meters). However, most of the lake area was less than 20 feet deep and did not stratify.

The oxygen profile indicated that the hypolimnion was anoxic. Oxygen depletion occurred only at depths below 20 feet. Thus only a small volume of water was oxygen depleted because most of the lake bottom is no deeper than 20

feet. Oxygen depletion did not occur above 20 feet due to mixing of bottom water with surface water.

The yearly average unfiltered orthophosphorus concentration for the mixed water column was 0.021 mg/l and the nitrate-nitrogen concentration was 0.058 mg/l. Based on nutrient data, the lake was classified as mesotrophic to eutrophic. The average Secchi disc value for the summer months was 6.2 feet (1.9 meters). Using Bortleson's classification system, the physical factors indicated that the lake has a natural potential to be mesotrophic.

Magician Lake

Magician Lake was similar to the other lakes in the study area in that oxygen depletion occurred in the deeper holes of the lake. Measurements taken at the three deepest stations sampled during September 1979 showed that the dissolved oxygen declined to 0.0 ppm (0.0mg/l) at the bottom and the temperature changed from approximately 75.2°F (24.0°C) to 50°F (10°C). Stations sampled in less than 10 feet (3 meters) of water did not exhibit any stratification (Table 3-5).

The phytoplankton community of Magician Lake in June 1979 was dominated by diatoms. In September 1979, diatoms and blue-green algae were the two most abundant algal groups in the lake (Appendix I).

Keeler Lake

Keeler Lake was the smallest lake investigated during the June and September 1979 sampling trips. It is relatively shallow; most of the lake has a depth of 11 feet (3.3 meters) or less. Dissolved oxygen and temperature measurements taken from all five sampling sites indicated that Keeler Lake was well mixed and isothermal in September 1979. Light penetrated to the lake bottom over most of the lake, (based on Secchi disc measurements, Table 3-5). Keeler Lake had the lowest algal density of the eight lakes studied during the September 1979 sampling trip and was one of the few lakes that was not dominated by blue-green algae (Appendix I).

Indian Lake

All nine stations for the September 1979 sampling date indicated that Indian Lake was well-mixed and isothermal. The maximum depth sampled was 15 feet (4.5 meters) at sample site 55 (Table 3-5). Although the maximum depth is given as 35 feet (10.6 meters), most of the lake is probably less than 15 feet deep and these regions would be expected to have dissolved oxygen concentrations greater than 7.0 ppm (7.0 mg/l) throughout the water column.

The phytoplankton community was composed predominantly of a mixture of green algal species in June. By September, however, blue-green algae dominated the lake. Anacystis was the dominant blue-green algae in Indian, Crooked, Dewey, and Magician lakes during September (Appendix I).

3.1.3.3. Groundwater in the Study Area

Water supplies for the study area are obtained from groundwater sources associated with the glacial geology. Outwash deposits constitute the most productive aquifers in the study area. The stratified sands and gravels of these deposits may be highly permeable, continuous over great distances, and readily recharged by precipitation. Terminal moraines in the study area contain layers, or lenses, of sand and gravel that are highly permeable. However, due to the complex stratigraphy of morainal deposits, productive formations may be difficult to locate. Ancient lake sediments (generally fine-grained) as well as bedrock formations (chiefly shale) are poor aquifers and yield little water to wells in this area (Giroux 1972).

Water wells in the study area are used predominantly for domestic purposes. They generally consist of 2-inch (5-centimeter) diameter jetted wells with jet pumps. The maximum capacity of these wells typically is 4-gallons per minute (gpm; 24 cubic meters per day [m^3/d]). However, numerous 4-inch (10-centimeter) diameter wells have been drilled in the study area. These wells contain submersible pumps. The capacities of these wells may be as high as 100 gpm (532 m^3/d), but typically are 13.4 mp (73 m^3/d). A few 6-inch (15.2-centimeter) diameter wells also have been drilled in the study area. These wells also utilize submersible pumps and are capable of producing over 100 gpm (532 m^3/d).

One 12-inch (30.5-centimeter) diameter irrigation well is located in Section 16, Township 55, Range 16 W. The well was drilled to a total depth of 109 feet (33.2 meters) and was installed in medium to coarse sand. A pumping test performed at 134 gpm (7,300 m^3/d) resulted in a 15 foot (4.6 meter) drawdown at the well.

The regional water table in the study area is shown in Figure 3-4. This map was constructed on the basis of information obtained from topographic maps and water well records. Because stream flow into or away from the lakes is limited, it is probable that most of the circulation in the lakes is due to groundwater flow. Based on the available data, it appears that the levels of the lakes and streams of the study area reflect the level of the water table.

In general, groundwater is probably recharged in the outwash plains and is discharged to the Dowagiac River, to Silver Creek, and to the St. Joseph River. However, because the lakes in this area intercept the unconfined water table, groundwater probably constitutes an important part of the hydrologic budget in these lakes.

A groundwater quality survey of the project area was conducted by WAPORA during June 1979. A total of sixty residential wells located around the lakes were selected for sampling (Figure 3-5). The location of these wells represented suspected "problem areas" for septic tank systems (areas with high density housing, high water tables, and steep slopes) and "no problem areas" (areas with low potential for contamination of the well). Results of the nutrient and coliform analysis of the water samples collected from the representative wells are shown in Table 3-8. The nitrate-nitrogen data (Table 3-8) indicated that the groundwater was contaminated in localized areas. The majority of wells sampled (75%) had nitrate-nitrogen concentrations of less than 1 mg/l. Fifteen wells (25% of total wells samples) had concentrations greater than 1 mg/l; and 5 out of these 15 wells had nitrate-nitrogen concentrations greater than the 10 mg/l criteria for domestic water supply. The data also indicated that most of the higher nitrate-nitrogen concentrations are associated with higher concentrations of chlorides. Thus the most likely source of nitrate contamination of these localized wells appeared to be the effluent from septic tanks. The total phosphorus concentrations in the well samples ranged from less than 0.001 to 0.026 mg/l. Pipestone Lake had the

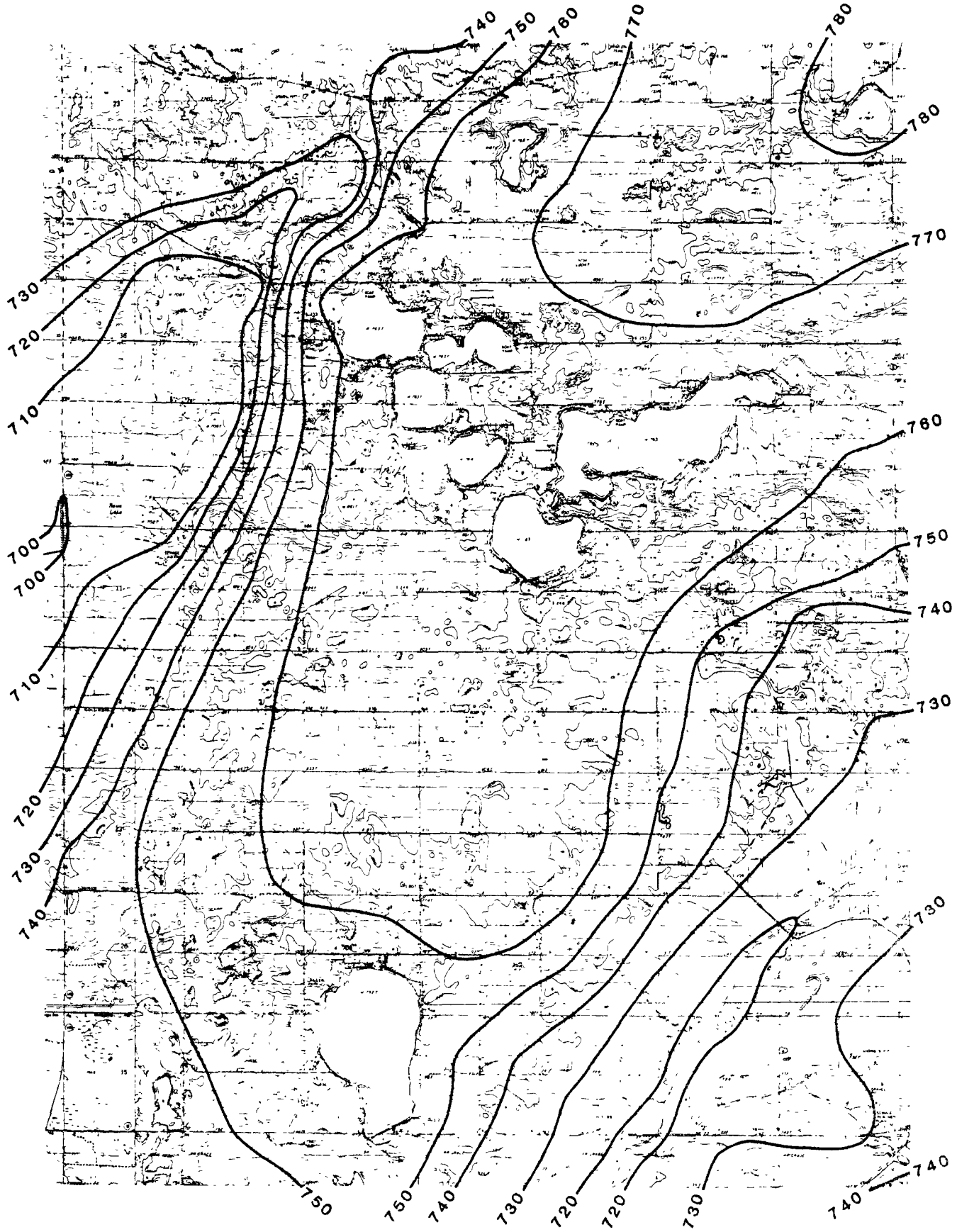


Figure 3-4. Groundwater contours in the study area.

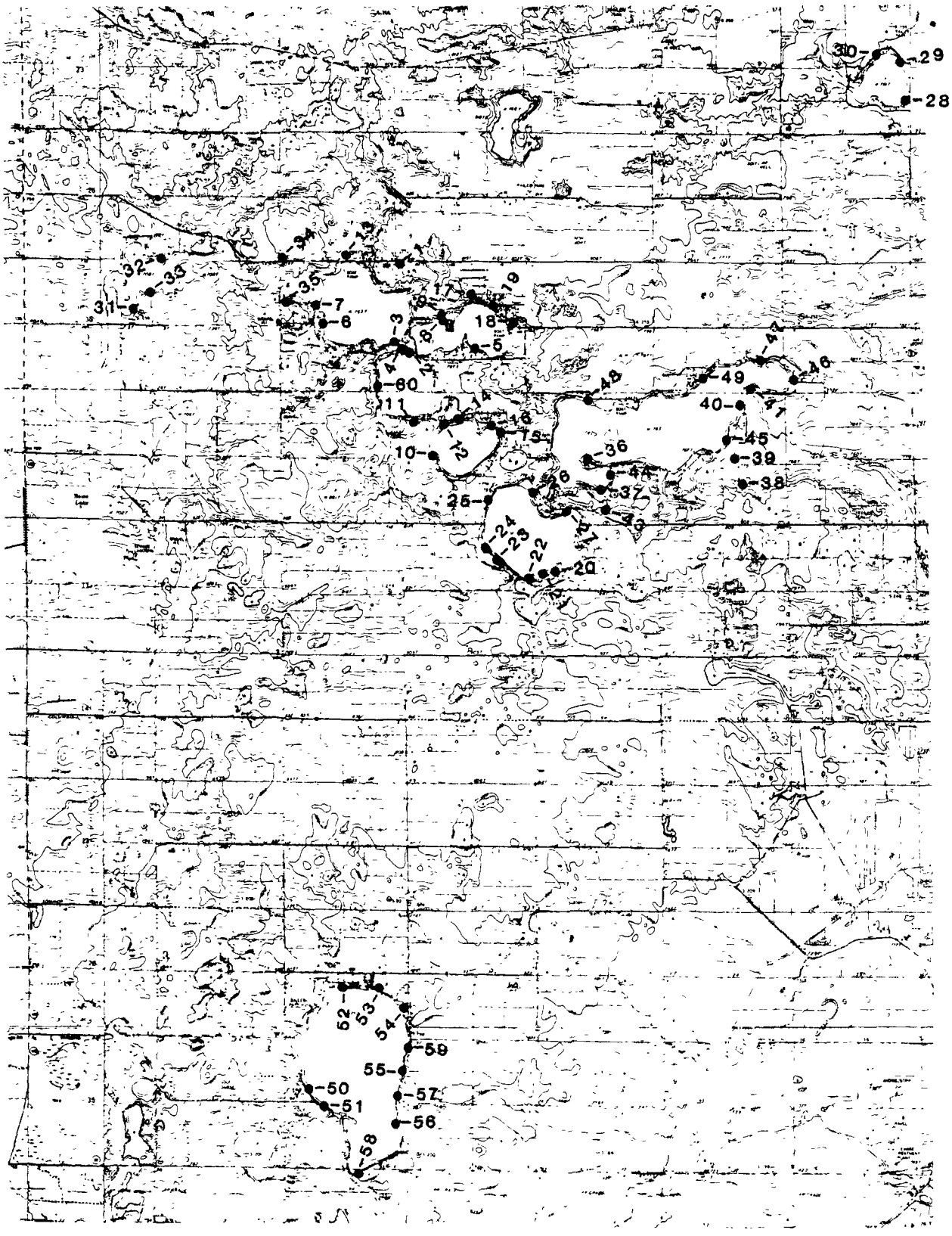


Figure 3-5. Well sampling sites for the groundwater survey

Table 3-8. Results of the groundwater survey of the Indian Lake-Sister Lakes study area that was conducted by WAPORA, Inc., between 11 and 15 June 1979.

Lake	Owner's Name	Station #	Well Depth (ft)	Total Coliform (#/100 ml)	Total Ammonia[a]	Total Phosphate[a] (as Phosphorus)	Nitrate[a] (as Nitrogen)	Chloride[a]
Big Crooked	M. Bloom	17	30	<1	<0.1	0.004	0.6	62.0
	D. Mitchell	5	90	<1	0.4	0.008	0.3	19.5
	R. New	18	36	<1	<0.1	0.008	1.8	55.0
	G. Pearl	9	45	<1	<0.1	0.002	0.2	6.0
	R. Sines	19	30	<1	<0.1	0.008	4.4	56.0
	G. Tillman	8	55	<1	0.2	0.025	0.2	14.0
Cable	W. Cox	10	43	<1	0.2	0.017	0.2	3.0
	R. Kimball	12	18	<1	<0.1	0.006	1.7	6.0
	R. Korpal	16	163	<1	<0.1	0.002	0.2	3.0
	R. Stark	15	NA	<1	<0.1	0.006	0.2	3.0
	H. Stockman	14	18	<1	<0.1	0.010	0.7	24.0
Dewey	C. Chitillo	20	NA	<1	0.3	0.009	0.3	4.0
	D. Demming	22	20	<1	0.2	0.007	0.3	35.0
	A. Duchossois	25	75	<1	<0.1	0.005	0.2	11.0
	N. Grange	21	NA	<1	0.4	0.018	0.3	5.0
	F. Nevins #2	23	40	<1	<0.1	0.003	0.4	60.0
	F. Nevins #3	24	40	<1	0.1	0.008	0.2	38.0
	C. Rigali	26	NA	<1	0.7	0.013	0.2	9.0
	C. Sanders	27	48	<1	0.2	0.017	0.2	4.0
Indian	J. Black	54	42	<1	<0.1	0.003	7.2	9.0
	J. Collins	59	45	<1	<0.1	0.002	25.1	40.0
	J. Hanson	58	60	<1	0.2	0.009	0.2	4.0
	R. Lindgren	56	NA	11	<0.1	0.025	0.3	10.0
	S. Lynch	50	NA	<1	0.1	0.003	0.3	9.0
	G. Sangmeister	53	70	<1	0.1	0.002	0.2	17.0
	R. Sherwood	52	NA	<1	<0.1	<0.001	9.0	8.0
	G. Vanderberg	57	65	<1	0.1	0.002	0.2	17.0
	J. Veleich	55	46	<1	<0.1	0.017	22.5	28.0
Keeler	K. Jensen	30	59	<1	<0.1	0.008	34.6	16.0
	W. Pullin	29	32	<1	<0.1	0.008	9.4	9.0
	D. Stover	28	45	<1	<0.1	0.004	0.3	11.0
Little Crooked	C. Clark	2	25	<1	0.8	0.018	0.3	35.5
	R. Galbreath	11	94	<1	0.1	<0.001	0.3	6.0
	W. Stanley	60	35	<1	0.2	0.009	0.2	10.0
	I. Wexelberg	4	33	<1	<0.1	0.008	4.5	146.5

Table 3-8. Results of the groundwater survey of the Indian Lake-Sister Lakes study area (concluded).

Lake	Owner's Name	Station #	Well Depth (ft)	Total Coliform (#/100 ml)	Total Ammonia[a]	Total Phosphate[a] (as Phosphorus)	Nitrate[a] (as Nitrogen)	Chloride[a]
Magician	R. Alexander	41	NA	<1	1.0	0.007	0.3	4.0
	M. Andrews	46	NA	1	<0.1	0.013	0.3	14.0
	J. Bray	40	NA	<1	0.1	0.016	0.2	7.0
	N. Hannewald	37	NA	6	0.3	0.003	4.8	13.0
	G. Harley	51	20	<1	<0.1	0.004	0.2	11.0
	R. Judd	36	40	5	0.1	0.009	0.3	5.0
	A. Kickert	45	NA	<1	<0.1	0.004	0.2	5.0
	W. Murray	48	145	<1	<0.1	0.006	0.2	8.0
	R. Neff	47	200	<1	<0.1	0.008	1.2	7.0
	R. Rottier	49	NA	<1	<0.1	0.001	16.4	49.0
	S. Zook	44	37	<1	0.4	0.011	0.2	33.0
Pipestone	J. Gard	33	128	<1	0.1	0.026	0.3	7.5
	F. Hauch	31	99	<1	0.2	0.015	0.4	4.5
	G. Rambert	32	165	<1	0.2	0.016	0.4	14.0
Round	F. Clupper	13	92	<1	0.1	0.009	0.4	23.0
	J. Holthof	7	150	<1	0.6	0.009	0.3	5.0
	R. Barnes	6	90	<1	0.2	0.005	0.2	5.0
	P. Bromfield	3	200	<1	<0.1	0.008	0.3	5.5
Background samples	T. Bauer	43	90	8	<0.1	0.008	0.2	18.0
	J. Cooper	1	180	<1	<0.1	0.006	0.4	8.0
	M. Couldry	34	NA	<1	0.2	0.008	0.3	5.0
	S. Eckstrom	35	60	13	<0.1	<0.001	0.4	6.5
	E. Miller	42	NA	<1	<0.1	0.001	1.1	92.0
	R. Osborne	39	NA	<1	<0.1	0.010	0.3	7.0
	J. Strom	38	83	12	<0.1	<0.001	10.4	121.0

[a]Values express concentrations in milligrams per liter.

highest average phosphorus concentration of 0.019 mg/l (3 samples). There was no apparent correlation between high phosphorus concentrations and high nitrate concentrations or between high phosphorus concentrations and high chloride concentration at the 60 sampling stations. Therefore the slightly elevated phosphorus concentrations found in wells around Pipestone Lake is not strictly associated with effluent from septic tank drainfields.

The quality of the groundwater was sampled at Burnette Farms Packing Co., Keeler, Michigan in 1963 (USGS 1963). The results are consistent with those of tests from other samples taken within Van Buren County. The results of this well sample, shown below, probably are indicative of baseline cation and anion concentrations found in groundwater associated with the lower aquifers located in glacial drift in this region:

Calcium (Ca)	56 ppm
Magnesium (Mg)	25 ppm
Sodium (Na)	3.8 ppm
Potassium (K)	0.7 ppm
Bicarbonate (HCO_3)	262 ppm
Carbonate (CO_3)	0 ppm
Sulfate (SO_4)	30 ppm
Chloride (Cl)	6.0 ppm
Dissolved solids (residue on evaporation	263 ppm
Hardness as $CaCO_3$	
Calcium-magnesium	243 ppm
Noncarbonate	28 ppm
pH	7.6
Specific conductance	465 micromhos at 25°C

3.1.3.4. Nutrient Inputs into Inland Lakes

The major water quality concern for Indian Lake and the Sister Lakes is the eutrophication process. All the lakes have some degree of eutrophication. Eutrophic lakes are characterized by high biological productivity, resulting in an algal cell density that can be high enough to give the water a thick green appearance. The problem is compounded when blue-green algae dominate. This form of algae collects together in dense colonies forming floating mats on the lake surface. This presents an unsightly condition that discourages water sports and often generates disagreeable odors.

Another problem is the depletion of dissolved oxygen caused by the die-off of large numbers of phytoplankton and other organisms. When the organisms in the lake die, they settle to the bottom and the organic matter is decomposed by bacteria and other microorganisms. The bacteria and microorganisms consume oxygen, depleting the oxygen in the bottom waters. Fish and the other organisms that require oxygen are unable to survive in such waters.

Eutrophication or increased productivity of the lake is generally caused by an increase in the input of nutrients to the lake. For most freshwater bodies, phosphorus is the key nutritive element for aquatic plant growth. In most cases, by restricting the input of phosphorus, productivity of the lakes can be reduced. One of the water quality benefits associated with centralized collection systems is the reduction of the phosphorus load entering the lakes. However, in evaluating the potential benefit of sewers in terms of lake water quality, it is important to look at all sources of phosphorus entering the lakes and the significance of the septic tank source in relation to other sources. It is conceivable that the removal of one source (septic tank effluents) may not change the water quality of these lakes significantly. Water quality improvements may require the control of many sources in order to realize maximum benefits from a reduced phosphorus load.

Estimation of the amount of nutrient loading to Indian Lake and the Sister Lakes requires measurements of the nutrient inputs from various sources. In this study, the three major nutrient sources identified were: nonpoint sources (general sources of pollution, such as surface runoff, not originating from a single controllable point), direct precipitation, and septic tank leachate.

In order to properly estimate the nutrient inputs, direct measurements of contributions from surface runoff, precipitation, and septic tank leachate should be made. A comprehensive data base of these direct measurements is rare for most studies and does not exist for this study. A direct calculation of the nutrient loading, therefore, cannot be developed. Instead, a "theoretical loading" was derived using the available literature values for contributions from nonpoint sources, precipitation, and septic tank leachate.

Numerous methods have been reported by various researchers (Dillon and Rigler 1975; Dillon and Kirchner 1975; Omernik 1977; and USEPA 1980b) for estimating the nutrient export rates from watersheds (Figure 3-6). In the Indian Lake-Sister Lakes study area, nutrient export coefficients from USEPA (1980b) were used for nonpoint source inputs. The export rates associated with the different land use/cover types used in this analysis appear in Table 3-9. The phosphorus loadings from nonpoint sources are given in Table 3-10. Land use/cover type acreage in each of the seven study area watersheds is presented in Section 3.2.2.2, Table 3-27.

Nutrient contributions to the lakes from direct precipitation (Table 3-10) were estimated using 0.13 kilograms (kg) of total phosphorus per acre of lake surface per year (USEPA 1980b).

Several different estimates of phosphorus loads in septic tank leachate have been reported: 0.8 kilograms per capita per year (kg/cap/yr) (Dillon and Rigler 1975); 1.5 kg/cap/yr (Richardson 1974); and 0.8 kg/cap/yr (NES 1974). For consistency, the NES value of 0.8 kg/cap/yr was utilized as a baseline concentration. A soil retention coefficient of 88% was used to estimate the percent of phosphorus removed by soil which is within a range used by USEPA (1980b) and Jones and Lee (1977). Therefore, the value of 0.1 kg/cap/yr was used to calculate the phosphorus contributions from septic tanks to lake waters. The nutrient loadings from septic systems and other sources are presented in Table 3-10. As indicated, the nonpoint sources contribute a significant amount of phosphorus to all the lakes.

The sources of nutrient inputs to the lakes are dependent upon the predominant land use/cover type of the watersheds. Dewey Lake, Indian Lake, and

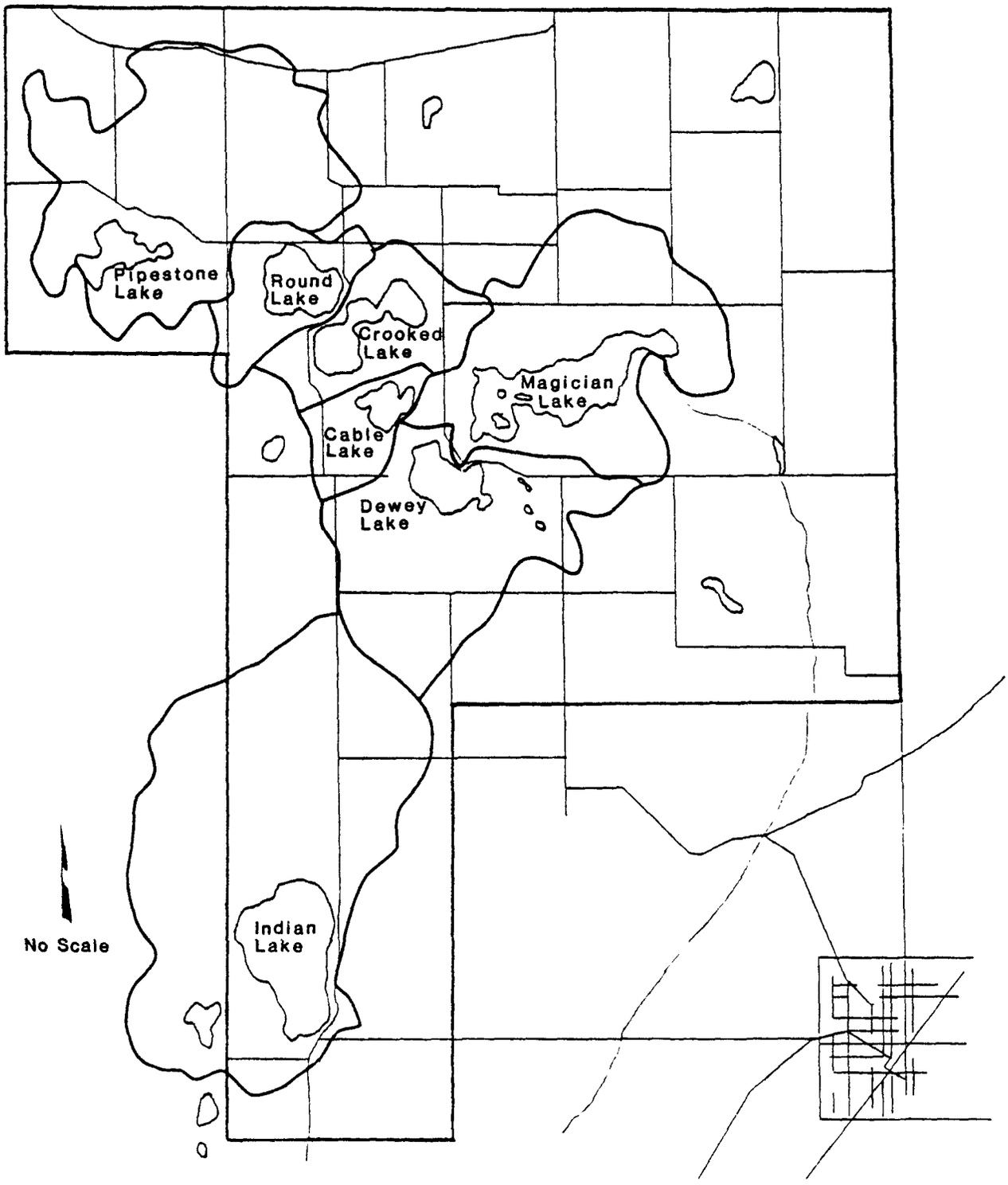


Figure 3-6. Surface watersheds in the study area.

Table 3-9. Mean nutrient export from nonpoint sources by land use/cover type (USEPA 1980b).

Land Use/Cover Type	Total Phosphorus (Kg/acre/yr)
Agricultural	0.26
Residential	0.14
Commercial	0.81
Industrial	0.30
Recreational areas	0.08
Forest	0.11
Wetland	0.06

Table 3-10. Total phosphorus inputs by source.

Lake	Phosphorus (kg/yr) Nonpoint Source (Land Cover)	Septic System	Precipitation	Total
Cable	59.4	29.0	9.9	98.3
Crooked	96.2	103.0	29.5	228.7
Dewey	392.7	52.0	28.5	473.2
Indian	659.6	122.0	65.9	847.4
Magician	410.3	160.0	58.6	628.9
Pipestone	493.4	19.0	16.5	528.9
Round	112.6	52.0	25.1	189.7

Pipestone Lake watersheds had the highest percentages of phosphorus inputs from nonpoint sources, and a significant percentage of each watershed was used for agricultural purposes. The Crooked Lake watershed, with the highest percentage of residential land, had the highest percentage of phosphorus loadings from septic tank leachate.

The nonpoint source load to the lakes does not differentiate the load contributed by surface runoff and groundwater. Indian Lake and the Sister Lakes are primarily seepage lakes and do not have any major tributary inlets or stream linkages between lakes. The lakes are fed primarily by groundwater

recharge. Water balance estimates and well water chemical analysis for Pipestone Lake indicated that groundwater is the major source of phosphorus to the lake (National Biocentric Inc. 1978). Similar water balance data for the other lakes are not available. However, the concentration of total phosphorus in the groundwater surrounding the lakes, except Pipestone Lake, is relatively low.

The amount of phosphorus that actually enters the lake from septic tanks would depend on the ability of drainage field soils to immobilize the phosphorus. When subsurface disposal systems are built on proper soil and are located at proper distances from the receiving water body, there is nearly 100% removal of the phosphorus from septic tank effluent by the soil (Jones and Lee 1977). However, when the distances between the disposal system and lake are limited or when the drainage field has failed, a high proportion of the phosphorus from the system moves into the groundwater or into the lake or river. The value of 0.1 kg/cap/yr used to calculate the load from septic tank effluent that has filtered through the drainfield and transversed the distance through the soil to lake waters. This 0.1 kg/cap/yr value represents about an 88% reduction in phosphorus content of the septic tank leachate by the drainage field soils and other soils between the on-site system and lake.

To better understand the nutrient contribution of septic tanks to the lakes, a comprehensive septic leachate survey of Indian Lake and Sister Lakes shorelines was performed in October 1979 by K-V Associates, Inc. The septic leachate survey included continuous monitoring of sections of the shoreline of all the lakes by a recording leachate instrument (Septic Snooper). Water quality analysis of identified stream or groundwater plumes detected by the septic snooper supplied evidence of domestic wastewater infiltration into the lakes. The October sampling dates should have detected groundwater plumes originating from permanent residences because permanent residences would be continuously contributing sewage to on-site systems. Most seasonal residences would have been vacated by October, and therefore it is probably that some seasonal residences that may have been emitting erupting plumes were not detected at the time of the septic snooper survey. The following conclusions

were drawn from the survey:

- A total of 47 locations exhibited noticeable erupting effluent plume characteristics, specifically occurring on Crooked Lake, Magician Lake, Indian Lake, and Pipestone Lake (Table 3-11). The other (smaller) lakeshores had fewer potential point source problem sites and had water quality influenced by the surrounding land use

- At least 16 of the plumes were associated with stream inlets, with 12 such inlets on Pipestone Lake alone. Plume occurrence was predominantly along northern shores, corresponding quite well with observed groundwater flow intrusion

- Fecal coliform bacterial contamination had not reached a level of major concern with the possible exception of levels found in Pipestone Lake. Of 38 locations sampled around the eight lakes, only one (a drainpipe on Pipestone Lake) exceeded 75 colonies/100 ml of water

- A total of 115 lake samples were analyzed: 84% of the samples showed NO_3 values less than 0.100 ppm and 90% of the samples did not exceed 0.040 ppm of total phosphorus, the maximum being 0.883 ppm

- Consistently high ammonia (greater than 1 ppm - indicating reducing conditions) appeared only on Pipestone Lake. Residential areas showing plume problems and beset with high groundwater included the north shores of Magician and Pipestone Lakes and more elevated areas of the southwestern corner of Magician Lake and the western shore of Indian Lake

- Major pathways of nutrient loading detected by the septic leachate survey appear to come from surface runoff streams rather than groundwater plumes.

Another method of detecting malfunctioning septic systems was conducted by stereoscopic viewing of color aerial photographs taken on 16 May 1979 (USEPA 1979). The detection capability is contingent upon excessive septic tank effluent rising to or near the soil surface. Effluent that does not rise toward the soil surface, but continues to seep laterally or downward through the lower soil horizon, is not detectable. The detection of a malfunctioning on-lot septic system by remote sensing is supplemented by a ground survey. The aerial survey of May 1979 identified 97 on-lot septic systems with indications of a potential malfunction. Of the 97 septic systems identified, 51 systems were located within 100 meters of the lakeshore (Table 3-11), with the majority of the sites found around Magician Lake. A field inspection to verify the suspicious on-lot septic system was made in August 1979. A random

Table 3-11. Septic leachate and septic system aerial surveys.

Lake	No. of Active Wastewater Plumes[a] Groundwater Plume	Stream Source Plume	Potentially Malfunctioning[b] Septic Systems
Dewey Lake	0	0	4
Cable Lake	0	0	1
Magician Lake	17	3	26
Pipestone Lake	1	12	4
Indian Lake	7	1	11
Crooked Lake	5	1	4
Round Lake	1	0	1

[a] Septic leachate survey (K-V Associates, Inc. 1980).

[b] Aerial survey Indian Lake-Sister Lakes region (USEPA 1979c); Table includes only those sites within 100 meters of the lakeshore.

review of 25 systems revealed that two septic systems were failing and fifteen systems would require further testing and monitoring.

In conclusion, the different phosphorus loads to Indian Lake and the Sister Lakes is an important factor affecting the water quality of the lakes. A general lake model which predicts the current phosphorus loading rate as well as the expected changes that may occur with implementation of the various wastewater alternatives is given in Section 4.1.2.3.

3.1.4. Aquatic Biota

3.1.4.1. Phytoplankton

Information on phytoplankton for the lakes in the study area is discussed in Section 3.1.5.2.1. Appendix I contains summary tables of the species lists and densities.

3.1.4.2. Mollusks

No data are available on the mollusk populations of the Indian Lake-Sister Lakes study area. However, the naiad mollusks (Class Pelecypoda) normally inhabit moving waters (rivers and streams), and generally would not be expected to occur in the lakes. A few species could inhabit the shallow water in some of the lakes. Freshwater snails (Class Gastropoda) would be expected to inhabit the lakes. Endangered and threatened species of Mollusks in Michigan are shown in Table 3-12.

Table 3-12. Species of mollusks designated by the State of Michigan as endangered and threatened (MDNR 1980). T indicates threatened and E indicates endangered.

Scientific Name	Status
Actinonaias ellipsiformis	T
Anodonta subgibbosa	T
Anguispira kochi	T
Cyclonias tuberculata	T
Discus patulus	T
Dysnomia triquetra	T
Elliptio complanatus	T
Haplotrema concavum	T
Lampsilis fasciola	T
Lymnaea megasoma	T
Mesodon elevata	T
Mesodon Sayana	T
Mesomphix cupreus	T
Obovaria leibii	E
Fontigens (= *Paludestrina*) *nickliniana*	T
Pleurobema clava	T
Pomatiopsis cincinnatiensis	T
Simpsoniconcha ambigua	E
Triodopsis denotata	T
Zoogenetes harpa	T

One other mollusk, the white cat's eye (*Epioblasma sulcata delicata*), is listed in the 19 January 1979 *Federal Register* as endangered in Michigan, Ohio, and Indiana. However, this record is not recognized by the MDNR.

3.1.4.3. Fisheries

Warm water lakes are typically shallow and do not become stratified. All of the lakes in the study area are classified as warm water lakes capable of support fish such as sunfish (By telephone, Mr. Don Reynolds, MDNR, Fisheries Division, to WAPORA, Inc., 18 May 1979). No species of fish that have been designated by the State of Michigan as endangered or threatened are known to occur in the Indian Lake-Sister Lakes study area (Table 3-13).

Table 3-13. Species of fish designated by the State of Michigan as endangered and threatened (MDNR 1980). T indicates threatened and E indicates endangered.

Scientific Name	Common Name	Status
Acipenser fulvescens	Lake sturgeon	T
Ammocrypta pellucida	Eastern sand darter	T
Clinostomus elongatus	Redside dace	T
Coregonus alpenae	Longjaw cisco	E
Coregonus artedii	Cisco	T
Coregonus hoyi	Bloater	T
Coregonus johannae	Deepwater cisco	E
Coregonus kiyi	Kiyi	T
Coregonus nigripinnis	Blackfin cisco	E
Coregonus reighardi	Shortnose cisco	E
Coregonus zenithicus	Shortjaw cisco	E
Moxostoma carinatum	River redhorse	T
Notropis photogenis	Silver shiner	T
Noturus stigmosus	Northern madtom	T
Stizostedion vitreum glaucum	Blue pike	E

The general characteristics of of the seven lakes and the species of fish recorded in each lake are discussed briefly below.

Cable Lake

This small lake has a total surface area of 91.2 acres (36.9 hectares). The maximum depth is 41 feet (12.5 meters), but 20% of the lake is less than 10 feet (3 meters) in depth. At the time of the last MDNR survey in 1941, the predominant species of fish were bluegill, perch, and largemouth bass.

Crooked Lake

This lake has a maximum depth of 62 feet (18.8 meters) and a total surface area of 226.8 acres (92 hectares). The bottom material is composed of organic debris and sand. During the last MDNR survey, conducted in 1965, the predominant species of fish were yellow perch, bluegill, crappie, largemouth bass, pumpkinseed, mud pickerel, bullhead, and sucker.

Dewey Lake

This lake has a total surface area of 189.4 acres (77 hectares) and a maximum depth of 45 feet (13.7 meters). Ten percent of the lake is less than 6 feet (1.8 meters) deep, 80% ranges from 6 feet to 40 feet (12.2 meters), and 10% is greater than 40 feet deep. At the time of the last MDNR survey in 1963 the predominant species of fish were crappie, pumpkinseed, largemouth bass, smallmouth bass, and various rough fish.

Indian Lake

Indian Lake has a total surface area of 481.5 acres (195 hectares) and a maximum depth of 35 feet (10.6 meters). Eighty percent of the lake is deeper than 6 feet (1.8 meters). At the time of the last MDNR survey in 1964, the predominant species of fish were bluegill, pumpkinseed, black crappie, largemouth bass, bullhead, northern pike, and carp.

Magician Lake

This lake has a total surface area of 468.7 acres (190 hectares) and a maximum depth of 60 feet (18.2 meters). Ten percent of the lake is less than 6 feet (1.8 meters) deep, 80% ranges from 6 feet to 40 feet (12.2 meters), and 10% is deeper than 40 feet. At the time of the last MDNR survey in 1963, the predominant species of fish were crappie, pumpkinseed, largemouth bass, smallmouth bass, and various rough fish.

Pipestone Lake

This lake has a total surface area of 106.0 acres (43 hectares) and a maximum depth of 30 feet (9.1 meters). The diversity of fish species is high in this lake because it is connected to the St. Joseph River by Pipestone

Creek. The predominant species of fish were bluegill, pumpkinseed, crappie, yellow perch, and largemouth bass. Other species present included carp, chubsucker, warmouth, bullhead, lake chubsucker, spotted sucker, white sucker, alewife, gizzard shad, chinook salmon, and coho salmon.

Round Lake

Round Lake has a total surface area of 198.7 acres (80 hectares) and a maximum depth of 35 feet (10.6 meters); 40% of the lake is less than 6 feet (1.8 meters) in depth and the remaining 60% ranges from 6 feet to 35 feet in depth. In 1971, Round Lake was chemically treated to kill sunfish and rough fish and was restocked with hybrid sunfish, rainbow trout, largemouth bass, and tiger muskie. The most recent fish survey by the MDNR (1977) indicated that the predominant species of fish were bluegill, tiger muskie, and largemouth bass.

3.1.5. Terrestrial Biota

3.1.5.1. Amphibians and Reptiles

There are 41 species of amphibians and reptiles with ranges that include the study area, including 8 species of turtles, 12 species of snakes and skinks, 9 species of salamanders, and 11 species of toads and frogs (Conant 1975). Three species of amphibians and 5 species of reptiles have been designated as endangered or threatened by the State of Michigan (MDNR 1980) (Table 3-14). Three of these species, the marbled salamander, the black rat snake, and the eastern box turtle have distribution ranges that include the study area. No data are available specifically for the study area which documents the presence and/or absence of any of these species. Habitat preference for each threatened species is given in Table 3-14. These are generalized habitat types and not intended to be exclusive for any one species.

3.1.5.2. Birds

The diverse habitats that occur within the study area support many species of birds and make it a prime waterfowl site. The study area lies within the migration routes of several species of waterfowl. Mallards, Blue-winged

Table 3-14. Species of amphibians and reptiles designated as threatened or endangered by the State of Michigan that have ranges that include Berrien County, Cass County, and Van Buren County (MDNR 1980). Habitat key: F = Forest; S = Marsh, Swamp, Bog; O = Open or Grassland; A = Aquatic; R = Rocky Terrain. Status key: T = Threatened; E = Endangered.

Scientific Name	Common Name	Habitat	Status
Ambystoma opacum	Marbled salamander	F,S	T
Ambystoma texanum	Small-mouthed salamander	F,O,R	T
Siren intermedia nettingi	Western lesser siren	A	T
Elaphe obsoleta obsoleta	Black rat snake	R	T
Nerodia erythrogaster neglecta	Northern copperbelly	S, A	T
Clonophis kirtlandi	Kirtland's water snake	A, R	E
Terrapene carolina carolina	Eastern box turtle	F	T

Teal, and Wood-ducks inhabit a waterfowl concentration area in northeastern Van Buren County during the summer months.

A total of 109 species of grassland birds, woodland birds and waterfowl have been recorded in Cass County (Gove Associates, Inc. 1977). This list does not include a large number of migratory waterfowl, shorebirds, warblers, and other species which include Cass County in their migratory range.

Twelve species of birds are considered by the State of Michigan to be endangered or threatened (Table 3-15). Several of the species listed, including the Peregrine Falcon, the Bald Eagle, and Kirtland's Warbler, may utilize the study area, but sufficient data are not available to document their presence. Habitat preference is given for each species listed in Table 3-15. Again, these are generalized and represent habitats most used by these species.

3.1.5.3. Mammals

Within the Great Lakes Region, transitions occur between the boreal forest, the southern coastal plain, and the western grassland zones. This diversity of major vegetation zones, and the abundance of lakes have significantly influenced the number and distribution of mammals in this region.

Table 3-15. Species of birds designated by the State of Michigan as endangered and threatened (MDNR 1980). T indicates threatened and E indicates endangered. Habitat key: F = Forest; W = Near Water; O = Open or Grassland; C = Coniferous Forest.

Scientific Name	Common Name	Status	Habitat
Accipiter cooperi	Cooper's Hawk	T	F
Buteo lineatus	Red-shouldered Hawk	T	F
Charadrius melodus	Piping Plover	T	W
Circus cyaneus	Marsh Hawk	T	O
Dendroica kirtlandii	Kirtland's Warbler	E	C
Falco peregrinus	Peregrine Falcon	E	O
Haliaeetus leucocephalus	Bald Eagle	T	W,O-F
Lanius ludovicianus	Loggerhead Shrike	T	O
Pandion haliaetus	Osprey	T	W
Phalacrocorax auritus	Double-crested Cormorant	E	W
Tympanuchus cupido	Greater Prairie Chicken	T	O
Tyto alba	Barn Owl	T	O

Seventy-eight species of mammals are known to occur in the Great Lakes Region. Of these, 61 species have been recorded in the State of Michigan (Burt 1957). Approximately 42 species of mammals have ranges that include Berrien County, Cass County, and Van Buren County (Cooley 1979).

Mammal populations within the study area have changed considerably since the area was settled and developed. The eastern timber wolf, the black bear, and the elk, once native to the area, have disappeared from southwestern Michigan while other native species of mammals have increased. Non-native species such as the Norway rat, the house mouse, and the European hare have been introduced by man. Specific information on the abundance and distribution of mammals in the study area is not available (By telephone, Mr. Marvin Cooley, MDNR to WAPORA, Inc., 12 November 1981).

The State of Michigan has identified 5 species of mammals known to inhabit the State as endangered or threatened species (Table 3-16). Of these species, the Indiana bat, the pygmy shrew, and the southern bog lemming, have ranges that encompass the study area. Data indicating the presence or absence

Table 3-16. Species of mammals designated by the State of Michigan as endangered and threatened (MDNR 1980) T indicates threatened and E indicates endangered. Habitat key: F = Forest; O = Open or Grassland; C = Coniferous Forest; (E) = Edge; Ca = Cave; W = Near Water.

Scientific Name	Common Name	Status	Habitat
Canis lupus	Gray wolf	E	F
Martes americana	Pine marten	T	C
Microsorex boyi thompsoni	Pygmy shrew	T	F, O
Myotis sodalis	Indiana bat	E	Ca, W
Synaptomys cooperi	Southern bog lemming	T	O

of endangered or threatened species within the study area are not available. The habitat type in which each listed species is most likely to be found is indicated on Table 3-16.

3.1.5.4. Vegetation

The presettlement vegetation of Berrien, Cass and Van Buren counties included beech-maple and oak-hickory forests (Braun 1950; Kenoyer 1930). Outliers of prairie also were present in the three counties (Transeau 1936). These prairies consisted of large grasses, such as big bluestem, little bluestem, and Indian grass, plus various forbs such as prairie white indigo and compass plant (Veatch 1928). Wet prairie sites with alkaline water sources, known as fens, supported an unusual and diverse flora that was distinct from the flora present in drier prairie sites.

A total of 38 species of plants (mostly native herbaceous) are listed as endangered or threatened in Berrien County (Appendix J, Table J-1). Six of these are designated as endangered or threatened at the federal level (Ayensu and De Filipps 1978). These include white lady's-slipper, prairie fringed orchid, smaller whorled pogonia, Pitcher's thistle, and rosinweed. The small whorled pogonia is the rarest orchid in the United States.

A total of 25 species of plants (mostly native herbaceous) are listed as endangered, threatened, or rare in Cass County (Appendix J, Table J-2). Of

these, two threatened and one endangered species also are included on the federal list: the tubercled orchid, ginseng, and rosinweed (Ayensu and De Filipps 1978).

In Van Buren County, 26 species of plants (mostly native herbaceous) are classified as endangered or threatened (Appendix J, Table J-3). Included in this total are three threatened and one endangered species that are on the federal list: the tubercled orchid, gingseng, Pitcher's thistle, and rosinweed (Ayensu and De Fillips 1978).

The location of these species, if known, are kept on file by the Endangered Species Coordinator for the State of Michigan. All plants regarded as endangered, threatened, or rare are included in a computer list that is organized by county (Beaman unpublished). This information can be used only by authorized personnel who agree to not release information on the site-specific locations of any species.

3.1.6. Wetlands

Wetlands can be defined in general terms as "lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface" (Cowardin and others 1979). Such lands comprise 7% of the four-township area (Section 3.2.2.2.2, Table 3-26). The majority of the wetlands are located in Keeler and Silver Creek Townships.

Wetlands in the study area were mapped at a scale of 1:36,000 by the USEPA, Environmental Monitoring System Laboratory on the basis of aerial photographs taken in May and July 1979 (USEPA 1979c). These photographs were used to update a 1978 land use/land cover survey prepared by the Southwestern Michigan Regional Planning Commission (SMRPC 1978a). Three types of wetlands were identified:

- Wooded swamp
  This includes wetlands dominated by trees. The soil surface is seasonally flooded with up to one foot of water. Several levels of vegetation usually are present, including trees, shrubs, and herbaceous plants. Broad-leaved swamps, coniferous swamps, and wooded bogs are categorized as forest land rather than wetlands in this scheme

- Shrub Swamp
  This class applies to wetlands dominated by shrubs where the soil surface is seasonally or permanently flooded with as much as twelve inches of water. Characteristic emergent plants providing cover beneath the shrubs are the sedge and sensitive fern. Meadow or marsh emergents occupy open areas. Willow-buttonbush associations are those aquatic shrub swamps with greater than 50% shrub cover and average water depth of less than six inches

- Non-Forested (Non-Wooded) Wetlands (Marsh)
  Nonforested wetlands are dominated by wetland herbaceous vegetation. These wetlands include inland nontidal fresh marshes, freshwater meadows, wet prairies, and open bogs. Both narrow-leaved emergents such as cattail, bulrush, sedges, and other grasses, and broad-leaved emergents such as water lily, pickerelweed, arrow arum, and arrowhead typically are found in fresh water locations. Mosses and sedges grow in wet meadows and bogs.

These definitions are consistent with the State of Michigan's land use/land cover classification system.

Most of the wetland areas mapped by the USEPA are located in the northern half of the study area. Many small wooded and scrub swamps are located between Magician Lake and Keeler Lake. Large areas of wood swamps also are located along the shores of Cable and Dewey Lakes and in Bainbridge Township, north of Pipestone Lake.

Marshes are scattered throughout the study area. Larger marshes are found along the northern boundary of the study area. Other marshes are located along drains and creeks and adjacent to the lakes.

3.2. Man-made Environment

3.2.1. Demography

3.2.1.1. Historic and Current Population

Historic and current population trends were analyzed for the four townships (Bainbridge, Keeler, Pokagon, and Silver Creek) and three counties (Berrien, Cass, and Van Buren) in which the study area is located. The townships are the smallest geographic units for which comprehensive demographic data are available. Approximately 25% of the permanent population of the four townships resided in the service area in 1980.

Each of the four townships has experienced continuous permanent population growth since 1950 (Table 3-17). The four townships combined percentage increase in population during the 30-year period from 1950 to 1980 was 63.4%. The percentage increase in population during the same period for the three counties and the State was 57.1% and 45.3%, respectively. The four-township area has experienced more rapid growth since 1950 than the surrounding area and the state (Table 3-17). The more rapid rate of growth probably can be attributed to tourism and recreation-related development, although this industry has not experienced growth in recent years.

Table 3-17. Population growth in the four-township area, three-county area, and in Michigan between 1950 and 1980 (US Bureau of the Census 1952, 1963, 1973, 1982).

Township	1950	1960	1970	1980	Percent Change 1950-1980
Bainbridge	2,194	2,503	2,784	2,879	31.2%
Keeler	1,414	2,109	2,234	2,638	86.6
Pokagon	1,518	1,935	2,189	2,394	57.7
Silver Creek	1,773	2,108	2,886	3,361	89.6
Total	6,899	8,655	10,093	11,272	63.4
County					
Cass	28,185	36,932	43,312	49,499	75.6%
Van Buren	39,184	48,395	56,173	66,814	70.5
Berrien	115,702	149,865	163,940	171,276	48.0
Total	183,071	235,192	263,425	287,589	57.1
Michigan	6,371,766	7,823,194	8,881,826	9,258,344	45.3

Growth rates for the four townships varied considerably during the 30-year period. The increases ranged from a low of 31.2% in Bainbridge Township to 89.6% in Silver Creek Township. The rapid growth in Silver Creek Township also is noteworthy because of the high proportion of township residents who live in the study area.

From 1970 to 1980 the population of the four townships increased by 1,179 (US Bureau of the Census 1982). Keeler Township recorded the highest rate of increase, 18.1%, but Silver Creek Township, which includes a considerable amount of development around the Sister Lakes, also recorded a high growth

rate (16.5%). Population data for the four-township area from 1970 to 1980 are summarized in Table 3-18.

Table 3-18. Population growth in the four-township area, 1970 to 1980 (US Bureau of the Census 1973, 1982).

Township	1970	1980	Population Change 1970 - 1980 No.	Percent
Bainbridge	2,784	2,879	95	3.4%
Keeler	2,234	2,638	404	18.1
Pokagon	2,189	2,394	205	9.4
Silver Creek	2,886	3,361	475	16.5
Total	10,093	11,272	1,179	11.7

Although the rate of growth in the four-township area generally exceeded the rate of growth in the three-county area and in the state, the growth rates have declined over time. Peak population growth rates occurred, in all three situations, during the 1950s (Table 3-19). The four-township area grew by 25.5% from 1950 to 1960. This rate of increase declined in the last decade to 11.7%. In addition, Bainbridge Township grew at a slower rate from 1970 to 1980, 3.4%, than did the State (4.2%).

In spite of the low rate of growth in Bainbridge Township, the overall growth rate in the four-township area from 1970 to 1980 exceeded the growth rate of the three-county area and the State of Michigan. This more rapid growth parallels trends in rural, non-metropolitan areas nationwide. It also may reflect the area's economic links to non-manufacturing industries, which were more stable during the 1970s than manufacturing industries were.

Table 3-19. Population growth rates in the four-township area, three-county area, and in Michigan between 1950 and 1980 (US Bureau of the Census 1952, 1963, 1973, 1982).

Township	1950-1960	1960-1970	1970-1980	1950-1980
Bainbridge	14.1%	11.2%	3.4%	31.2%
Keeler	49.2	5.9	18.1	86.6
Pokagon	27.5	13.1	9.4	57.7
Silver Creek	18.9	36.9	16.5	89.6
Four Township Area	25.5	16.6	11.7	63.4
County				
Cass	31.0	17.3	14.3	75.6
Van Buren	23.5	16.1	18.9	70.5
Berrien	29.5	9.4	4.5	48.0
Three-County Area	28.5	12.0	9.2	57.1
Michigan	22.8	13.5	4.2	45.3

3.2.1.2. Service Area Population Estimates

Gove Associates, Inc. developed service area populations based on a house count and the 1970 average household size for the four-township area. Seasonal and permanent population estimates were developed from estimates by local officials and area residents. In 1979, Gove Associates, Inc. prepared an updated house count based on revised land use maps (Gove Associates, Inc. 1980). Seasonal and permanent residence identification was based on the address of the landowner in the tax records.

Subsequent to that count it was recognized that numerous problems were encountered in differentiating between residences and outbuildings. Also, numerous seasonal residences were noted as being permanent residences. In 1979, WAPORA counted dwelling units from updated maps but, in this count, a larger area than that designated as the service area was included. In 1981, WAPORA completed another count of the dwelling units within the designated service area using final inspection records for septic systems and partial

field checks of the maps. The identification of seasonal and permanent residences was made from addresses on the 1978 tax rolls and on interviews for the major leaseholds and resorts. Because the 1977 and 1978 tax rolls were used, the 1981 permanent population probably is underestimated.

A comparison of the results of these house counts is presented in Table 3-20. The major discrepancy between the Gove and WAPORA counts occurs for Pipestone Lake. These dwelling units were counted from aerial photographs and problems in distinguishing residences and outbuildings were encountered.

Gove Associates identified on the eligibility maps the residences constructed after 1972 with information from building permit records. WAPORA made some corrections to this count based on septic tank installation records. The numbers of new dwelling units are given in Table 3-21. According to the septic tank records examined, the number of residences constructed from 1972 to 1977 may have been underestimated in the Facility Plan by approximately 40 residences. A large number of building permits for residences were granted in 1972 prior to the October cutoff date for grant eligibility determination. These residences may have been constructed and inhabited in subsequent years; thus, the final inspection dates on the septic tank records would indicate the later habitation. These data show that fewer new dwelling units on undeveloped lots are being constructed than during the middle of the decade. Most of the new dwellings are probably permanent residences although the addresses of the owners show more seasonal than permanent residences. The owner's address may reflect his former address rather than his present one.

In order to calculate service area populations, Gove Associates used the 1970 average household size (3.24 persons per dwelling unit) for the four-township area for both permanent and seasonal dwellings. An evaluation of 1980 Census data indicated that this household size factor is high for permanent residences. According to the 1980 census (By telephone, US Bureau of the Census, to WAPORA, Inc., 16 November 1981) the average household sizes for permanent households in the four townships are:

Silver Creek - 2.77	Keeler - 2.97
Bainbridge - 2.86	Pokagon - 3.04

Table 3-20. Comparison of counts of residential dwelling units within the Indian Lake-Sister Lakes service areas by Gove Associates, Inc. (1978a, 1980) and WAPORA, Inc. (1979, 1981).

Service Area	Gove 1977	Gove 1979	WAPORA 1979[a]	WAPORA 1981
Indian Lake				
Permanent	332	298	221	203
Seasonal	221	200	299	338
% Seasonal	40	40	57	62
Total	553	498	520	541
Pipestone Lake				
Permanent	45	87	65	42
Seasonal	30	16	22	26
% seasonal	40	16	25	38
Total	75	103	87	68
Sister Lakes				
Permanent	949	958	816	746
Seasonal	949	872	1,064	1,180
% seasonal	50	48	57	61
Total	1,898	1,830	1,880	1,926
Total				
Permanent	1,326	1,343	1,102	991
Seasonal	1,200	1,098	1,385	1,544
% seasonal	47	45	56	61
Total	2,526	2,431	2,487	2,535

[a] Includes some dwelling units outside the service area.

Table 3-21. Number of new residences constructed on undeveloped lots in the Indian Lake-Sister Lakes service areas.

Service Area	1972-1977	1977-1980	1972-1980
Indian Lake			
Permanent	28	3	31
Seasonal	11	3	14
Total	39	6	45
Pipestone Lake			
Permanent	1	0	1
Seasonal	1	0	1
Total	2	0	2
Sister Lakes			
Permanent	48	14	62
Seasonal	68	15	83
Total	116	29	145
Total Service Area			
Permanent	77	17	94
Seasonal	80	18	98
Total	157	35	192
Average per year	31	12	24

Determining the average household size for seasonal residences is more problematic. No conclusive data are available for this area and no generic factors have been developed. Also, the average seasonal use probably differs significantly from the peak one-day seasonal use. For lack of a well-defined rate, the factor proposed is 3.5 persons per dwelling unit. This factor may be low in accounting for the one-day peak, but high for the seasonal average.

The 1980 population estimates for the service areas were calculated from the house count from maps prepared by Gove Associates and updated by WAPORA in 1981. Two methods were employed to calculate current population. One used the permanent and seasonal determination based on addresses of owners and the other used the seasonal and permanent percentages recommended by the planning directors, township supervisors, and realtors. The 1980 service area populations were then calculated based on the household size factors noted above (Table 3-22).

Table 3-22. Housing units and population by service area and township, 1980.

	Determined by Address of Owners						Determined by Recommended Percentages[a]					
	Permanent		Seasonal		Total		Total		Permanent		Seasonal	
	Housing Units	Population	Housing Units	Population	Housing Units	Population	Housing Units	Population	Housing Units	Population	Housing Units	Population
Service Area												
Indian Lake												
Pokagon Twp.	7	21	12	42	19	63	19	61	11	33	8	28
Silver Creek Twp.	196	543	326	1,141	522	1,684	522	1,599	313	867	209	732
Total	203	564	338	1,183	541	1,747	541	1,660	324	900	217	760
Sister Lakes												
Bainbridge Twp.	42	120	26	91	68	211	68	212	41	117	27	95
Keeler Twp.	363	1,078	551	1,929	914	3,007	914	2,957	457	1,357	457	1,600
Silver Creek Twp.	384	1,064	630	2,205	1,014	3,269	1,404	3,179	507	1,404	507	1,775
Total	789	2,262	1,207	4,225	1,996	6,487	1,996	6,348	1,005	2,878	991	3,469
Combined Total	992	2,826	1,545	5,408	2,537	8,234	2,537	8,008	1,329	3,778	1,208	4,228

[a] Indian Lake service area - 40% seasonal; Sister Lakes service area: Bainbridge Township - 40% seasonal, Keeler and Silver Creek Townships - 50% seasonal.

It should be noted, that while there has been virtually no new building activity around any of the lakes in the last few years, the conversion of seasonal homes to permanent dwellings continues. It is not possible to calculate the number of conversions being made, or in which areas, but it can be theorized that as the proportion of permanent to seasonal homes increases, the wide range in the population from summer to winter will diminish. Again, there are no conclusive data available to verify or quantify these apparent trends. In the absence of such data, it is felt that the opinions of local residents and businessmen accurately depict the situation.

3.2.1.3. Population Projections

SMRPC developed permanent population projections in 1978 for the four townships for 1985, 1990 and 2000 (Table 2-23 and Figure 3-7). The SMRPC will not revise these population projections until more complete census data are available.

Table 3-23. Population projections, anticipated growth rates, and 1980 Bureau of the Census population by township (SMRPC 1978a; US Bureau of the Census 1982).

Township	1980 Census Population	SMRPC Projections 1985	1990	2000	Anticipated Growth Rate 1970 - 2000
Bainbridge	2,879	2,650	2,600	2,500	-10.2%
Keeler	2,638	2,708	2,884	3,200	43.2%
Pokagon	2,394	2,440	2,552	2,731	24.8%
Silver Creek	3,361	3,228	3,363	3,601	24.8%

The expected population decline in Bainbridge Township is related to its distance from urban centers and lack of recreational facilities. Growth in the three other townships is occurring more rapidly than expected. SMRPC projected a 1985 population for Silver Creek Township of 3,228; The 1980 population reported by the US Census however, exceeded the 1985 projection. In Keeler and Pokagon Townships, current growth trends also indicate that the projections are probably somewhat low.

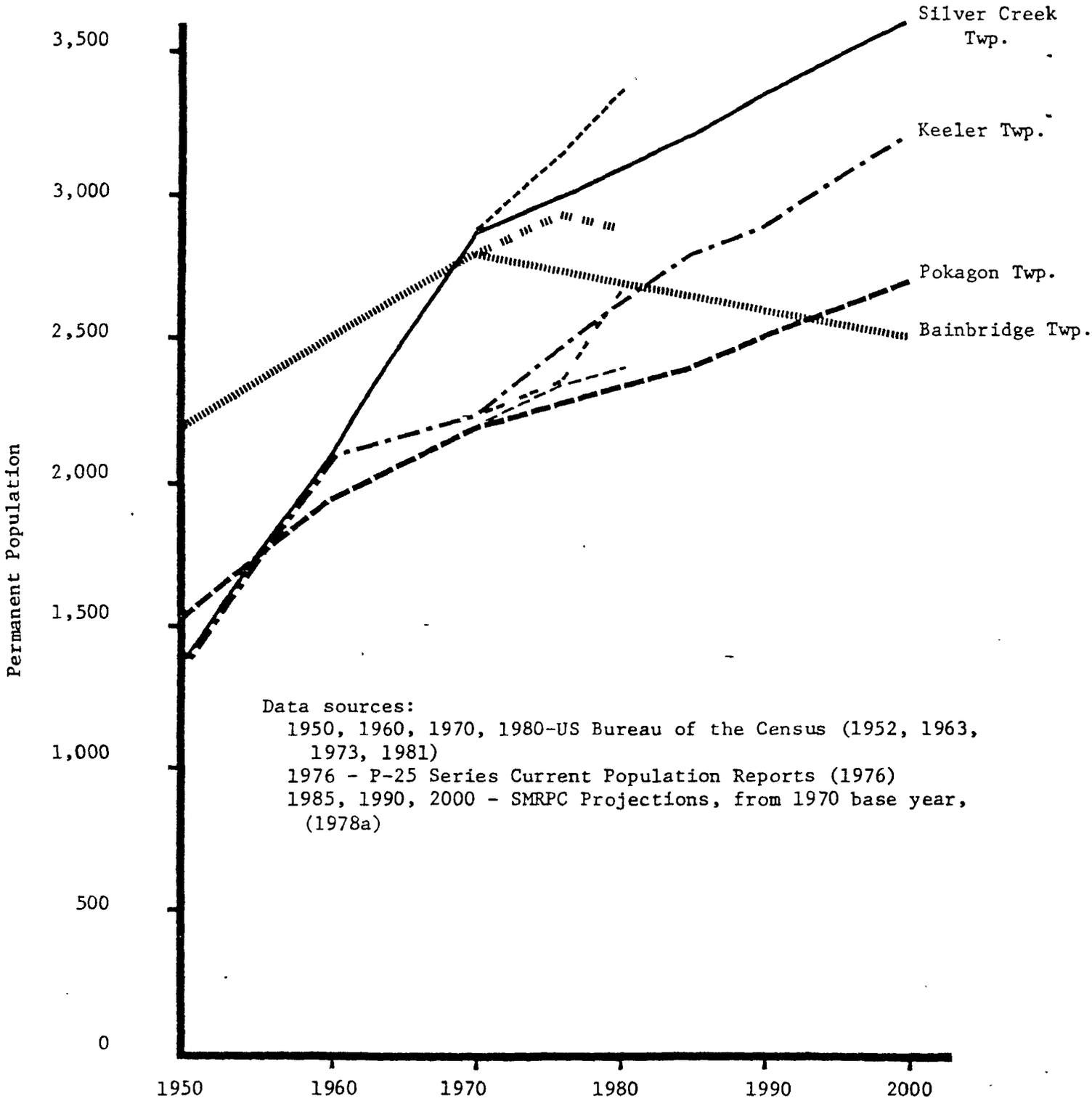


Figure 3-7. Population growth, historic and projected, for the four-township area.

The permanent population projections for the service areas (Table 3-24) were calculated from the population growth rates (Table 3-23) and the 1980 populations (Table 3-22). The 1980 populations that were calculated from the house count and the recommended percentages for permanent populations were used in developing the population projections because locally recommended percentages would be more acceptable in the area. Although the 1980 census data indicate that township projected growth rates were exceeded in the past decade, there has been a considerable slackening in building activity. Within these townships, much of the increase in permanent population also may be occurring outside the service areas.

Table 3-24. Service area permanent population projections for 1985, 1990, and 2000, and estimated 1980 permanent populations.

	1980	1985	1990	2000
Indian Lake Service Area				
Pokagon Township	33	34	36	38
Silver Creek Township	867	894	931	993
Totals	900	928	967	1,031
Sister Lakes Service Area				
Bainbridge Township	117	117	117	117
Keeler Township	1,357	1,438	1,529	1,691
Silver Creek Township	1,404	1,452	1,508	1,607
Totals	2,878	3,007	3,154	3,415
Combined Total	3,778	3,935	4,121	4,446

Four methods were developed for projecting seasonal population, each based on a different assumption. Method 1 assumed that the ratio of seasonal residents to permanent residents would remain constant (i.e., that both components would grow at the same rate). Method 2 assumed that the rate of seasonal population growth would be only half that of the permanent population growth. In Method 3 the seasonal population was held constant for the projection period (1980-2000). Method 4 was based on the assumption by Gove Associates, Inc. (1977) that the seasonal population, taken to mean residences, as a percentage of the total population, would decline by 50% by the year 2000. The results of these four methods were combined with the permanent population projections and are presented in Table 3-25.

Table 3-25. Service area total population (permanent and seasonal), based on four methods for forecasting seasonal population.

Service Area	1980	1985				1990				2000			
		Method 1	Method 2	Method 3	Method 4	Method 1	Method 2	Method 3	Method 4	Method 1	Method 2	Method 3	Method 4
Indian Lake													
Pokagon Twp.	57	58	58	58	51	60	60	59	49	64	63	61	44
Silver Creek Twp.	1,565	1,625	1,611	1,595	1,478	1,683	1,656	1,628	1,401	1,804	1,740	1,692	1,276
Total	1,622	1,682	1,669	1,655	1,529	1,742	1,716	1,687	1,450	1,866	1,803	1,753	1,320
Sister Lakes													
Bainbridge Twp.	204	204	204	204	204	204	204	204	204	204	204	204	204
Keeler Twp.	2,816	2,994	2,943	2,893	2,616	3,170	3,070	2,969	2,449	3,525	3,324	3,122	2,190
Silver Creek Twp.	3,124	3,242	3,209	3,175	2,832	3,363	3,276	3,227	2,598	3,599	3,464	3,329	2,236
Total	6,142	6,440	6,356	6,272	5,652	6,737	6,550	6,400	5,251	7,328	6,992	6,654	4,630
Combined Total	7,763	8,122	8,025	7,927	7,181	8,479	8,266	8,087	6,701	9,194	8,795	8,406	5,950

Methods 1 and 2 produced final projections that exceed the assimilative capacity of the service area, based on the limited amounts of undeveloped lakeshore, current zoning restrictions and development controls, and recent declines in tourism. Method 4 yielded a projection that appeared to be unrealistically low; it forecasted a seasonal population loss so substantial that it was not offset by gains in the permanent population. Method 3 provided the most reasonable projections, indicating a constant seasonal population with an equilibrium between growth in the seasonal housing stock and the conversion of existing seasonal units to permanent homes. If the occupancy rates continue to remain the same, approximately 220 new dwelling units would be required to house the expanding population. By comparison, septic tank installation records indicate that about 220 residences were constructed in the 1970s.

3.2.2. Land Use

3.2.2.1. Local Land Use Trends

The four-township area extends over 88,721 acres of land. Agriculture is the predominant land use/cover type in the four-township area. Cultivated cropland, pastureland, orchards, bushfruits, vineyards, nurseries, and confined feed lots comprise approximately 66% of the total acreage in the four townships. Fruit production is an important facet of the local agricultural economy. The moderating effect of Lake Michigan on the climate produces a favorable growing season and a temperature range well suited for orchards.

Forests constitute the second largest land use, covering approximately 19% of the four-township area. Deciduous forests, coniferous forests, mixed deciduous and coniferous forests, active timber harvest areas, and shrub rangelands are included in this category.

Wetlands cover approximately 7% of the four-township area. Wetland cover types included wooded swamps, shrub swamps, and marshes. Residential uses ranked fourth (5%), followed by water (2%). Commercial, industrial, and transportation uses and open space each accounted for less than 1% of the four-township area. The small proportion of commercial and industrial land use in the townships reflects the rural agricultural character of the area. Most of the commercial and industrial land use in southwestern Michigan is concentrated in Dowagiac, St. Joseph-Benton Harbor, and Niles.

The acreage of each land use in each of the four townships is presented in Table 3-26. The percentage of each land use/cover type in the four-township area also is given.

3.2.2.2. Study Area Land Use Trends

Land use in the study area is very similar to land use in the surrounding four-township area. Agricultural land, orchards, deciduous forests, water, and wooded swamps constitute approximately 87% of the land use/cover. One significant difference between the four-township area and the study area is the percentage of residential land use. Approximately 12% or twice the percentage of land use in the study area watersheds is residentially developed.

Land use data were collected and analyzed by watershed for each of the seven major lakes (Cable, Crooked, Dewey, Indian, Magician, Pipestone and Round) in the study area. In total, these watersheds extend over 13,252 acres of land and constitute approximately 15% of the surrounding, four-township area. The spatial distribution of the land use/cover categories in the area watersheds is presented in Figure 3-8.

Land use/cover types were identified and planimetered for each of the seven watersheds (Tables 3-27 to 3-29). In 1977, agricultural land constituted 6,354 acres (2,571 hectares), or approximately 48% of the area and was the predominant land use/cover type. The Dewey Lake and Pipestone Lake watersheds contained 52% of the total agricultural land. Nearly one-third of the agricultural land (1,999 acres or 809 hectares) was categorized as orchards. Most of the orchards (69%) were located in the Pipestone Lake and Indian Lake watersheds.

Forest land was the second largest land/use cover category, constituting 14.% of the total watershed area. The Indian Lake watershed had the greatest amount of forest, with 16% of the watershed area classified as deciduous forest. Water was the next largest category (13%), followed by wetland (12%). The Pipestone Lake watershed included 62% of all of the wetlands in the watersheds, primarily wooded swamps.

Table 3-26. Total acres of land use/cover types in the four-township area (SMRPC 1978a).

Township	Residential	Commercial	Industrial	Transportation	Open Space	Agricultural	Forest	Water	Wetlands	Total
Bainbridge	613	30	0	0	20	16,816	3,034	119	1,176	21,817
Keeler	899	39	50	0	20	15,314	4,011	573	1,877	22,783
Pokagon	1,067	72	109	0	197	13,602	5,380	39	1,242	21,708
Silver Creek	2,006	57	173	15	79	12,444	4,478	1,373	1,788	22,413
Total	4,585	198	332	15	316	58,176	16,912	2,104	6,083	88,721
Percent of total area	5.2	0.2	0.4	--	0.3	65.6	19.1	2.4	6.9	100.1

Table 3-27. Acres of each land use/cover type in the seven watersheds in the Indian Lake-Sister Lakes study area.

Land Use/Cover Type	Cable Lake	Crooked Lake	Dewey Lake	Indian Lake	Magician Lake	Pipestone Lake	Round Lake	Total
Agricultural								
Cultivated crops	67.7	62.2	1,011.6	1,259.5	773.5	428.5	15.5	3,618.7
Hay		32.9	101.6	66.1	114.1	359.1	30.9	704.7
Orchards	13.7	31.3	170.5	674.4	268.7	701.3	139.2	1,999.1
Other agricultural					19.5	12.3		31.8
Subtotal	81.4	126.4	1,283.9	2,000.0	1,175.8	1,501.2	185.6	6,354.3
Residential								
Single/duplex (low density)	22.7	200.7	70.1	82.6	261.7			637.8
Single/duplex (medium density)	11.8	17.2		33.9	12.3			75.2
Rural residential	57.3	67.3	113.4	255.0	171.7	15.1	150.3	830.1
Subtotal	91.8	285.2	183.5	371.5	445.7	15.1	150.3	1,543.1
Commercial								
Central business district			5.1				17.2	22.3
Institutional							12.3	12.3
Subtotal			5.1				29.5	34.6
Industrial								
Medium/large industry		6.5					13.5	20.0
Subtotal		6.5					13.5	20.0
Open Space								
Outdoor recreation		17.2		119.9				137.1
Subtotal		17.2		119.9				137.1
Forest								
Deciduous forest	57.8	97.9	192.6	589.7	274.0	347.8	122.5	1,682.3
Coniferous forest			6.3		11.8	16.9		35.0
Brush land	14.6	30.9	26.7	14.4	21.6	15.5		123.7
Subtotal	72.4	128.8	225.6	604.1	307.4	380.2	122.5	1,841.0
Wetland								
Wooded swamp	93.0	9.3	122.0	50.7	30.4	881.3	33.2	1,219.9
Non-forested wetland		16.9		141.5	50.6	110.2		319.2
Shrub swamp			16.9		54.1		4.2	75.2
Subtotal	93.0	26.2	138.9	192.2	135.1	991.5	37.4	1,614.3
Water								
Water	76.1	133.4	219.0	507.4	451.2	127.4	193.5	1,708.0
Subtotal	76.1	133.4	219.0	507.4	451.2	127.4	193.5	1,708.0
Total	414.7	723.7	2,056.0	3,795.1	2,515.2	3,015.4	732.3	13,252.4

Table 3-28. Percentage of the total watershed covered by each land use/cover type in the Indian Lake-Sister Lakes study area.

Land Use/Cover Type	Cable Lake	Crooked Lake	Dewey Lake	Indian Lake	Magician Lake	Pipestone Lake	Round Lake
Agricultural							
Cultivated crops	16	9	49	33	31	14	2
Hay		5	5	2	5	12	4
Orchards	3	4	8	18	11	23	19
Other agricultural					0.8	0.4	
Residential							
Single/duplex (low density)	5	28	3	2	10		
Single/duplex (medium density)	3	2		0.9	0.5		
Rural residential	14	9	6	7	0.7	0.5	21
Commercial							
Central business district			0.2				2
Institutional							2
Industrial							
Medium/large industry		0.9					2
Open space							
Outdoor recreation		2		3			
Forest							
Deciduous forest	14	14	9	16	11	12	17
Coniferous forest			0.3		0.5	0.6	
Brush land	4	4	1	0.4	0.9	0.5	
Wetland							
Wooded Swamp	22	1	6	1	1	29	5
Non-forested wetland		2		4	2	4	
Shrub swamp			0.8		2		0.6
Water							
Water	18	18	11	13	18	4	26

Table 3-29. Land use/cover types in the seven watersheds by number of acres and by percent of the total acreage.

Land Use/Cover	Number of Acres	Percent of Total Acreage
Agricultural	6,354.3	48
Residential	1,543.1	12
Commercial	34.6	0.3
Industrial	20.0	0.2
Open space	137.1	1.0
Forest	1,841.0	14
Wetland	1,614.3	12
Water	1,708.0	13
Total	13,252.4	100.0

Rural and low density housing stock dominated the residential land use sector. Development was located primarily along the shorelines of the seven lakes. Nearly 12% of the watershed area was classified as residential. Magician Lake had the most acres of residential development (445.7 or 180 hectares) and Crooked Lake had the largest percentage of residential development (39%). Commercial-institutional uses were concentrated northeast of Round Lake, and included a school, a church, and a small convenience shopping area. The only industrial uses were gravel pits, located southwest of Round Lake.

3.2.2.3. Prime and Unique Farmland in the Study Area

In recent years the Federal Government has emphasized the need to protect lands having the best physical and chemical qualities for production of food, feed, fiber, forage, and oilseed crops. The national criteria utilized to define prime farmland are based on a combination of the soil, water, and

climatic factors that influence productivity. Unique farmland is defined as land especially suited for the production of certain specialty crops, due to unique combinations of soil quality, location, length of growing season, and moisture supply.

Prime farmland in the study area where detailed soil mapping is available is presented in Figure 3-9. The mapped areas were based on the detailed soils mapping and the list of prime farmland units in Michigan (SCS 1980a). Unique farmland is not shown on any map because it has not been identified in a consistent manner between counties. The areas in orchards and small fruits comprise much of the unique farmland within the study area.

3.2.2.4. Future Land Use

The rural recreational character of the study area, combined with state and national economic conditions will affect the patterns of residential, commercial, and industrial land use that emerge in the study area. Residential infill and the conversion of seasonal housing to permanent housing along the lakeshores is expected to continue. Residential land use will not be affected significantly by this phenomenon because of the limited number of developable lake front lots. If interest rates decline and the state and local economies improve, residential development can be expected to expand into the back lots along the lakes and other areas. The residential development which would occur would likely be to provide bedroom communities for persons working in Dowagiac, Benton Harbor, or Niles who are attracted to the study area for its rural and recreational amenities.

If residential development does increase, some commercial development would occur to provide services for new residents in the area. Industrial development in the area is dependent primarily on state and national economic conditions. Little expansion of industrial land use is likely to occur until interest rates decline and the state and national business climates improve. Future expansion of agricultural land is limited by the availability of tillable soils.

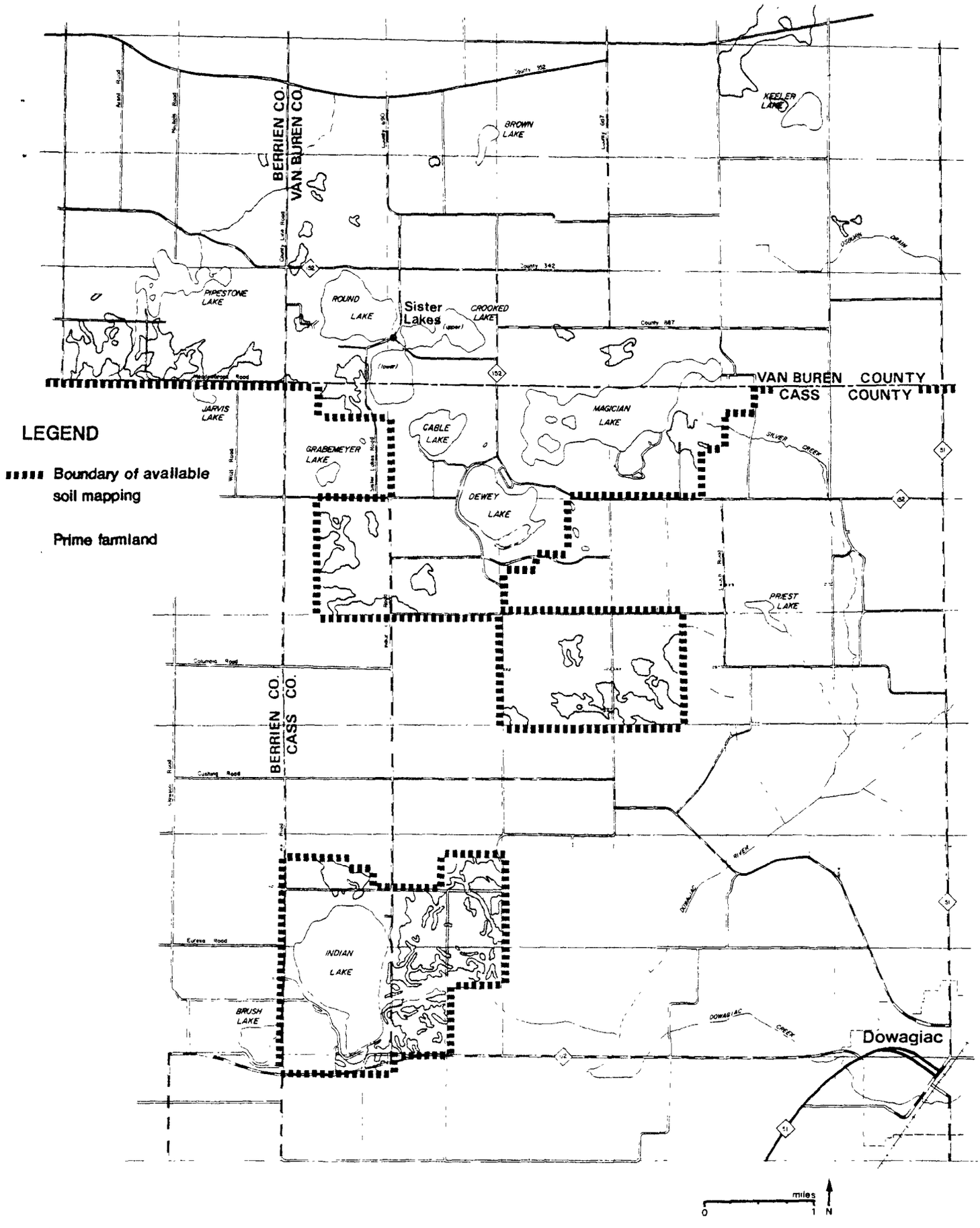


Figure 3-9. Prime farmland in the areas where soil mapping is available.

3.2.2.5. Development Potential

3.2.2.5.1. Natural Constraints

The three predominant natural constraints on development in the study area are steep slopes, high water table, and soils that are unsuitable for building construction and for on-site sewage treatment systems. These natural constraints also provide the basis for many of the legal constraints that attempt to regulate development in sensitive areas characterized by one or more of the above features. A description of natural constraints is presented in Section 3.1.2.2.

3.2.2.5.2. Man-made Constraints

Zoning Ordinances and Sanitary Codes

The State of Michigan has extended statutory authority to the counties to establish planning commissions, enact regulations, and regulate land use. However, Berrien, Cass, and Van Buren counties have deferred this responsibility to the townships. Zoning ordinances have been promulgated by each of the four townships that include the study area. Lot sizes, building setbacks and heights, planned unit development requirements, and agricultural districts are among the provisions found in these ordinances. Zoning constraints are not likely to limit housing growth in the area since the lakeshore is extensively developed and considerable backlot areas are available.

The health departments of each county have been assigned the responsibility of enforcing sanitary codes under the Michigan State Public Health Act of 1965. All three counties have adopted sanitary codes which have provisions governing on-site sewage disposal systems. Enforcement of the sanitary codes restricts development where lot characteristics do not permit adequate distances between drainfields and structures, wells, or natural bodies of water; where soils have extremely high percolation rates; where tight soils inhibit infiltration or are saturated; and where soils have a less than acceptable minimum depth to bedrock or to the water table. Away from the already extensively developed lakeshore, these lot characteristics rarely limit installation of on-site systems.

Subdivision and Building Laws and Regulations

The State of Michigan enacted the Subdivision Control Act in 1967. Under the terms of this act, any land that has been subdivided into five or more parcels which are 10 acres or less in size, or land that has been divided successively over a 10-year period, must be surveyed and platted. The plats are subject to the approval of the County Drain Commissioner, the County Health Department, and the governing body of the local unit of government that is affected. Enforcement authority is given to the Attorney General or to the County Prosecuting Attorney.

The State Construction Code Act of 1972 established regulations for the construction of buildings. Although counties in Michigan normally are responsible for administration and enforcement of the Act, townships are exempted if they adopt and enforce a nationally recognized model code. The State, the three counties (Berrien, Cass, and Van Buren), and Keeler Township have adopted the Basic Building Code of the Building Officials Conference of America. Bainbridge Township, Pokagon Township, and Silver Creek Township have adopted the Uniform Building Code of the International Conference of Building Officials.

Other Constraints

The Farmland and Open Space Preservation Act of 1974 (Act 116) promotes the preservation of farmland and open areas through the execution of agreements that reserve the development rights for the public in perpetuity or for a specified term of not less than 10 years. Subsequent to the agreement, farmland is taxed only on the basis of the agricultural value of the land involved, and open space is exempt from ad valorem taxation.

Significant acreages currently are protected under the Act 116 program in Bainbridge and Keeler Townships (By telephone, Mr. Leslie Hainey, Soil Conservation Service, and Ms. Leslie Poole, Van Buren County Planner to WAPORA, Inc., 24 February 1982). None of the land in Bainbridge Township, however, is within the boundaries of the study area. The acreage in the Keeler Township portion of the study area is not available. There is no significant acreage protected by Act 116 in Silver Creek Township (By telephone, Mr. John Meacham, Soil Conservation Service, to WAPORA, Inc. 24 February 1982).

Executive Order 11990, Protection of Wetlands, was issued by President Jimmy Carter on 24 May 1977 (Federal Register 42:26961). The terms of Order require USEPA and other Federal agencies to avoid adverse affects on wetlands wherever possible, to minimize destruction of wetlands, and to preserve and enhance the natural and beneficial values of such areas during the discharge of the agency's responsibilities related to the construction and improvements undertaken by, financed by, or assisted by the Federal Government, such as wastewater treatment facilities. The State of Michigan passed a wetland protection act (Act No. 203 of the Public Acts of 1979) that became effective 1 October 1980. This act places restrictions on the development or drainage of wetlands greater than five acres in size.

The Soil Erosion and Sedimentation Control Act of 1972 requires that any earth change activity (a man-made change in the natural cover or topography other than that resulting from crop production), that involves one or more acres or that is within 500 feet from lake or stream, must have a county permit attesting to compliance with the Act and applicable rules. A permit will not be granted if the activity would cause significant soil erosion or water sedimentation. The provisions of this act generally apply to construction programs and not to long-term operations.

Solid waste disposal is closely regulated by the State. The State Health Department is the licensing agent. The SMRPC has developed two model ordinances that are directed at the regulation and control of nonpoint sources of water pollution. These ordinances, which could be adopted in the future by units of government in the study area, focus on the collection and disposal of surface runoff and on the installation of on-site sewage treatment systems on lands adjacent to surface waters.

3.2.3. Economics

3.2.3.1. Regional Employment Trends

The early economic history of Cass, Berrien, and Van Buren counties was dominated by agriculture. As agriculture flourished, the industries associated with agriculture prospered. The first industries to develop were shipbuilding, flour milling, and sawmilling. These industries were followed by firms that manufactured primary metals, machinery and household appliances.

By 1970, the area's economy had shifted from agriculture to industry. In 1970, manufacturing comprised nearly half of the total employment and was by far the largest employment sector. Economic sector analysis, employment multipliers, and historic data are presented in WAPORA (1979).

Manufacturing, food processing, and tourism have been identified as potential growth industries in the three-county area (SMRPC 1978b). The future growth of agriculture, the dominant land use in the study area, is limited to the availability of additional tillable land. Even if the productivity per acre of agricultural land increases, employment opportunities probably will not increase because of the expanding capital intensity of modern farming operations.

The economic future of the study area may be shaped by the increased conversion of the lake areas into bedroom communities for Dowagiac, Benton Harbor-St. Joseph, and Niles. Small retail and service businesses would be expected to appear as this conversion continues.

In summary, no major expansion of economic activity in the study area is expected in the near future. However, better transportation, increased opportunities in the nearby major employment centers, and improved community services could stimulate some additional local growth.

3.2.3.2. Income

Per capita income levels in Berrien, Cass, and Van Buren counties consistently were below the state level during the 6-year period between 1974 and 1980 (Table 3-30). Growth of per capita income in the three counties during this same period also was less rapid than the statewide average. Moreover, per capita income in Cass County decreased from $8,137 in 1979 to $7,169 in 1980. The low levels of income and slow growth of income may reflect the out-migration of high-income individuals from Berrien and Cass counties during recent years (By telephone, Mr. Steve Harris, Michigan Municipal Finance Commission to WAPORA, Inc., 9 October 1981).

Table 3-30. Per capita personal income in dollars in Berrien, Cass, and Van Buren counties and the State of Michigan.

	1974[a]	1975[a]	1976[a]	1977[a]	1978[a]	1979[a]	1980
Berrien	5,486	5,646	6,026	6,751	7,596	8,271	9,156[b]
Cass	4,961	5,230	5,979	6,508	7,479	8,137	7,169[b]
Van Buren	4,690	4,836	5,334	5,897	6,764	7,499	8,316[b]
Michigan	5,687	6,008	6,760	7,603	8,507	9,381	10,647[c]

a By telephone Ms. Jan Hanson, Michigan Employment Security Commission, to WAPORA, Inc., January 1982.

b By telephone, Mr. Peter Elliott, SMRPC, to WAPORA, Inc., January 1982.

c By telephone, Mr. William Rice, US Department of Labor, to WAPORA Inc., January 1982. Average per capita personal income for the State of Michigan was calculated by multiplying Michigan's 1979 per capita income by the annual average increase of the US Consumer Price Index (CPI) for 1980. The CPI has historically been a reliable parameter for calculating income estimates. The CPI is derived from the rate of inflation of consumer goods and services which may differ from real increases or decreases in personal incomes.

3.2.3.3. Unemployment

Unemployment trends in Berrien, Cass, and Van Buren counties parallel national cycles of business activity (Table 3-31). During the 1970s, the highest unemployment rates recorded by the three counties occurred during the 1975 recession. Unemployment rose sharply again during 1980 surpassing, at the state level, the unemployment figures for 1975. The 1980 unemployment rate in Van Buren county was 10.3% or 2.3% lower than the state average. Unemployment rates in Berrien and Cass counties were 13.2% and 13.1%, respectively. The relatively high unemployment rates in the three counties for 1980 reflects the problems in the automobile industry and a continuing loss of industry and jobs to states in the south and southwest (By telephone, Mr. Stephen Harris, Michigan Municipal Finance Commission to WAPORA, Inc. 9 October 1981).

Table 3-31. Civilian labor unemployment trends in the three counties and in the state of Michigan (By telephone, Ms. Jan Hanson, Michigan Employment Security Commission, to WAPORA, Inc., 20 January 1982)

Percent of Civilian Force Unemployed

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Berrien County	5.7	6.8	6.1	6.0	7.3	15.6	11.5	9.9	8.4	8.9	13.2
Cass County	9.5	7.3	5.8	5.1	7.8	14.1	8.6	7.4	5.8	7.8	13.0
Van Buren County	6.4	7.6	6.7	5.7	6.8	11.9	8.9	7.6	6.7	7.2	10.3
Michigan	6.7	7.6	7.0	5.8	7.4	12.5	9.4	8.2	6.9	7.8	12.6

3.2.4. Recreation and Tourism Resources

Although the contributions of the recreation and tourism industry to employment and income in the three counties are significant, the importance of this industry has declined in the study area since the 1930s and 1940s. This decline can be attributed to outmoded resort facilities, conversion of seasonal housing units to year-round homes, and the development of other recreation areas in northern Michigan. An examination of recent trends indicated that vacationers travel longer distances and frequently bypass the study area (By telephone, Mr. Tom Hufnagel, Michigan Department of Commerce, to WAPORA, Inc. 26 February 1979).

The recreation and tourism industry in Michigan is expected to continue to grow at a rate of approximately 12% annually (Michigan Department of Commerce 1976). In 1974 and 1975, this industry generated 3,738 jobs, or 3.54% of the total employment in the three-county area. Expenditures during the period amounted to $107,714,976 and accounted for 1.91% of the total personal income in the three counties (SMRPC 1978b).

The future of the recreation and tourism industry in the study area is uncertain at this time. While land development proposals that provide recreational and open space areas are encouraged throughout southwestern Michigan, open space in the four townships is projected to decrease by 44 acres by the year 2000 (SMRPC 1978a). Many of the resorts and housekeeping cottages in the study area have been sold to individuals and the conversion of seasonal homes to year-round homes is expected to continue. However, high fuel costs and long-term gasoline shortages could result in increased spending of recreation and tourism dollars in the study area by residents of nearby Chicago and South Bend, Indiana.

3.2.4.1. Public Facilities

The SMRPC has identified 316 acres of open space in Bainbridge, Keeler Pokagon, and Silver Creek townships. This land includes parks, recreational developments, fairgrounds, outdoor public assembly areas, cemeteries, and vacant urban land (SMRPC 1978a). This accounted for only 0.4% of the total land area. Lions Park is the only public park in the study area. It is located near Crooked Lake in Keeler Township, and has a wide range of play-

ground facilities and a Go-Kart track. Usage data are not available for this facility.

Public access is maintained at two lakes in the service area. One is located on the north side of Magician Lake in Silver Creek Township, and the other is located on the north side of Round Lake in Keeler Township. The Magician Lake public access area has 10 parking spaces and a paved boat launch ramp. The Round Lake public access area has 20 parking spaces and a gravel boat launch ramp. Both public access areas have toilet facilities only. They are administered by the Waterways Division of MDNR. The MDNR collected data for these two access areas in 1977. The access site at Magician Lake was used most often in June, and the greatest number of vehicles with boats at one time was nine. June also was the busiest month at the Round Lake access site.

The predominant recreation activity in the study area is power-boating. While the number of boaters varies from year to year, it has been estimated that nearly every lakefront housing unit has either a motorboat, a pontoon boat with an outboard motor, or a rowboat with an outboard motor. On the basis of recent trends, it appears that sailboats and inboard motorboats are growing in popularity (By telephone, Ms. Judy Chapman, J&J 5 Mile Marina, to WAPORA, Inc., 16 May 1979).

3.2.4.2. Private Facilities

The private recreational facilities in the study area serve both the year-round population and the seasonal population. Most of these facilities are located at resorts. The resort locations and facilities are presented in Table 3-32.

There are 135 overnight units at the four resorts and 47 camping and trailer sites in the service areas. Most of the resort units are housekeeping cottages. The busiest season occurs during the last 2 weeks in July and the first 2 weeks in August. Hotel and motel proprietors have indicated that most of their guests are from the Chicago metropolitan area and usually are families with school-age children. The average length of stay has declined in recent seasons from 2 weeks to 1 week (By telephone, Mr. Tom Light, Beechwood Resort to WAPORA, Inc., 2 February 1979).

Table 3-32. Private resort facilities and recreation facilities in the Indian Lake-Sister Lakes sewer service areas.

Resort Name	Location	Recreation Facilities	Number of Overnight Rooms	Number of Campsites	Predominant Origin of Tourists and Seasonal Residents
Beechwood Resort[a]	Round Lake	Playground, shuffleboard, indoor recreation building, boats, swim raft, dock and beach	30	0	Chicago's southern suburbs
Shady Shores Resort[b]	Dewey Lake	Badminton, basketball, bicycles, boats, croquet, fishing, golf, horseshoes, pingpong, shuffle-board, playground, swimming, tennis, softball, volleyball, movies, square dancing, and other planned recreation activities	43	18	Chicago's northwestern and southern suburbs Cleveland OH; and Valparaiso IN
Bob's Harbor Resort[c]	Magician Lake	NA	18	7	Chicago's southern suburbs
Pearl Cottages[d]	Crooked Lake (Big)	Playground and beach	44	0	NA
Land O'Lakes Campsite	Round Lake	Playground, picnic area, swimming and boating	0	22	NA

[a] By telephone, Mr. Tom Light, owner, 27 February 1979.

[b] By telephone, Mrs. Nevins, owner, 27 February 1979.

[c] By telephone, Mrs. J. Shoemaker, owner, 26 February 1979.

[d] By telephone, Mr. Rocky Gulliver, owner of Land O'Lake Campsites, 27 February 1979.

NA = Not available.

Usage data for the private recreation facilities in the study area are not available. However, recreation participation estimates by activity and by provider (public/private) have been prepared for 14-State planning and development regions in Michigan by the MDNR. In Region 4 (Berrien County, Cass County, and Van Buren County), the majority of the recreational activities are provided by private organizations (MDNR 1978a). The most popular regional recreation activity, in terms of participation, is competitive sports (Appendix K, Table K-1). Additional estimates indicate that 4.8 million recreation activity participations by Region 4 residents occurred outside of Region 4 and that 2.3 million recreation activity participations in Region 4 were by non-residents. The higher number of recreation activity participations that occurred outside of Region 4 reflects the decline of recreation and tourism in the study area and in the three counties.

3.2.5. Public Finance

A variety of community services are provided for the residents of Berrien, Cass, and Van Buren counties. Among them are health and welfare services, transportation facilities, police protection, recreation facilities, wastewater collection and treatment, and tax collection. The ability to maintain and improve these services is dependent on the continued ability of county residents to finance them. Income and employment levels can be used to measure a community's ability to support community services. Market value and assessed valuation of property directly affect tax revenues collected by local governments and, consequently, their financial capabilities.

3.2.5.1. Assessed Valuation and Market Value

The 1980 state equalized valuations (SEV) of real and personal property for each county and the market values of property are presented in Table 3-33. The SEV for Berrien County, the most populated county in southwestern Michigan, was nearly twice the SEV of the remaining counties combined. The ratio of the state equalized valuation to market value is 0.5 in Michigan.

3.2.5.2. Total Revenues

Intergovernmental transfers, special assessments, taxes, and charges for services were the primary sources of revenue for the three counties. In 1980,

Berrien County collected revenues totalling $13,528,818. The combined total revenues collected by Cass and Van Buren counties for 1980 were 63% of Berrien County (Table 3-33).

3.2.5.3. Debt, Debt Service, and Debt Limits

The general obligation bonding authority of local governments in Michigan is limited to 10% of the SEV. Berrien County has a self-imposed debt limit of 65% of the 10% state required debt limit. The general obligation debt limit and levels of debt and debt service for each county are presented in Table 3-33.

In 1980 Berrien County had a debt level of $57,920,000 or 53% of its debt limit. Cass County had a debt level of $1,335,000 or 3% of its debt limit. Van Buren County debt level was $2,045,000 or 4% of its debt limit. The combined debt of Cass and Van Buren Counties was 6% of Berrien County's total debt. None of the three counties is near its state or local debt limit.

The three counties pay debt service primarily on bonds which support public works projects. A small percentage of total debt service is paid to support county-owned housing and land. Berrien County's debt service for 1980 was $6,073,649. Cass and Van Buren Counties combined debt service was 5% of Berrien County's total debt service.

Criteria for prudent fiscal management have been developed by several authors. Whether or not a county can incur additional debt safely can be estimated by applying three common debt measures adapted from Moak and Hillhouse (1975). As shown in Table 3-34, Berrien, Cass and Van Buren Counties are rated as being below all of the standard upper debt limits and can, according to these limits, increase their level of debt. None of the three counties is near the state general obligation debt limit. Berrien County's total debt has reached only 53% of its self-imposed debt limit.

3.2.6. Transportation

3.2.6.1. Highways

No major highways pass through the study area. Interstate 94, located 15 miles west and 11 miles north of the study area, provides direct access from

Table 3-33. Selected financial characteristics for Berrien, Cass, and Van Buren Counties (By telephone, Mr. Hark Patzer, Berrien County Treasurer's Office; Ms. Candy Cooper, Cass County Treasurer's Office; Mrs. Stephayn, Van Buren County Treasurer's Office, to WAPORA, Inc. 28 December 1981).

County	Total Revenues	Total State Equalized Assessed Valuation	Market Value	Debt	Debt Service	General Obligatio Debt Limit
Berrien	$ 13,525,818	$1,676,427,415	$3,352,854,830	$57,920,000	$6,073,649	$108,967,781
Cass	3,902,076	420,747,938	841,495,876	1,335,000	87,410	42,074,793
Van Buren	4,598,116	475,947,554	951,895,108	2,045,000	242,032	47,594,755

Table 3-34. County debt measures (Adapted from Moak and Hillhouse 1975).

	Standard Upper Limits	Counties		
		Berrien[2]	Cass	Van Buren
Debt/Total market value[1]	10% of current market value	1.7%	.2%	.2%
Debt service/Total Revenue	25% of total revenues	4.5%	2.2%	5.3%
Debt/State equalized assessed valuation	10% of state equalized assessed valuation[3]	3.5%	.3%	.4%
Debt/Per capita personal income	7%[4]	3.7%	.4%	.4%

[1] The general obligation bonding authority of local governments in Michigan is limited to 10% of the SEV.

[2] Berrien County has a self imposed debt limit of 65% of the 10% state required debt limit.

[3] The calculations for deriving the counties debt per capital income ratio are presented in Appendix L.

[4] Not an upper limit but a national average in 1970.

the study area to all major metropolitan areas except South Bend, Indiana. South Bend is accessible from the study area via I-33. State routes M-51, M-62, M-140 and M-152 are located in or adjacent to the study area. Traffic volumes in the four township area are growing (By letter, Mr. Bill Camburn, Van Buren County Road Commission, to WAPORA, Inc., March 1979). Amtrack provides daily passenger train service to Dowagiac and to Niles. Freight service is provided via Conrail to Benton Harbor, St. Joseph, South Bend, and Kalamazoo. The nearest intercity bus station serving the study area is located in Dowagiac. Each of the three counties has a county-wide rural public transportation system that serves the elderly and the handicapped. Additional data on roads and transportation facilities are presented in WAPORA 1979.

3.2.6.2. Airport Facilities

Numerous regional, commercial, and general aviation airports are located within or in proximity to the study area (By letter, Mr. E. Mellman, Michigan Department of Transportaton to WAPORA, Inc., 2 March 1979). A regional airport is located in South Bend and another regional airport is planned for Kalamazoo. Republic Airlines provides commercial passenger and freight services from the Twin Cities airport (Foss Field) in Benton Harbor. In addition, six general aviation airports are located in the three-county area.

3.2.6.3. Port Facilities

The nearest port facility is located in Benton Harbor at the confluence of the St. Joseph River with Lake Michigan. It provides accessibility to international waterways via the Great Lakes-St. Lawrence Seaway System and the Chicago Sanitary and Ship Canal/Mississippi River System. There also are recreational port facilities on Lake Michigan at South Harvey and New Buffalo, Michigan, located southwest of the study area.

3.2.7. Energy

The fuel types available for residential, commercial, and industrial heating in the three-county area are fuel oil, coal, natural gas, propane, butane, and electricity. Fuel oil is the predominant energy source for residential heating within the four-township area followed by natural gas, pro-

pane, butane, electricity, and coal. Within the service area, natural gas was the predominant energy source, followed by fuel oil. Wood likely provides a fuel source for many area residents. Data on the extent of use and availability of wood are not available. The amount of each fuel type required to heat a single family home is presented in Appendix M, Table M-1. An estimate of the total 1977 fuel consumption, for home heating in the four-township area is presented in Table 3-35.

3.2.8. Cultural Resources

3.2.8.1. Early History

The three counties in the study area were inhabited by Miami and Pottawatomie Indians at the time of initial French exploration in 1675. In that year, Father Marquette traveled along the eastern shore of Lake Michigan and down the River of Miami (St. Joseph River) (Ellis 1880). Four years later, the French explorer LaSalle established a fort near Niles that served as a vital military post until the 1760s. Fort Miami, later known as Fort St. Joseph, passed into Spanish, English, and finally American hands as political fortunes changed on the early western frontier.

During the period of white settlement, the dominant Potawatomi tribe was divided into three bands led by Chiefs Pokagon, Weesaw, and Sharehead. Through a series of treaties executed between 1821 and 1833, they ceded all of their land to the US and were transported to areas west of the Mississippi River. However, Chief Pokagon, a prominent local historical figure, refused to sign or consent to any treaties until his fellow Catholic Indians received guarantees that they would be allowed to remain in Michigan. Although forced to leave his native site in Berrien County, he purchased 750 acres of land in Cass County (Silver Creek Township) and established an Indian settlement there. In 1838, Chief Pokagon built the first Catholic church in Silver Creek Township.

The first permanent white settlers were people of French and English decent. Bartholomew Sharrai and a man named Ruleaux (Ellis 1880) established initial settlements in Bainbridge Township. Dolphin Morris settled in Van Buren County in 1829. The first settler in Silver Creek Township, James McDaniel, arrived in 1834 or 1835 and built the first sawmill in that area.

Table 3-35. Energy consumption by fuel type for residential heating in the four-township area in the Indian Lake-Sister Lakes study area (US Bureau of the Census 1970; Michigan Department of Commerce 1978).

Fuel Type	Residential Fuel Use	Quantity of Fuel Used	Trillion Btu	Total Costs (Thousands of 1977 Dollars)
Fuel oil	1,685	2.42×10^6 gal	336	1,140
Natural gas	700	1.37×10^{12} ft^3	140	272
Electricity	165	6.29×10^6 kwh	21.4	229
Propane/butane	265	0.562×10^6 gal	53.0	227
Coal	44	372.2 tons	8.8	9
Total	2,859	--	559.2	1,877

Although some lumbering occurred in nearby areas, most of the residents were engaged in farming. As the population expanded, new trade routes were established that stimulated further growth. The construction of the "Old Chicago Road" (US Highway 12), which connected Chicago and Detroit, was decreed by an Act of Congress in 1825. The Road passed through Niles and followed the Sauk and Fox Indian Trail (Glover 1906; Dunbar 1965). The Old Territorial Road, constructed in 1836 and 1837, is located in the northern part of the study area in Bainbridge Township and Keeler Township.

3.2.8.2. Archaeological Sites

The Michigan History Division of the Michigan Department of State has a considerable amount of information on the prehistory of the study area; these data are unprocessed, however, and not readily available (By letter, Martha M. Bigelow, Director, Michigan History Division and State Historic Preservation Officer, to WAPORA, Inc., January 1979). A search of the files of the Michigan History Division revealed the existence of a registered Indian site in the study area. This site is located in Section 7 of Silver Creek Township (T5S, R16W). It is likely that additional, undocumented sites are present on high ground near streams, lakes, and rivers in the study area (By telephone, Dr. John Halsey, Michigan Visitors Division, to WAPORA, Inc., April 1979). The following sections may contain prehistorical sites, based on an analysis of topographic maps:

- Bainbridge Township (T4S, 17W), Section 25
- Bainbridge Township, Section 26
- Keeler Township (T4S, 16W), Section 31
- Keeler Township, Section 32
- Silver Creek Township (T4S, R16W) Section 2
- Silver Creek Township, Section 3
- Silver Creek Township, Section 4
- Silver Creek Township, Section 6
- Silver Creek Township, Section 30
- Silver Creek Township, Section 31
- Silver Creek Township, Section 32.

Undocumented archaeological sites also may exist along meandering parts of Highway M-152 in Bainbridge Township, where the highway follows an old Indian trail. In addition, a site in Section 14 of Silver Creek Township was a temporary home for Chief Pokagon's tribe from 1836 to 1838, before their relocation to Sections 21 and 22, which are adjacent to the study area (Claspy 1966).

3.2.8.3. Historic Sites

There are no sites in the study area that are listed on the National Register of Historic Places. However a survey for eligible sites has not been conducted (By telephone, Mr. Bob Christensen, Michigan History Division to WAPORA, Inc. 4 January 1982). Three structures in the study area are listed on the Michigan Register of Historic Sites. The Sacred Heart of Mary Catholic Church was constructed by Chief Pokagon in 1838 and was been rebuilt twice. It stands on the grave of Chief Pokagon and is the oldest Catholic church still in use in southwestern Michigan. The second structure, the Cushing Corner School, is a one-room schoolhouse that was built in 1873. It has local historical significance and is one of the few old buildings in the area that has not been modified. The third structure, the Sprague House, is a simple clapboard frame house that was built in 1868 on the Old Orchard Farm. The farmstead has been listed as a "Centennial Farm" by the Michigan History Division. These are:

WAPORA personnel conducted a brief field survey of the study area during February 1979 and identified 14 additional sites of architectural significance. These are:

- Franz House
- Tudor Revival style bungalow
- Barn
- Italianate style house
- Gingerbread style house
- Halfert House and Barn
- Genung House
- Jeru House
- Queen Anne style house
- House
- Keeler United Methodist Church
- Silver Creek Methodist Church
- Schoolhouse
- Indian Lake School.

4.0. ENVIRONMENTAL CONSEQUENCES

The potential environmental consequences of the system alternatives that are described in Section 2.3. are discussed in the following sections. The impacts resulting from the construction and operation of the alternatives may be beneficial or adverse, and may vary in duration (either short-term or long-term) and significance. The significant impacts of each alternative are summarized in Table 4-1.

Environmental effects are classified as either primary or secondary impacts. Primary impacts result directly from the construction and/or operation of the proposed project. Short-term primary impacts generally occur during construction. Long-term primary impacts occur throughout the life of the project.

Secondary impacts are indirect effects of the project, such as changes in demographic and other socioeconomic characteristics. As these changes occur, associated impacts (e.g., air and water pollution, increased ambient noise levels, increased consumption of energy and other resources, demand for expanded public infrastructure, increased development pressure on agricultural lands, woodlands, and other environmentally sensitive areas, decreased wildlife habitats, increases in employment and business activity, increased property values) can result. Secondary impacts also may be either short-term or long-term. Short-term secondary impacts, for example, can result from disruption of the environment that occurs during the construction of secondary development. Long-term secondary impacts can result, for example, from urban runoff that occurs indefinitely after development of agricultural land or open space/undeveloped areas.

Possible mitigative measures also are discussed in this chapter. Adverse impacts can be controlled and many should be of short duration. Possible mitigative measures include planning activities and construction techniques that reduce the severity of both primary and secondary adverse impacts. Plans and specifications, which are to be developed by the County, must include mitigative measures.

Table 4-1. Potential major primary and secondary impacts from the construction and operation of wastewater treatment facilities in the Indian Lake/Sister Lake Area.

	No Action Alternative	Alternatives 2-5	Alternative 6	Alternative 7	Alternative 8A & 8B	Alternative 9
Atmosphere	Construction: No significant impacts are anticipated.	Construction: The construction of WWTPs and sewage collection systems will temporarily adversely affect the atmosphere of the study area. Fugutive dust, noise and odors from construction eqipment and activities will create a nuisance for a short period of time	Construction: Same as Alt. 2-5 except a smaller WWTP would be built for the Sister Lakes.	Construction: Same as Alt 2-5 except construction activities associated with WWTPs would be confined to the expansion of the Dowagiac Plant	Construction: The construction of on-site and cluster systems will temporarily adversely affect the atmosphere of the study area. Fugitive dust, odors, hydro-carbons and noise from construction equipment and activities will create a nuisance for a short period of time.	Construction: Same as Alt 8A&8B except no cluster systems will be built.
	Operation: Failing on-site systems will continue releasing odors. Some truck traffic for sludge and septage hauling will be noticed.	Operation: WWTPs' will release some low level odors aerosols and, potentially, hazardous gases. Odors at pump stations would be more problematic. The occurance of a "spring turnover" in settling ponds would create anerobic conditions and result in septic sewage odors that ma persist as long as a month.	Operation: Same as Alt. 2-5	Operation: Same as Alt. 2-5 except no lagoons or WWTPs' would be located within the study area. Low level odors, gases and aerosals associated with WWTPs would be limited to the Dowagiac WWTP.	Operation: Occasional failures of on-site system, septic pumping and hauling may create temporary malordorous conditions.	Operation: Same as Alt. 8A&8B
	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.

Table 4-1 continued.

	No Action Alternative	Alternatives 2-5	Alternative 6	Alternative 7	Alternative 8A & 8B	Alternative 9
Vegetation	Construction: No significant impacts are anticipated.	Construction: Conveyance line routes would result in the removal of some natural vegetation, and agricultural crops. Treatment and land disposal sites would replace agricultural crops or orchards.	Construction: Same as Alt. 2-5 for proposed WWTP in Section 11.	Construction: Conveyance line routes would result in the removal of some natural vegetation, and agricultural crops.	Construction: Placement of cluster drainfields and collection sewers would probably disturb maintained lawns and back yard vegetation.	Construction: No significant impacts are anticipated.
	Operation: No significant impacts are anticipated.	Operation: Waste application to land disposal (Alternative 3) may result in potentially harmful concentrations of heavy metals, other toxic substances, or micronutrients in the crops or other vegetation.	Operation: No significant impacts are anticipated.	Operation: No significant impacts are anticipated.	Operation: No significant impacts are anticipated.	Operation: No significant impacts are anticipated.
	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.

Table 4-1 continued.

	No Action Alternative	Alternatives 2-5B	Alternative 6	Alternative 7	Alternative 8A & 8B	Alternative 9
Soils	Construction: No significant impacts are anticipated.	Construction: The extensive sewering and treatment plant site would result in considerable disturbance and potential for erosion and sedimentation. Alternative 5B (conventional-gravity sewers) would expose the greatest area to erosion.	Construction: Same as Alt. 2-5 except one treatment plant site for the Sister Sister Lakes.	Construction: Same as Alt 2-5B, except no treatment plant sites are included. WWTPs would be confined to the expansion of the Dowagiac Plant.	Construction: Limited area sewering and cluster drain field sites would expose soils to erosion and sedimentation. The on-site system upgrading would expose small areas to erosion and sedimentation.	Construction: Extensive on-site system upgrading would expose limited areas to erosion and sedimentation.
	Operation: The nutrient attenuating capacity of the soils would continue to be exceeded around some soil absorption systems.	Operation: Only Alt. 3 involving land application of lagoon effluent would have an impact on soils at the application area. Soil properties would be enhanced by effluent application.	Operation: No significant impacts are anticipated.	Operation: No significant impacts are anticipated.	Operation: The capacity of soils are sorb phosphorus and to attenuate nitrogen is not expected to be exceeded.	Operation: The capacity of the soils to sorb phosphorus and to attenuate nitrogen may be exceeded on some lots.
	Secondary: No significant impacts are anticipated.	Secondary: Development of additional lake shore lots may result in increased soil erosion sedimentation and in additional nonpoint source nutrients to the lakes.	Secondary: Same as Alt. 2-5B.	Secondary: Same as Alt. 2-5B.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.

Table 4-1 continued.

	No Action	Alternatives 2-5	Alternative 6	Alternative 7	Alternative 8A & 8B	Alternative 9
Surface Water	Primary Impacts Construction: No significant impacts are anticipated.	Primary Impacts Construction: Surface runoff from disturbed areas could increase turbidity and sedimentation. in adjacent wetlands, lakes or waterways resulting in water quality degradation and potentially adverse conditions for aquatic biota.	Primary Impacts Construction: Same as Alt. 2-5.	Primary Impacts Construction: Same as Alt. 2-5.	Primary Impacts Construction: Similar to Alt. 2-5, lower sediment load would be expected, smaller impact on water degradation.	Primary Impacts Construction: Same as Alt 8A & 8
	Operation: Phosphorus load expected to increase in project area lakes, adversely affecting water quality in in Round, Crooked, and Cable Lakes. Potential for bacterial contamination arising from failing on-site systems.	Operation: Phosphorus load associated with on-site systems would be expected for Cable, Crooked and Round Lakes. Streams receiving discharge from treatment lagoons should effectively dilute oxidize effluent BOD, suspended solids, ammonia, bacteria and residential chlorine. For Alt. 3, no discharge to receiving streams. Runoff could contain elevated levels of nutrients and suspended solids.	Operation: Same as Alt. 2-5	Operation: Same as Alt. 2-5	Operation: Phosphorus loads to lakes would be decreased. Water quality improvement would be expected for Cable, Crooked, and Round Lakes.	Operation: Same as Alt 8A & 8
	Secondary: No significant impacts are anticipated.	Secondary: Increased runoff and and an increase in use of the lake for recreation or fishing purposes may be expected with an increase in settlement of the area resulting in possible degradation of the water quality.	Secondary: Same as Alt. 2-5	Secondary: Same as Alt. 2-5	Secondary: Same as Alt 2-5	Secondary: Same as Alt 2-5

Table 4-1 continued.

	No Action Alternative	Alternatives 2-5	Alternative 6	Alternative 7	Alternative 8A & 8B	Alternative 9
Wildlife	Construction: No significant impacts are anticipated.	Construction: Permanent displacement of wildlife from primarily agricultural lands would occur from construction of new WWTPs. Temporary disturbance of wildlife along road rights of way from construction of conveyance lines and mortality to some small mammals and reptiles from all construction activities would occur.	Construction: Same as Alt. 2-5 for the proposed WWTP in section 11. No significant effects expected for use of the existing Dowaglac WWTP. Placement of conveyance lines for both sites would have the same effect as Alternatives 2-5.	Construction: Placement of conveyance lines would have the same effect as Alt. 2-5. No significant effects expected for use of the existing Dowaglac WWTP.	Construction: Construction activities would temporarily disturb wildlife, most likely those species commonly found in areas of human habitation.	Construction: No significant impacts are anticipated.
	Operation: No significant impacts are anticipated.	Operation: Some wildlife will be disturbed during waste application for Alternative 3, but temporary displacement is expected. No significant effects expected for other alternatives.	Operation: No significant impacts are anticipated.	Operation: No significant impacts are anticipated.	Operation: No significant impacts are anticipated.	Operation: No significant impacts are anticipated.
	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.

Table 4-1 continued.

	No Action Alternative	Alternatives 2-5	Alternative 6	Alternative 7	Alternative 8A & 8B	Alternative 9
Demography	Construction: No significant impacts are anticipated	Construction: No new residents will be attracted to the study area by temporary jobs created by construction of WWTP and sewer system. Positions will be filled by workers from the study area and three county areas.	Construction: Same as Alt. 2-5	Construction: Same as Alt 2-5	Construction: No new jobs will created in the study area that would attract new residents to the study area.	Construction: Same as Alt 8A & 8
	Operation: No significant impacts are anticipated.	Operation: No new residents will be attracted to the area by long term jobs created by the operation of WWTP's and sewer system. Positions will likely be filled by persons from the study area or the three county area.	Operation: Same as Alt. 2-5	Operation: No new jobs would be created in the study area that would attract new residents to the study area.	Operation: Same as Alt. 7.	Operation: Same as Alt 7.
	Secondary: No significant impacts are anticipated.	Secondary: Induced growth is not anticipated. High costs may displace a limited number of families.	Secondary: Same as Alts. 2-5.	Secondary: Same as Alt. 2-5.	Secondary: Induced growth is not anticipated.	Secondary: Same as Alt. 8A & 8B except population increases are limited to the carrying capacity of the land.

Table 4-1 continued.

	No Action Alternative	Alternatives 2-5	Alternative 6	Alternative 7	Alternative 8A & 8B	Alternative 9
Land Use	Construction: No significant impacts are anticipated.	Construction: Depending on final design and location of the wastewater treatment facilities some agricultural farm land would be removed from production Construction of sewer systems may temporarily interrupt land uses along right of ways.	Construction: Same as Alt. 2-5	Construction: Construction of sewer system may temporarily interrupt land uses along right of ways.	Construction: Some cluster systems may be built on agricultural areas. Less than 40 acres of land is anticipated to be converted.	Construction: Residential land uses may be temporarily interrupted during construction of on site systems.
	Operation: Release of odors from failing on site systems would adversely affect adjacent land uses.	Operation: The release of low level odors and aerosals from WWTP's and the knowledge that hazardous gases could potentially be released from those plants may affect land use adjacent to the plants. Construction easements of sewer system would become grassed corridors. Periodic maintenance and repairs of sewer system may temporarily adversely affect adjacent land uses.	Operation: Same as Alts. 2-5	Operation: Same as Alt. 2-5	Operation: Improper maintenance of cluster and on site systems may create maladorous conditions which would adversely affect adjacent land uses.	Operation: Same as Alt. 8A&8B
	Secondary: Continued and increased nuisances attributable to failing on site systems in residential areas would make infill development of those areas less desirable.	Secondary: Any future development would likely occur along the sewer system.	Secondary: Same as Alts. 2-5	Secondary: Same as Alt. 2-5	Secondary: Any future development would be limited to the carrying capacity of residential land and land adjacent to residential areas.	Secondary: Any future development would be limited to the carrying capacity of residential land

Table 4-1 continued.

	No Action Alternative	Alternatives 2-5	Alternative 6	Alternative 7	Alternative 8A & 8B	Alternative 9
Economics	Construction: No significant impacts are anticipated.	Construction: Creates a limited number of short-term jobs. Jobs would likely be filled by persons living within the study area or the Three County Area. Purchase of goods and services attributable to construction activities would benefit that community.	Construction: Same as Alt. 2-5	Construction: Same as Alt. 2-5	Construction: Same as Alt. 2-5	Construction: Same as Alt. 2-5
	Operation: No significant impacts are anticipated.	Operation: Few long-term jobs would be created. Persons within the study area may fill these positions. Work opportunities for on-site system installers and septage haulers will decline in the study area.	Operation: Same as Alt. 2-5	Operation: No new jobs would be created within the study area.	Operation: Septage haulers may increase their business activities.	Operation: Same as Alts. 8A&B
	Secondary: Increased and continuing nuisances created by failing on-site system would detract from the study areas reputation as a desirable recreational area. Recreation and tourist revenues would likely decline.	Secondary: Added wastewater treatment capacity is unlikely to induce economic growth within the study area.	Secondary: Same as Alt. 2-5	Secondary: Same as Alt. 2-5	Secondary: Same as Alt. 2-5	Secondary: Same as Alt. 2-5

Table 4-1 continued.

	No Action Alternative	Alternatives 2-5	Alternative 6	Alternative 7	Alternative 8A & 8B	Alternative 9
Transportation	Construction: No significant impacts are anticipated.	Construction: Vehicular traffic would be inconvienced by construction of sewer system. Some roads would be temporarily closed. Increased traffic congestion.	Construction: Same as Alt. 2-5	Construction: Same as Alt. 2-5	Construction: Same as Alt. 2-5 except no roads are likely to be closed.	Construction: Same as Alt. 2-5 except no roads are likely to to be closed.
	Operation: No significant impacts are anticipated.	Operation: Vehicular traffic would be inconvienced by occasional repair and maintenance activities associated with seven systems. Occasionally, some roads may be temporarily closed.	Operation: Same as Alt. 2-5	Operation: Same as Alt. 2-5	Operation: Truck traffic associated with repairs and sludge hauling would occur periodically.	Operation: Same as Alts. 8A&8
	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.

Table 4-1 continued.

	No Action Alternative	Alternatives 2-5	Alternative 6	Alternative 7	Alternative 8A & 8B	Alternative 9
Recreation & Tourism	Construction: No significant impacts are anticipated.	Construction: Access to recreation facilities interrupted by construction activities may curtail recreational and tourist activities. Construction of discharge lines into surface waters would temporarily interrupt use of that shoreline under Alts. 2, 4, 5A & 5B.	Construction: Same as Alt. 2-5	Construction: Same as Alt. 2-5 except impacts arising from construction of discharge lines into surface waters would be avoided.	Construction: No significant impacts are anticipated.	Construction: No significant impacts are anticipated.
	Operation: Odors emanating from failing on-site systems may curtail outdoor recreational activities in the near vicinity.	Operation: Recreational activities would be curtailed by the degradation of surface water quality created by discharge of pollutants from failing WWTP's under Alts. 2, 4, 5A&5B.	Operation: Same as Alts. 2-5	Operation: No significant impacts are anticipated.	Operation: Odors emanating from malfunctioning on-site systems may curtail outdoor recreational activities in the near vicinity.	Operation: Same as Alts 8A&8B
	Secondary: Increased and continuing nuisances created by failing on-site system would detract from the study areas reputation as a desirable recreational area. Recreation and tourist activities would likely decline.	Secondary: Significant increases in water quality may increase recreational and tourist activities.	Secondary: Same as Alt. 2-5	Secondary: Same as Alt. 2-5	Secondary: Same as Alt. 2-5	Secondary: Same as Alt. 2-5

Table 4-1 continued.

	No Action Alternative	Alternatives 2-5	Alternative 6	Alternative 7	Alternative 8A & 8B	Alternative 9
Cultural Resources	Construction: No significant impacts are anticipated.	Construction: Construction activity associated with wastewater treatment facilities will not adversely affect historic sites or buildings within the study area. Adverse impacts which may affect archeological sites are impossible to assess at this time because of lack of readily available data. Construction excavations could uncover significant cultural resources which otherwise might not be found.	Construction: Same as Alt. 2-5	Construction: Same as Alt 2-5	Construction: Same as Alt. 2-5	Construction: Same as Alt. 2-5.
	Operation: No significant impacts are anticipated.	Operation: No significant impacts are anticipated.	Operation: No significant impacts are anticipated.	Operation: No significant impacts are anticipated.	Operation: No significant impacts are anticipated.	Operation: No significant impacts are anticipated.
	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.

Table 4-1 continued.

	No Action Alternative	Alternatives 2-5	Alternative 6	Alternative 7	Alternative 8A & 8B	Alternative 9
Energy	Construction: No significant impacts are anticipated.	Construction: Trucks and construction equipment would temporarily increase demand for local supplies of fossil fuel.	Construction: Same as Alt. 2-5	Construction: Same as Alt 2-5	Construction: Same as Alt. 2-5	Construction: Same as Alt. 2-5
	Operation: No significant impacts are anticipated.	Operation: Requires more electricity and fossil fuel than Alts. 8A, 8B&9.	Operation: Same as Alts. 2-5	Operation: Same as Alt. 2-5	Operation: Requires less electricity and fossil fuel than Alts. 2-5.	Operation: Same as Alt. 8A&8B
	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.	Secondary: No significant impacts are anticipated.

4.1. Primary Impacts

4.1.1. Construction Impacts

Each of the alternatives, excluding the No Action Alternative, involve some construction initially; thus, these are called "build" alternatives throughout the impact analyses. The No Action Alternative includes some construction of new systems and upgraded systems throughout the life of the project; therefore, this is discussed under operation impacts (Section 4.1.2.). The impacts are addressed in the following subsections for each of the major categories of the natural and man-made environments.

4.1.1.1. Atmosphere

Construction activities associated with the "build" alternatives cluster drainfields, and on-site systems will produce short-term adverse impacts to local air quality. Cleaning, grading, excavating, backfilling, and other related construction activities will generate fugitive dust, noise, and odors. Emission of fumes and noise from construction equipment will be a temporary nuisance to residents living near the construction sites.

4.1.1.2. Soil Erosion and Sedimentation

Soils exposed during construction will be subjected to accelerated erosion until the soil surface is protected by revegetation or other means. Most of the sewers and force mains will be laid within road right-of-ways where runoff tends to concentrate in roadside drainageways. Most rainfalls do not result in significant runoff because the sandy soils readily absorb precipitation. Major storms, though, could cause considerable erosion in some drainageways that have large drainage areas. The alternatives that involve considerable lengths of sewers and force mains can be expected to result in the greatest erosion and subsequent sedimentation. Adverse consequences due to increased sedimentation include excessive phosphorus inputs to lakes and streams, clogging of road culverts, localized flooding where drainageways are filled with sediment, and filling of lakes so that a substrate for macrophyte growth is provided.

4.1.1.3. Surface Water

Wastewater collection system and treatment plant construction activities (Alternatives 2-7) could produce discharge of turbid waters pumped from excavations and trenches and turbid surface runoff from disturbed areas resulting in increased turbidity and sedimentation in adjacent wetlands, lakes, or waterways. This sediment transport could result in water quality degradation and the potential for adverse impacts to aquatic biota. Upgrading on-site systems (Alternatives 8A, 8B, and 9) and construction of collection systems for cluster drainfields (Alternatives 8A and 8B) would contribute turbid runoff to lakes or waterways, but to a lesser extent compared to the construction of the centralized collection and treatment alternatives.

4.1.1.4. Groundwater

Groundwater may be impacted by construction activities in localized areas. Construction dewatering may cause some shallow wells to fail, especially where pump stations are to be constructed. A potential change in water quality would likely occur where organic soils are disturbed either directly or by altering the watertable. Organics may leach out of these areas and affect the taste of water in nearby wells. Spilled fuel and other construction materials could quickly pass through the sandy soils to contaminate the groundwater.

4.1.1.5. Terrestrial Biota

Construction activities associated with various components of the proposed alternatives would result in impacts to wildlife and vegetation to various degrees. Collection sewers (Alternatives 2-7), some cluster drainfields (Alternatives 8A and 8B), and upgraded systems (Alternative 9) would be placed on residential lots; temporary loss of grassed areas and the removal or death of trees would result from construction of these facilities. Disruption of backyard vegetation and the presence of construction equipment and noises would cause temporary displacement of most vertebrate species and mortality of a few (probably small mammal) species, but replacement of vegetation and cessation of construction activities would allow re-establishment of the

animals to the areas. More likely the animals commonly associated with human habitation (e.g., eastern cottontail rabbits, house sparrows, European starlings) that would be displaced, would move to suitable neighboring habitat and induce no density-related stress upon neighboring habitats.

Proposed conveyance lines for Alternatives 2 through 7 generally parallel and are contiguous to existing road rights-of-way. Approximately 20 feet of roadside vegetation would be destroyed during construction along county road right-of-ways and approximately 50 feet would be disrupted for placement of force mains along M-62.

Agricultural cropland and orchards are the primary land uses along the proposed lines. Small woodlots border the routes at scattered locations; second-growth roadside shrubbery would likely be destroyed.

Birds and mobile mammals, reptiles, and amphibians that reside on or near the proposed routes would migrate from disturbed areas during construction. Small mammals and reptiles would incur some mortality from construction. Displacement of most animals would be temporary, however, coinciding with the duration of construction.

The placement of WWTPs and some cluster drainfields proposed for Alternatives 2-7 and 8A and 8B, respectively, would adversely affect vegetation and wildlife to varying degrees, during construction, depending upon the proposed site.

A new WWTP in Section 11 would require 80 (Alternative 2) to 100 acres (Alternative 4). Construction activities would disrupt a larger area of agricultural cropland and possibly adjacent wetlands. Any wetlands construction involving fill would require a Section 404 permit issued by the US Army COE or MDNR permits issued by the Division of Land Resources Program.

Construction of the proposed WWTPs at this site would result in the permanent displacement or mortality of various animals commonly associated with cultivated fields. This habitat does not support a highly diverse vertebrate population, however, so losses would not be significant. Following

completion of construction, areas adjacent to the proposed plant would probably be reoccupied by wildlife communities similar in composition to preconstruction communities.

Construction activities associated with the proposed WWTP on agricultural land in Sections 8 (Alternative 3) and 29 and 32 (Alternatives 2 and 5) probably would not destroy any native vegetation. A larger area (100 acres) would be required for Alternatives 3 and 5 than would be needed for Alternative 2 (25 acres). No wetlands would be affected during construction of the WWTP at either site, but outfall sewers for the proposed plants in Sections 29 and 32 may disrupt a wetland area occurring along the receiving stream. No significant impacts to terrestrial wildlife would be expected. Disruption of existing communities would be similar to that expected in Section 11.

Conversion of orchard to agricultural cropland would be necessitated to accommodate the land application site proposed for Section 8. The area required would depend upon exact placement of the site. This change in vegetation would represent a permanent decrease in habitat diversity and result in a corresponding change in diversity of vertebrate populations.

Placement of cluster drainfields surrounding the lakes (Alternatives 8A and 8B) would primarily be adjacent to residential areas, and little disruption of vegetation or wildlife would be expected by construction activities. Temporary displacement of wildlife in the vicinity of construction is likely to occur, but no permanent adverse effects would be expected.

The impacts on terrestrial biota that would result from upgrading the existing systems (Alternative 8A, 8B, and 9) would be insignificant because a relatively small amount of construction on developed land would be required to complete the project.

4.1.1.6. Land Use

Construction activities associated with the implementation of any of the "build" alternatives would require some conversion of land use in the study area. Under Alternatives 2-5 residential, agricultural, orchard, forests, and

wetland areas would be affected to varying degrees. The construction of WWTPs under these alternatives would require the greatest conversion of land, primarily agricultural land. Under Alternative 3 two hundred and fifty-five acres of cultivated crop land and orchards, located in Section 8 of Silver Creek Township, would be used as part of a regional treatment and land disposal system. The orchards would be converted to cultivated cropland. Less than 1% of the agricultural land within the study area would be converted to lagoons for wastewater treatment purposes. Under Alternatives 2, 4, 5A, and 5B less than 2% of the agricultural land within the study area (less than 1% of the agricultural land within the four township area) would be used for the construction and operation of WWTPs. The existing Dowagiac WWTP would be used under Alternative 6 and 7, eliminating the need for any significant changes in land use within the study area.

The construction of a sewer system under Alternatives 2-7 would occur primarily in residential areas, however, certain environmentally sensitive areas would be affected. Agricultural, wetland, orchard, and forest areas will be traversed by connector sewers under these alternatives. Following construction of the sewer systems a 30 to 40 foot easement may be enforced to insure access to the sewer system for repairs and maintenance. The magnitude of these impacts is not anticipated to be significant because most of the sewer system would follow existing rights-of-way, such as those along roadways.

Wetlands may be subject to sedimentation during construction of the sewer collection system. Water circulation patterns within these wetlands may be permanently modified. Excavation, clearing, grading, and backfilling may temporarily affect the productivity and aesthetic value of wetland agricultural, orchard, and forest lands during construction of conveyance lines.

The construction of on-site and cluster systems under Alternatives 8A, 8B, and 9 would occur primarily on lots which are already developed for residential use. Some cluster systems may be built on land designated as being agricultural or open space which is adjacent to residential areas. An insignificant amount of these areas would be necessary for the construction of cluster systems. No significant overall land use impacts would occur under Alternatives 8A, 8B, and 9.

Prime Agricultural Land

The amount of prime agricultural farmland, as classified by the SCS, affected by construction activities is dependent upon the actual location of the wastewater treatment facilities. No information on prime agricultural farmland is available for Section 11 (Cass County) of the study area, therefore it is impossible at this time to assess impacts under Alternatives 4 and 6. Under Alternatives 2, 3, 5A, and 5B, the affects of construction activities associated with wastewater treatment are dependent upon the exact location of those facilities in Sections 8, 29, and 32. These sections contain prime agricultural farmland. The irreversible loss of agricultural land to other land uses is a growing national concern. The Council on Environmental Quality (CEQ) issued a memorandum (CEQ 1976) to all Federal agencies requesting that efforts be made to insure that prime and unique farmlands (as designated by SCS) are not irreversibly converted to other uses unless other national interests override the importance or benefits derived from their protection.

The USEPA has a policy of not allowing the construction of a treatment plant or the placement of interceptor sewers, funded through the Construction Grants Program, in prime agricultural lands unless it is necessary to eliminate existing point discharges and accommodate flows from existing habitation that violates the requirements of the Clean Water Act (USEPA 1981b). The policy of USEPA is to protect prime agricultural land from being adversely affected by primary and secondary impacts. It is considered to be a significant impact if 40 or more acres of prime agricultural land are diverted from production.

Less than 40 acres of prime agricultural land are likely to be affected under Alternatives 2-6. These lands would be taken out of production for use as lagoons, treatment facilities, buffer zones, and access roads. The actual amount of acres of prime agricultural land taken out of production for these treatment alternatives is dependent upon the precise location and placement of the treatment sites and interceptor routes.

Less than 40 acres of prime agricultural land are likely to be converted for use as cluster system sites under Alternatives 8A and 8B. Therefore, no significant impacts are expected to occur.

4.1.1.7. Demography

Temporary jobs created by the construction of wastewater collection and treatment facilities under the "build" alternatives are not likely to attract any new permanent residents to the study area. These positions would be filled by workers from the study area and surrounding three-county area. Some seasonal residents may reduce time spent in their study area home while construction of on-site or sewer systems occurs on their property. No significant demographic impacts will occur during construction of wastewater facilities.

4.1.1.8. Economics

The construction of wastewater treatment facilities under the "build" alternatives would create a limited number of short-term construction jobs. Masons, pipefitters, heavy equipment operators, electricians, truck drivers, plumbers, roofers, painters, and carpenters would be among the tradesmen necessary to complete construction of the proposed facilities. Most jobs would be filled by persons living within the study area or within a reasonable commuting distance of the study area.

The purchase of construction materials from study area merchants would benefit the local economy. However, few firms offering materials required for the construction of wastewater facilities are established within the study area. Thus, most materials would be imported from outside of the study area. Purchases made by construction workers within the study area also would benefit the local economy. These purchases would likely be for fuel, food, and clothing. Patronage may be reduced for some business along sewer lines when road closings and disruptions occur. No significant economic impacts are anticipated to occur during the construction of wastewater facilities under any of the alternatives.

4.1.1.9. Recreation and Tourism

Any increase or decrease of tourism and the use of recreational facilities, within the study area, attributable to the construction of wastewater facilities is dependent upon construction activities which detract from study area recreational amenities. Most recreational activities in the study occur on or along the perimeter of the lakes. No major air, water, noise, or traffic impacts are expected to occur near the lakes which would interupt tourism and recreation activities. Under Alternatives 5A and 5B the construction of a discharge line into Indian Lake would create a temporary and minor interruption of use along that shoreline of Indian Lake. Access to recreation facilities interrupted by construction activities may curtail some recreation and tourist activities. However, these impacts are not anticipated to be significant.

4.1.1.10. Transportation

Increased truck and grading equipment traffic during the construction of wastewater treatment facilities under the "build" alternatives would increase street congestion. Vehicular traffic would be inconvenienced by excavating, grading, backfilling, and temporary road closures during construction of conveyance lines along roadways under Alternatives 2-7, 8A, and 8B. The inconvenience experienced during these periods is not anticipated to be significant.

4.1.1.11. Energy Resources

Residential, commercial, and industrial energy requirements are not likely to be affected during the construction of wastewater facilities under any of the alternatives. Active competition for specific energy sources would become apparent if a national fuel crisis reoccurred such as the one precipitated by the oil embargo of 1977. Trucks and construction equipment used during the construction of wastewater treatment facilities would increase demand for local supplies of gasoline and diesel fuel. The highest demand created by trucks and construction equipment would occur under Alternatives 6 and 7. The lowest energy demand created by trucks and construction equipment

would occur under Alternatives 8A, 8B, and 9. No significant demands on local energy supplies are anticipated during construction of wastewater facilities under any of the alternatives.

4.1.1.12. Cultural Resources

Archaeological data for the study area are unprocessed and not readily available (Section 3.2.8.). Three structures in the study area are listed on the Michigan Register of Historic Sites. Fourteen additional sites of architectural significance were identified by WAPORA personnel in 1979 (Section 3.2.8.). Because no research has been completed, it is impossible to assess adverse impacts attributable to construction activities which may affect historic, archaeological, and architectural sites (By letter, Martha M. Bigelow, Director, Michigan History Division and State Historic Preservation Officer, to WAPORA, Inc., 8 January 1979). Final routings and WWTP sites should be presented to the SHPO for assessment before construction activities begin. Construction excavations could uncover significant cultural resources which otherwise might not be found. To provide adequate consideration of impacts affecting these resources an archaeological survey of specific sites should be conducted following the selection of an alternative.

4.1.2. Operation Impacts

Each of the alternatives, including the No Action Alternative, involve operations that will continue through the project period. Included in the definition of operations are constructing new septic tank systems for new structures and upgrading on-site systems that fail under the No Action Alternative and Alternatives 8A, 8B, and 9. The impacts are addressed for each of the major categories of the natural and man-made environments.

4.1.2.1. Atmosphere

The potential emissions from the operation of the wastewater management alternatives include aerosols, hazardous gases, and odors. The emissions could pose a public health risk or be a nuisance.

Aerosols are defined as solid or liquid particles, ranging in size from 0.01 to 50 micrometers that are suspended in the air. These particles are produced at wastewater treatment facilities during various treatment processes. Some of the constituents of aerosols could be pathogenic and could cause respiratory and gastrointestinal infections. Concentrations of bacteria or viruses in aerosols, however, are generally insignificant (Hickey and Reist 1975). The vast majority of the microorganisms in aerosols are destroyed by solar radiation, desiccation, and other environmental phenomena. There are no records of disease outbreaks resulting from pathogens present in aerosols. Therefore, no adverse impacts are expected from aerosol emissions for any of the alternatives.

Discharges of hazardous gases could have adverse affects on public health and the environment. Explosive, toxic, noxious, lachrymose (causing tears), and asphyxiating gases can be produced at wastewater treatment facilities. These gases include chlorine, methane, ammonia, hydrogen sulfide, carbon monoxide, nitrogen oxides, sulfur, and phosphorus. The knowledge of the possibility that such gases can escape from the facilities or into work areas in dangerous or nuisance concentrations might affect the operation of the facilities and the adjacent land uses. Gaseous emissions, however, can be controlled by proper design, operation, and-maintenance procedures.

Odor is a property of a substance that affects the sense of smell. Organic material that contains sulfur or nitrogen may be partially oxidized anaerobically and result in the emission of byproducts that may be malodorous. Common emissions, such as hydrogen sulfide and ammonia, are often referred to as sewer gases and have odors of rotten eggs and concentrated urine, respectively. Some organic acids, aldehydes, mercaptans, skatoles, indoles, and amines also may be odorous, either individually or in combination with other compounds. Sources of wastewater treatment related odors include:

- Fresh, septic, or incompletely treated wastewater
- Screenings, grit, and skimmings containing septic or putrescible matter
- Oil, grease, fats, and soaps from food handling enterprises, homes, and surface runoff

- Gaseous emissions from treatment processes, manholes, wet wells, pumping stations, leaking containers, turbulent flow areas, and outfall areas
- Raw or incompletely stabilized sludge or septage.

Wastewater stabilization lagoons typically emit considerable odors when the ice cover goes out in the spring. These odors are likely to be noticeable for at least one-half mile in the wind direction. Odors from septic tank effluent sewers may escape from lift stations where turbulent flow occurs unless proper design steps are taken to minimize odors. Sewage may become septic and odorous in the lengthy force mains that are part of some alternatives, especially during the low-flow winter season.

The occasional failure of an on-site system may release some odors. Septage haulers using inadequate or improperly maintained equipment may create odor nuisances.

4.1.2.2. Soils

The operation of the land application site and cluster drainfield sites for wastewater treatment would alter the soils of these sites over the life of the project. The potential changes depend on the existing soil chemical and hydraulic properties and on the chemical characteristics and application rate of the effluent. The cropping and tillage practices on the land application sites will, to some extent, effect the changes in the soil.

The chemical and physical properties of typical soils of the area are given in Appendix G and a report by Ellis and Erickson (1969). The pH, cation exchange capacity, and phosphorus retention capacity are adequate to insure that most constituents in the effluent will be removed effectively at the proposed irrigation rates.

Organic constituents in the applied water would be oxidized by natural biological processes within the top few inches of soil (USEPA and others 1977). At Muskegon, Michigan the BOD of renovated water from the underdrainage system ranged from 1.2 mg/l to 2.2 mg/l (Demirjian 1975). Suspended solids in the applied water also are removed by the soil through filtration.

The volatile solids are biologically oxidized and inorganic solids become part of the soil matrix (USEPA and others 1977).

Phosphorus would be present in the storage pond or septic tank effluent in an inorganic form as orthophosphate (primarily HPO_4^{-2}), as polyphosphates (or condensed phosphates), and as organic phosphate compounds. Because the pH of wastewater is alkaline, the predominant form usually is orthophosphate (USEPA 1976). Polyphosphate is converted quickly to orthophosphate in conventional wastewater treatment, in soil, or in water. Dissolved organic phosphorus is converted more slowly (day to weeks) to orthophosphate.

When effluent is applied to soils, dissolved inorganic phosphorus (orthophosphate) may be adsorbed by the iron, aluminum, and/or calcium compounds, or may be precipitated through with soluble iron, aluminum, and calcium. Because it is difficult to distinguish between adsorption and precipitation reactions, the term "sorption" is utilized to refer to the removal of phosphorus by both processes (USEPA and others 1977). The degree to which wastewater phosphorus is sorbed in soil depends on its concentration, soil pH, temperature, time, total loading, and the concentration of other wastewater constituents that directly react with phosphorus, or that affect soil pH and oxidation-reduction reactions (USEPA and others 1977).

The phosphorus in the absorbed phase in soil exists in equilibrium with the concentration of dissolved soil phosphorus (USEPA and others 1977). As an increasing amount of existing adsorptive capacity is used, such as when wastewater enriched with phosphorus is applied, the dissolved phosphorus concentration similarly will be increased. This may result in an increased concentration of phosphorus in the percolate, and thus in the groundwater or in the recovered underdrainage water.

Eventually, adsorbed phosphorus is transformed into a crystalline-mineral state, re-establishing the adsorptive capacity of the soil. This transformation occurs slowly, requiring from months to years. Work by various researchers indicates that as much as 100% of the original adsorptive capacity may be recovered in as little as 3 months. However, in some instances it may take years for the adsorptive capacity to fully recover because the active

cations may become increasingly bound in the crystalline form. The possible amount of phosphorus that could precipitate to the crystalline form, based on a 2% to 4% iron and 5% to 7.5% aluminum soil content, is estimated to be 250,000 pounds of phosphorus per acre-foot of soil (Ellis and Erickson 1969).

Dissolved organic phosphorus in applied wastewater can move quickly through the soil and enter the groundwater. Adequate retention of the wastewater in the unsaturated soil zone is necessary to allow enough time for the organic phosphorus to be hydrolized by microorganisms to the orthophosphate form. In the orthophosphate form, it then can be adsorbed.

A limited phosphorus sorption test was conducted following the methodology utilized by Enfield and Bledsoe (1975). The data from this 5-day test for samples from the study area indicate a range of phosphorus adsorption values of from 62 mg/kg to 371 mg/kg. The adsorptive capacity of the soils apparently decreases with depth. This reflects the lower organic matter content and reduced soil development with increasing depth.

The surface soil of the loamy sands sampled (up to approximately 5 feet) has an average phosphorus adsorptive capacity of approximately 165 mg/kg. The underlying material below 5 feet was not extensively sampled, and no samples were taken from below a depth of 68 inches. Assuming that soil forming processes are less and the grain-size is larger at depths in excess of 5 feet, a conservative estimate of 50 mg/kg for a 5-day test equivalent value appears reasonable. Enfield and Bledsoe (1975) determined that phosphorus sorption after a 4-month test period was from 1.5 to 3.0 times the 5-day sorption value, reflecting a more steady-state approximation. An approximation for long-term sorption would be greater, a value of 3.5 was used in this study.

Based on similar analyses (Ellis and Erickson 1969), the study area soils should have adequate sorption capacity for phosphorus where drain beds of current design are constructed. The water quality sampling results appear to verify it. Because dry wells result in a considerably smaller soil mass being contacted by the percolating effluent as compared to drain beds and drainfields, the soil material would become saturated more quickly with phosphorus. Also, the dry well introduces effluent lower in the soil profile where the

sorption capacity of soils is generally lower. Ellis and others (1978) recommended that dry wells be discontinued from further application for that reason. Increases in phosphorus levels in groundwater over time can be expected, although the specific increases would be highly variable, and minimal where the residence is occupied seasonally.

The alternative that incorporates land application of lagoon effluent for treatment would result in increased levels of phosphorus in the soils. Irrigation onto the soil surface utilizes the surface soil for sorption of phosphorus. These surface soils have considerably greater sorption capabilities than the underlying soil (Appendix G).

Nitrogen loadings in the wastewater are of greatest concern. Nitrogen would be present in applied wastewater principally in the form of ammonium (NH_4), nitrates (NO_3), and organic nitrogen. When wastewater is applied to soils, the natural supply of soil nitrogen is increased. As in the natural processes, most added organic nitrogen slowly is converted to ionized ammonia by microbial action in the soil. This form of nitrogen, and any ionized ammonia in the effluent, is adsorbed by soil particles.

Plants and soil microbes both utilize ammonium directly. Microbes oxidize ammonium to nitrite (NO_2) that is quickly converted to the nitrate (NO_3) form through nitrification. Nitrate is highly soluble and is utilized by plants, or leached from the soil into the groundwater. Under anaerobic conditions (in the absence of oxygen), soil nitrate can be reduced by soil microbes to gaseous nitrogen forms (denitrification). These gaseous forms move upward through the soil atmosphere and are dissipated into the air. Denitrification depends on organic carbon for an energy source; thus, the interface between natural soil and the gravel fill in a drain bed has both requisite characteristics for denitrification.

Unlike phosphorus, nitrogen is not stored in soils except in organic matter. Organic matter increases within the soils would result from increased microbial action and from decreased oxidation. The increased organic matter improves the soil tilth (workability), water holding capacity, and capability of retaining plant nutrients.

4.1.2.3. Surface Waters

Nutrient Loads to Lakes and Rivers of the Study Area

A major water quality concern in the study area is the acceleration of eutrophication in the lakes. Two important nutrients in the eutrophication process are nitrogen and phosphorus (Zevenboom and others 1982) with phosphorus usually recognized as the most important (Smith and Shapiro 1981). To evaluate the impact of the alternatives, nutrient loading levels for phosphorus were calculated. Changes in phosphorus loadings due to wastewater management alternatives are presented in Table 4-2. These changes reflect the percent increase or decrease of phosphorus loading compared to the current loading rates estimated in Section 3.1.3.4.

If the No Action Alternative were implemented in the study area the phosphorus loading to all lakes would increase compared to present conditions (Table 4-2). The increase is based on future population estimates around Indian Lake and Sister Lakes. An increased population would use additional on-site systems, resulting in greater phosphorus loads to the lakes. Alternatives 2-7 offer the largest percent decrease in phosphorus loads to the lakes. A centralized collection system effectively eliminates phosphorus loads asso-

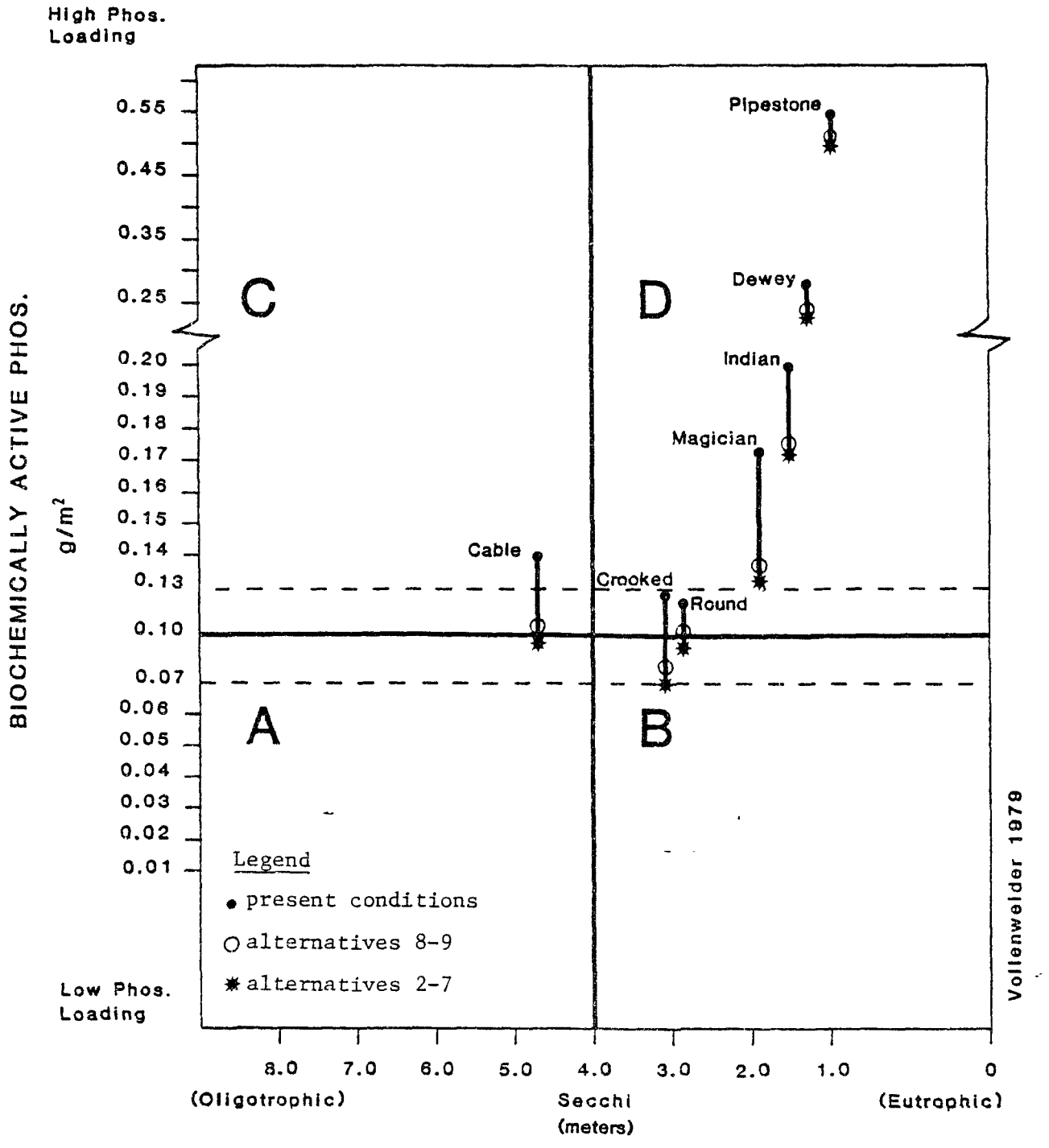
Table 4-2. Comparison of phosphorus loading rates associated with the various alternatives to the current loading rates.

Lake	No Action	Alternatives 2-7	Alternatives 8A & 8B	Alternative 9
Cable	5% increase	29% decrease	26% decrease	26% decrease
Crooked	8% increase	45% decrease	39% decrease	39% decrease
Dewey	2% increase	11% decrease	10% decrease	10% decrease
Indian	2% increase	14% decrease	13% decrease	13% decrease
Magician	4% increase	25% decrease	22% decrease	22% decrease
Pipestone	1% increase	5% decrease	4% decrease	4% decrease
Round	5% increase	27% decrease	24% decrease	24% decrease

ciated with on-site systems. Crooked Lake would experience the largest percent decrease. Alternatives 8A, 8B, and 9 are similar to the reduced phosphorus loads associated with the alternatives using centralized collection systems for several reasons. Jones and Lee (1977) demonstrated that a properly designed and installed septic tank drainfield could remove nearly 100% of the phosphorus load from the septic effluent. It was assumed for Alternatives 8A, 8B, and 9 that upgrading existing on-site systems and placing critical areas on a cluster collection system or on holding tanks would result in a 90% decrease in the phosphorus load from on-site systems compared to present conditions.

The changes in phosphorus loading imposed by various wastewater alternatives could affect the trophic status and management considerations of some of the lakes in the study area. Current trophic status is based on secchi disc readings, chlorophyll a, and phosphorus concentrations (when available; Section 3.1.3.2.2.). Future trophic conditions will be influenced by in-lake phosphorus concentrations, which are a function of the phosphorus load and other physical-chemical characteristics of each lake basin. It appears the "build" alternatives (Alternatives 2-7) would reduce the phosphorus load so that water quality would be enhanced for three lakes; Cable, Crooked, and Round. Some improvement in Magician Lake may occur, but Dewey Lake, Indian Lake, and Pipestone Lake would likely remain eutrophic (Figure 4-1). Implementation of Alternatives 8A, 8B or 9 is predicted to have effects similar to Alternatives 2-7 (Figure 4-1). The information plotted on Figure 4-1 should be interpreted with caution. Phosphorus loads and lake response is based on information currently available. In addition, the management schemes (Figure 4-1) have assumed that lake basins and the biological lake components respond in similar fashions. This is not always the case. Phosphorus dynamics and biological production will be greatly affected by unique factors occurring within each lake basin, which are unquantified at this time.

Some rivers of the study area would be directly impacted by discharge of wastewater effluents to a receiving stream under Alternatives 2, 4, 5A, 5B, 6, and 7 which include collection sewers and centralized treatment. Release of the treated wastewater effluent from the stabilization lagoons would occur between 1 March and 15 May annually. The release rate during this period is designed to cause minimum impacts.



A. No nutrient abatement steps necessary.
B. Strong renewal potential; long term benefits may be possible without extensive nutrient abatement.
C. Prompt action needed; degradation may be imminent if nutrient abatement steps are not taken.
D. Problem lakes; renovation desirable but lasting improvement may require extensive nutrient abatement.

Figure 4-1. Future phosphorus loading conditions for the centralized wastewater management alternatives (after Vollenweider 1979; Uttormark and Wall 1975).

The nutrient loads discharged to Silver Creek or Indian Lake Outlet coincide with high river flows of this time of year; thus, the nutrient loads would be assimilated by the streams. Slightly elevated nutrient levels should not be detrimental to the ecology of the receiving streams. Increased discharges to Dowagiac Creek from the Dowagiac WWTP would occur under Alternatives 6 and 7. The increased continuous discharge would affect Dowagiac Creek to some extent, although the assimilative capacity of the Creek was calculated when the effluent limits were set. The Dowagiac River, a cold water stream, would be affected to some extent by any of the wastewater treatment alternatives that have discharges to surface waters.

Coliform Bacteria Levels in Lakes and Rivers

Data regarding bacterial contamination of the lakes in the study area are somewhat inconclusive. Bacterial sampling efforts usually have involved one sample at each station for a single date. Federal Water Quality Regulations require that violations of standards be based on the geometric mean of a minimum of five samples.

Continued reliance on existing systems (No Action Alternative) in areas of high water tables (e.g., Pipestone Lake) has potential for bacterial contamination. For the "build" alternatives, the wastewater management alternatives should effectively prevent these problems, although bacteria contamination problems are still a possibility with centralized alternatives in case of pumping station malfunctions or with upgraded on-site systems in case of surface ponding of the effluent.

Land application of wastewater (to be considered under Alternative 3) is an effective way of eliminating or immobilizing sewage-borne pathogens. In fine-textured soil, bacteria can be filtered out by 1 to 2 meters of soil. Soils containing clay remove most organisms through adsorption. Sandy soil removes them through filtration (Lance 1978).

Suspended Solids and Organic Carbon Levels in Lakes and Rivers

Alternatives implementing on-site systems (Alternatives 8A, 8B, and 9) should effectively remove suspended solids from the wastewater effluent. Dissolved organic substances may move with the groundwater into the lakes. In the study area lakes the septic leachate survey detected groundwater plumes in each of the lakes. The groundwater plumes contain dissolved organics and salts as components. Dissolved organics will exert a BOD resulting in the consumption of dissolved oxygen within a lake. Within a properly maintained on-site system, BOD movement to lake waters should be insignificant.

Centralized collection and treatment alternatives that use receiving streams for discharge of treated wastewater effluents (Alternatives 2, 4, 5A, 5B, 6, and 7) have the discharge timed for release during the spring runoff period. The waste stabilization lagoons are designed to meet State and Federal discharge standards. Suspended solids and dissolved organics are expected to exert a BOD in the receiving stream that could depress dissolved oxygen levels. But most of the residual BOD and ammonia should be oxidized in the respective streams. Increased effluent discharge from the Dowagiac WWTP to Dowagiac Creek in Alternatives 6 and 7 would result in increased suspended solids and dissolved organic loadings. These should be within the discharge standards for the stream if the plant is designed and operated properly. Chlorination of the effluent from the Dowagiac plant may result in chlorinated organics (e.g., trihalomethanes) that are known to be carcinogenic.

Lake water levels may decline slightly with the centralized collection alternatives because water would be exported from the basin. Only Pipestone Lake has a continuous surface water discharge and Indian Lake and Magician Lakes have intermittent discharges. The groundwater inflow and outflow of the lakes, which cannot be quantified with present information, does not appear to be large for any of the lakes; thus, export of lake water could potentially lower lake levels slightly. Assuming no change in inflows and outflows, a volume of water equivalent to 2 inches of water would be exported from the Sister Lakes during the summer. The significance of this export volume depends on the inflow-outflow relationships, the configuration of the shorelines, and the total volume of the lakes. Because the requisite information

is not available, the impact of these potential water level declines cannot be assessed.

4.1.2.4. Groundwater

Long-term impacts that could be encountered in the operational phase of any of the alternatives concern the following types of pollutants: bacteria, dissolved organics and suspended solids; phosphorus; and nitrate-nitrogen. Movement to groundwater of other wastewater constituents or of soil chemicals would occur, but are not expected to significantly affect any of the uses of the groundwater.

Bacteria and dissolved organics are readily removed by filtration and adsorption onto soil particles. Two feet of soil material is generally adequate for bacterial removal, except in very coarse-grained, highly permeable soil material. Contamination of drinking water wells or surface water with bacteria and dissolved organics in the study area is unlikely under any of the alternatives.

Phosphorus is significant in groundwater because it can contribute to the excessive eutrophication of lakes. Section 4.1.2.2. contains a discussion of phosphorus sorption in soils and supports the conclusion that, except for dry well soil absorption systems, phosphorus contributions to the groundwater from any of the alternatives would be minimal.

The ability to predict phosphorus concentrations in percolate waters from soil treatment systems has not yet been demonstrated (Enfield 1978). Models that have been developed for this purpose have not yet been evaluated under field conditions. Field studies have shown that most soils, even medium sands, typically remove in excess of 95% of phosphates in relatively short distances from effluent sources (Jones and Lee 1977).

One potential source of phosphorus inputs to groundwater are the soil absorption systems included in the No Action Alternative and Alternatives 8A, 8B, and 9. The groundwater quality analyses performed in conjunction with the "Septic Snooper" survey (Appendix B) confirm that some phosphorus is reaching

the lakes by way of the groundwater. The majority of groundwater plumes sampled, though, had phosphorus concentrations less than 0.02 mg/l (25 out of 33 effluent-related plumes). The contribution of phosphorus to the lakes from on-site systems has not been quantified from the sampling data, but from theoretical data. Thus, on-site systems are likely stimulating algal growth in localized areas where effluent plumes emerge, but their contribution to lake eutrophication is not quantifiable. The greatest quantity of phosphorus would be contributed to groundwater under the No Action Alternative. A slight amount of phosphorus would be contributed to the groundwater under the alternatives that continue to rely on on-site systems.

Alternative 3, which incorporates land application of lagoon effluent is not expected to significantly increase the phosphorus concentration in the groundwater. Irrigation onto the soil surface results in utilization of the complete soil profile for sorption in contrast to on-site systems which utilize only the subsoil. Phosphorus in groundwater under a land application site is of concern only when surface waters are affected. Groundwater from the site would likely flow primarily to the west, but partially to the Sister Lakes.

The wastewater stabilization lagoons which are components of all of the centralized alternatives, except Alternative 7, may contribute phosphorus to the groundwater if seepage from the lagoons is considerable. A study of Minnesota wastewater stabilization lagoons (EA Hickok and Associates 1978) concluded that none of the ponds (all had natural soil liners) were capable of meeting the designed and specified seepage rates. Most of the ponds studied removed phosphorus effectively, although some had seepage rates considerably higher than the maximum allowable.

Nitrates in groundwater are of concern at concentrations greater than 10 mg/l as nitrogen because they cause methemoglobinemia in infants who ingest liquids prepared with such waters. This limit was set in the National Interim Primary Drinking Water Regulations (40 CFR 141) of the Safe Drinking Water Act (PL 93-523). A general discussion of nitrogen in soils is presented in Section 4.1.2.2.

The density of soil absorption systems is said to be the most important parameter influencing pollution levels of nitrates in groundwater (Scalf and Dunlop 1977). That source also notes, however, that currently available "information has not been sufficiently definitive nor quantitative to provide a basis for density criteria." The potential for high nitrate concentrations in groundwater is greater in areas of multi-tier or grid types of residential developments than in single tier developments. Depending on the groundwater flow direction and pumping rates of wells, nitrate contributions from soil absorption systems may become cumulative in multi-tier developments. Thus, separation distances are critical for new construction and maximum density codes are crucial for new subdivisions.

The groundwater sampling results (Section 3.1.3.3.) from wells show that elevated nitrates (greater than 4 mg/l as nitrogen) occurred in 11 of the 60 wells that were sampled. Some of these wells appeared to have sources of nitrates other than soil absorption systems, particularly the wells on Keeler Lake. Other values (two were greater than 20 mg/l) may indicate direct pollution from the surface or anomalous sampling error because the wells are 45 and 46 feet deep. None of the wells which were sampled under the auspices of the Van Buren County Health Department had nitrates present that exceed the limit (By interview, Linda Surlow, Van Buren County Health Department, to WAPORA, Inc. 15 July 1981).

These high levels of nitrate would perpetuate under the No Action Alternative and increased violations of the drinking water quality standard would occur. The alternatives that include continued use of on-site systems and cluster systems may not necessarily result in declines in concentrations of nitrates in the groundwater. Wells that continue to have high nitrate concentrations may need to be deepened so that a hydraulically limiting layer is penetrated.

Cluster drainfields are designed similarly to individual drainfields to ensure an adequate areal distribution of the effluent for satisfactory removals of phosphorus. Nitrate concentrations within the groundwater below a cluster drainfield are anticipated to be equivalent to those below an individual soil absorption system. Insufficient experimentation has been conducted

to enable designing for nitrogen removals from septic tank effluent. One precaution would be to locate the drainfield as far from wells as feasible. Once nitrates enter the groundwater, dilution is the only practical means of reducing the concentration.

Lagoon effluent typically contains nitrogen levels of approximately 12 mg/l (Urie 1979; Urie and others 1978). Nitrates in the groundwater below the land application sites probably would average considerably less than 10 mg/l, the drinking water quality standard. Volatilization, crop uptake and removal, soil storage, and denitrification would account for removal of nitrogen from the applied effluent. Some increase in nitrate concentration above background levels is anticipated, but no significant adverse impacts on the environment or proposed use is anticipated.

Seepage from the wastewater stabilization lagoons could result in elevated nitrate levels in the groundwater below the lagoons. Clay liners are not impermeable and plastic liners can be punctured or experience deterioration. Field studies (EA Hickok and Associates 1978) have shown that a seepage rate of 500 gallons per acre per day is very difficult to achieve even on in-place, fine-textured soils. On medium- to coarse-textured soils, the quality of the liner is of utmost concern for protection of groundwater quality. Monitoring wells are to be installed as part of lagoon construction and these are to be sampled on a regular basis. The sampling program would identify problems before neighboring residents are affected.

Changes in groundwater levels would occur with the centralized alternatives. Export of water from the lakeshore areas where it is typically recharged to the wastewater treatment system would change the groundwater levels slightly. The greatest change in groundwater levels would occur in the vicinity of the land application site. Inadequate data have been assembled to accurately predict the water table rise. The water table rise would affect not only the land application site, but also the surrounding area and the normal outflow areas. Either draintile or recovery wells on the land application area would prevent the water table from rising to the surface, if it is shown to be necessary through further studies.

4.1.2.5. Terrestrial Biota

The land disposal site proposed in Section 8 under Alternative 3 would affect the terrestrial biota during plant operation, however, no significant adverse long-term effects would be expected during normal plant operating conditions. Wildlife may avoid the area during waste application. Periodic monitoring should be performed to detect the presence of potentially harmful concentrations of heavy metals, other toxic susbstances, or micronutrients in the soil, crops, or other vegetation.

4.1.2.6. Land Use Impacts

The land use conversions discussed in Section 3.2.2. would remain in effect for the operation of the proposed wastewater treatment facilities under the "build" alternatives. Land use under the easement of sewage conveyance lines would be intermittently affected when maintenance or repairs were performed on sections of the lines. Periodic excavating and filling would disturb vegetation and soil along conveyance lines. The release of low level odors and aerosols from WWTPs and the knowledge that hazardous gases could potentially be released from those plants may affect land use adjacent to the plants. Improper maintenance of cluster and on-site systems may create malodorous conditions which would adversely affect adjacent land uses.

4.1.2.7. Demographics

The operation and maintenance of wastewater facilities proposed under the "build" alternatives will not have a significant impact on the demography of the study area. A limited number of long-term jobs created by the operation and maintenance of these facilities likely will be filled by persons living within the study area or within commuting distance. No new residents are expected to be attracted to the study area to fill these positions.

4.1.2.8. Economics

The operation of wastewater facilities under Alternatives 2, 3, 4, 5A, 5B, and 6 would create a few long-term jobs. These jobs could be filled by

persons residing in the study area. No new jobs would be created under Alternative 7. The existing staff at the Dowagiac WWTP is expected to assume any additional responsibilities as a result of implementing Alternative 7.

No new jobs are anticipated to be created under Alternatives 8A, 8B, and 9. Existing contractors are expected to satisfy local demand for construction and maintenance services of on-site systems. Contractors and tradesmen involved in the construction and maintenance of on-site systems will suffer a loss of work opportunities within the study area under Alternatives 2, 3, 4, 5A, 5B, 6, and 7. These contractors and tradesmen are likely to compete for work opportunities in neighboring areas. No significant economic impacts will occur during the operation of wastewater treatment facilities under any of the alternatives.

4.1.2.9. Recreation and Tourism

The operation of wastewater facilities under any of the "build" alternatives could affect tourist and recreational activities in the study area if a malfunction of those facilities occurred. A failure in the system components of the WWTPs under Alternatives 2, 4, 5A, 5B, and 6 could cause untreated or partially treated waste to be discharged into study area surface waters. This phenomenon would result in short-term water quality degradation and a reduction in the recreational use of that body of water. Odors emanating from malfunctioning on-site systems may curtail outdoor recreational activities in the near vicinity.

4.1.2.10. Transportation

Impacts arising during the construction of conveyance lines (Section 4.1.1.) would reoccur when maintenance or repairs are made on those lines. Occasionally some roads may be closed temporarily. Truck traffic to and from the proposed treatment facilities under Alternatives 2-7 will be associated with supply deliveries. Truck traffic associated with repairs and sludge hauling will occur periodically under Alternatives 8A, 8B, and 9.

4.1.2.11. Energy

The operation of wastewater treatment facilities and pump stations under the "build" alternatives require the use of electricity and fossil fuels. Alternatives 6 and 7 would require the greatest amount of these energy sources, Alternatives 8A, 8B, and 9 would require the least. No significant demands would be placed on local energy supplies under any of the alternatives.

4.1.3. Public Finance

The total project costs will be apportioned between the USEPA and the local residents. The apportionment is made on the basis of what costs are eligible to be funded by USEPA. The costs for each alternative are presented in Appendix N. The local construction costs and the entire cost of system operation and maintenance will be borne entirely by the system users. As discussed in Section 1.2., Federal funding through the National Municipal Wastewater Treatment Works Construction Grants Program will provide funds to cover 75% of the eligible planning design, and construction costs of conventional wastewater treatment facilities. "Innovative/alternative" components of the proposed treatment systems, such as pressure sewers, septic tank effluent sewers, septic tanks, and soil absorption systems are eligible for 85% Federal funding. The annual residential user costs for each alternative are presented in the Table 4-3. The detailed annual residential user cost analyses with and without Federal Grant monies are presented in Tables N-11 and N-12, respectively.

Wastewater treatment facilities can create significant financial impacts for communities and users who will pay the capital, operation, maintenance, and debt costs associated with sewage treatment facilities. Two guidelines for determining the magnitude of these impacts are the State of Michigan 10% of SEV general obligation bonding authority limit for local governments and the USEPA average annual user charge to median family income ratio (USEPA 1981b).

Table 4-3. Annual residential user costs.

Alternative	Annual Cost per Residence With Federal Grant	Annual Cost per Residence Without Federal Grant
2	264.77	1,044.93
3	258.95	1,043.29
4	265.69	1,059.58
5A	254.18	1,020.00
5B	599.66	1,266.02
6	271.62	1,033.69
7	329.30	1,061.16
8A	167.29	488.83
8B	161.34	481.56
9	126.21	233.32

Cass County would assume the local share of additional debt under any of the "build" alternatives. Berrien County and Van Buren County residents would be billed user charges by Cass County under any of the "build" alternatives.

The debt to state equalized assessed valuation ratio for four debt scenerios, which include the high- and low-cost capital shares for sewer and on-site systems are presented in Table 4-4. Under the highest local capital cost scenerio, Alternative 5B, Cass County's debt would rise $12,541,000 over its 1980 debt of $1,335,000 for a total of $13,876,000. Cass County's debt to state equalized assessed valuation ratio under Alternative 5B would reach 33% of the state of Michigan's general obligation bonding authority limit for local governments.

Under the lowest local capital cost scenerio, Alternative 9, Cass County's debt would rise $968,400 over its 1980 debt for a total of $2,303,400. Cass County's debt to state equalized assessed valuation ratio under Alternative 9 would reach 5% of the state of Michigan's general obligation bonding authority for local governments. Cass County would not approach its state mandated debt limit under any of the alternatives.

Table 4-4. Cass County debt as a percentage of state equalized assessed valuation under four local share capital cost scenerios.

Cass County	Existing Debt 1980[a]		Local Capital Share		Total Debt		Total State Equalized Assessed Valuation[a]	Debt/State Equalized Assessed Valuation	State of Michigan General Obligation Bonding Authority Limit for Local Governments
High capital cost sewer scenario (Alt. 5B)	1,335,000	+	12,541,000	=	13,876,000	÷	420,747,938 =	3.3	10 %
Low capital cost sewer scenario (Alt. 7)	1,335,000	+	3,722,900	=	5,057,900	÷	420,747,938 =	1.2	10 %
High capital cost on-site system Scenerio (Alt.8A)	1,335,000	+	1,452,600	=	2,057,900	÷	420,747,938 =	0.7	10 %
Low capital cost on-site system scenario (Alt. 9)	1,335,000	+	968,400	=	2,303,400	÷	420,747,938 =	0.5	10 %

[a] By telephone, Ms. Candy Cooper, Cass County Treasurers Officer to WAPORA, Inc., 28 December 1981.

The USEPA considers projects to be expensive and as having an adverse impact on the finances of users when average annual user charges are:

- 1.0% of median household incomes less than $10,000
- 1.5% of median family incomes between $10,000 and $17,000
- 1.75% of median household incomes greater than $17,000.

Median family incomes for Berrien, Cass and Van Buren Counties are $19,200, $18,600, and $20,500, respectively. (By telephone, Mr. John Maloney, Economic Market Analysis Division, US Department of Housing and Urban Development, Detroit, MI to WAPORA, Inc. 4 March 1982).

Incomes of system users residing in Van Buren County may be somewhat lower than $20,500 because Van Buren County is included in the Kalamazoo Standard Metropolitan Statistical Area (SMSA). Wages are likely to be higher in the Kalamazoo metropolitan area than in Van Buren County. The high wages paid in Kalamazoo tend to raise the median family income for the SMSA as a whole.

Average annual user charges expressed as a percentage of median family income for a household of four are presented in Table 4-5. User fees under Alternative 5B surpass suggested upper limit user fees for system users in all three counties. Under Alternative 7, user fees surpass suggested upper limit user fees for system users in Cass County. Thus, some system users under these alternatives would be financially adversely affected. Alternative 9 offers the lowest user fees for system users in all three counties. None of the other alternatives surpass suggested upper limit user fees as a percentage of median family income, indicating that none of these alternatives would be a "high cost" system that would pose a significant financial burden on system users.

The financial stress on low income families and the local share of capital cost for the proposed wastewater facilities, under any of the "build" alternatives, may be overstated in Tables 4-4 and 4-5 because of the uncertainty of how available Farmers Home Administration (FmHA) grants and loans may be applied. Cass County is currently eligible for a $1,200,000 grant and

Table 4-5. Average annual user charges for the "build" alternatives expressed as a percentage of median household income for Berrien, Cass and Van Buren Counties.[a]

Alternative	County		
	Berrien	Cass	Van Buren
2	1.38%	1.42%	1.29%
3	1.35%	1.39%	1.26%
4	1.38%	1.43%	1.30%
5A	1.32%	1.37%	1.24%
5B	3.12%[b]	3.22%[b]	2.93%[b]
6	1.41%	1.46%	1.32%
7	1.71%	1.77%[b]	1.61%
8A	0.87%	0.90%	0.82%
8B	0.84%	0.87%	0.79%
9	0.66%	0.68%	0.62%

[a] The USEPA considers a project expensive when average annual user charges exceed 1.75% of median household incomes greater than $17,000.

[b] The costs residents would pay under these alternatives would be considered expensive according to USEPA guidelines.

a $1,000,000 loan for 40 years at 5% interest from the FmHA (By telephone, Mr. Roy O'Breiter, FmHA District Office, Hastings MI to WAPORA, Inc. 2 February 1982). The grant and loan are set aside for wastewater facilities around Indian Lake. Cass County could apply for an additional loan to finance wastewater facilities in other parts of the study area. If FmHA grants and loans are incorporated into the public financing scheme for implementing any of the "build" alternatives, the financial stress on study area low income families and the local share of capital cost for the proposed wastewater facilities would be reduced.

4.2. Secondary Impacts

Each of the alternatives, including the No Action Alternative, will have effects that extend beyond primary or direct impacts. These impacts, secondary impacts, would occur because induced growth may occur or because changes in lake water quality may occur. The categories that may experience significant secondary impacts are described in the following sections.

4.2.1. Demographics

Wastewater management facilities historically have been a major factor in determining the capacity of an area to support population growth and development. On-site wastewater treatment facilities, although generally available to any potential user, limit development to areas with suitable soil and site characteristics. Sewer systems, while not always available at a specific location or with adequate capacity, allow development to be more site independent, since soil, slope, and drainage become less constraining design parameters. Consequently, the construction of sewers in an area usually increases the inventory of developable land and the density of development, often unleashing pent-up demand for or encouraging growth and development.

This phenomenon is not evident in the study area nor is it anticipated to occur during the planning period. Economic factors discussed in Section 3.2.3. which follow national, state, and regional trends, outweigh the incentive for growth which wastewater facilities provide.

Population growth in the study area as discussed in Section 3.2.1. is not likely to be significantly affected by the selection of any of the alternatives. The first tier of sewers away from the lakes proposed under Alternatives 2-7 would provide service to a corridor which is already developed and where few lots available for development exist. Little population increase is likely to occur in this corridor. The cost to users under Alternatives 2-7 may create a financial burden for families with low incomes. This could result in displacement of these families from the service area because they cannot afford user charges.

The selection of Alternative 8A or 8B would allow for the development of a limited number of lots which are not suitable for on-site systems. No significant population increase is anticipated to occur.

Under Alternatives 1 and 9, population growth would occur as discussed in Section 3.2.1. The projected conversion of seasonal dwellings to permanent homes would continue. Population increases would be dependant upon the carrying capacity of the land available for development. No significant population impacts would occur.

4.2.2. Land Use

Economic factors (Section 3.2.3) will have a greater influence than the provision of wastewater facilities (Section 4.2.) in determining land use for the study area during the planning period. The location of wastewater treatment facilities and sewer systems under Alternatives 2-7 will affect patterns of future development. Residential development would be likely to occur along sewer lines. Because little induced growth is predicted to occur, no significant land use impacts will occur.

Under Alternatives 8A, 8B, and 9 future development would be limited to the carrying capacity of the land. Continued and increased nuisances attributable to failing on-site systems in residential areas would make infill development of those areas less desirable.

Prime Agricultural land

Little prime agricultural farmland is likely to be taken out of production to accommodate wastewater treatment facilities. This will result in a minimal net loss of food and fibre which was previously produced on this land. The lack of induced growth created by implementing any of the alternatives removes the threat to prime agricultural farmland usually associated with the construction of wastewater facilities.

4.2.3. Surface Water

Increased housing development along lake shores may increase nutrient and sediment loads into the lakes as a result of the following:

- increased runoff from construction of impervious surfaces such as rooftops, parking areas, and paved roads
- increased housing density normally accelerates storm water runoff thereby increasing not only the amount of runoff, but also its ability to erode soil and to transport contaminants
- lawn and garden fertilization may create unnaturally high nutrient levels in runoff.

Accompanying housing development is the increase in the use of the lake for recreational and fishing purposes. An increase in fishing pressure may ultimately result in detrimental water quality effects. When larger piscivores are removed by angling, fewer planktivores are consumed, resulting in greater numbers of planktivores. The planktivore community then exerts high predation pressure on the zooplankton community. A decrease in the zooplankton community will reduce grazing pressure on phytoplankton resulting in an increase in the phytoplankton, and greater turbidity.

The installation of a centralized collection system probably would induce a more rapid development rate compared to alternatives calling for upgraded on-site systems.

4.2.4. Recreation and Tourism

Any increase or decrease of tourism and recreational activities within the study area attributable to the long-term operation of wastewater facilities under the "build" alternatives would occur when a quantum change in water quality of area lakes occurs. A significant decline in water quality would cause fewer tourists to visit the study area. Permanent and seasonal residents of the study area would likely decrease some of their recreational activities around area lakes under these conditions.

A significant increase in water quality may contribute to an increase of recreational activities among local residents and tourists within the study area. Other factors discussed in Section 3.2.4. would have a greater affect upon use of the study area by tourists and recreationists. Increased and continuing nuisances created by failing on-site systems under the No Action Alternative would detract from the study areas reputation as a desirable recreational area. Recreation and tourist activities would likely decline. No significant recreational or tourist impacts are likely to occur under any of the alternatives.

4.2.5. Economics

It is unlikely that the additional wastewater treatment capacity created under Alteratives 2-7 would create any population, development, or economic growth (Section 3.2.3.). Economic development would proceed as discussed in Section 3.2.3. under Alternatives 8A, 8B, and 9. Increased and continuing nuisances created by failing on-site systems under the No Action Alternative would detract from the study areas reputation as a desirable recreational area. Recreation and tourist activities would likely decline resulting in a loss of revenues for study area businesses.

4.2.6. Threatened and Endangered Species

No threatened or endangered species have been identified at the proposed plant sites or sewer lines. The habitats present, however, could be suitable for a number of endangered and threatened species in the State of Michigan (Tables 3-14, 3-15, and 3-16).

The MDNR should be consulted to determine whether any listed species are actually found in the vicinities of the proposed sites. If so, appropriate measures must be developed through consultation with Berrien, Cass, and Van Buren counties, MDNR, and US Fish and Wildlife Service, if appropriate, and other agencies that may be interested in the proposed action.

4.3. Mitigation of Adverse Impacts

As previously discussed, various adverse impacts would be associated with the proposed alternatives. Many of these adverse impacts could be reduced significantly by the application of mitigative measures. These mitigative measures consist of a variety of legal requirements, planning measures, and design practices. The extent to which these measures are applied will determine the ultimate impact of the selected action. Potential measures for alleviating construction, operation, and secondary effects presented in Sections 4.1. and 4.2. are discussed in the following sections.

4.3.1. Mitigation of Construction Impacts

The construction oriented impacts presented in Section 4.1. primarily are short-term effects resulting from construction activities at WWTP sites or along the route of proposed sewer systems. Proper design should minimize the potential impacts and the plans and specifications should incorporate mitigative measures consistent with the following discussion.

Fugitive dust from the excavation and backfilling operations for the force mains and treatment plants could be minimized by various techniques. Frequent street sweeping of dirt from construction activities would reduce the major source of dust. Prompt repaving of roads disturbed by construction also could reduce dust effectively. Construction sites, spoil piles, and unpaved access roads should be wetted periodically to minimize dust. Soil stockpiles and backfilled trenches should be seeded with a temporary or permanent seeding or covered with mulch to reduce susceptibility to wind erosion.

Street cleaning at sites where trucks and equipment gain access to construction sites and of roads along which a force main would be constructed would reduce loose dirt that otherwise would generate dust, create unsafe driving conditions, or be washed into roadside ditches or storm drains. Trucks transporting spoil material to disposal sites should cover their loads to eliminate the escape of dust while in transit.

Exhaust emissions and noise from construction equipment could be minimized by proper equipment maintenance. The resident engineer should have, and should exercise the authority, to ban from the site all poorly maintained equipment. Soil borings along the proposed force main rights-of-way conducted during system design, would identify organic soils that have the potential to release odors when excavated. These areas could be bypassed by rerouting the force main if, depending on the location, a significant impact might be expected.

Spoil disposal sites should be identified during the project design stage to ensure that adequate sites are available and that disposal site impacts are minimized. Landscaping and restoration of vegetation should be conducted immediately after disposal is completed to prevent impacts from dust generation and unsightly conditions.

Lands disturbed by trenching for force main construction should be regraded and compacted as necessary to prevent future subsidence. However, too much compaction will result in conditions unsuitable for vegetation.

Areas disturbed by trenching and grading at the plant site should be revegetated as soon as possible to prevent erosion and dust generation. Native plants and grasses should be used. This also will facilitate the re-establishment of wildlife habitat.

Construction-related disruption in the community can be minimized through considerate contractor scheduling and appropriate public announcements. The State and County highway departments have regulations concerning roadway disruptions, which should be rigorously applied. Special care should be taken to minimize disruption of access to frequently visited establishments.

Announcements should be published in local newspapers and broadcast from local radio stations to alert drivers of temporary traffic disruptions on primary routes. Street closings should be announced by fliers delivered to each affected household.

Planning of routes for heavy construction equipment and materials should ensure that surface load restrictions are considered. In this way, damage to streets and roadways would be avoided. Trucks hauling excavation spoil to disposal sites or fill material to the WWTP sites should be routed along primary arteries to minimize the threat to public safety and to reduce disturbance in residential environments.

Erosion and sedimentation must be minimized at all construction sites. USEPA Program Requirements Memorandum 78-1 establishes requirements for control of erosion and runoff from construction activities. Adherence to these requirements would serve to mitigate potential problems:

- Construction site selection should consider potential occurrence of erosion and sediment losses
- The project plan and layout should be designed to fit the local topography and soil conditions
- When appropriate, land grading and excavating should be kept at a minimum to reduce the possibility of creating runoff and erosion problems which require extensive control measures
- Whenever possible, topsoil should be removed and stockpiled before grading begins
- Land exposure should be minimized in terms of area and time
- Exposed areas subject to erosion should be covered as quickly as possible by means of mulching or vegetation
- Natural vegetation should be retained whenever feasible
- Appropriate structural or agronomic practices to control runoff and sedimentation should be provided during and after construction
- Early completion of stabilized drainage system (temporary and permanent systems) will substantially reduce erosion potential

- Access roadways should be paved or otherwise stabilized as soon as feasible

- Clearing and grading should not be started until a firm construction schedule is known and can be effectively coordinated with the grading and clearing activities.

The Natural Historic Preservation Act of 1966, Executive Order 11593 (1971), The Archaeological and Historic Preservation Act of 1974, and the 1973 Procedures of the Advisory Council on Historic Preservation require that care must be taken early in the planning process to identify cultural resources and minimize adverse effects on them. USEPA's final regulations for the preparation of EISs (40 CFR 1500) also specify that compliance with these regulations is required when a Federally funded, licensed, or permitted project is undertaken. The State Historic Preservation Officer must have an opportunity to determine that the requirements have been satisfied.

Once an alternative is selected and design work begins, a thorough pedestrian archaeological survey may be required for those areas affected by the proposed facility. In addition to the information already collected through a literature review (WAPORA 1979) and consultation with the State Historic Preservation Officer and other knowledgeable informants, a controlled surface collection of discovered sites and minor subsurface testing should be conducted. A similar survey would be required of historic structures, sites, properties, and objects in and adjacent to the construction areas, if they might be affected by the construction or operation of the project.

In consultation with the State Historic Preservation Officer, it would be determined if any of the resources identified by the surveys appear to be eligible for the National Register of Historic Places. Subsequently, an evaluation would be made of the probable effects of the project on these resources and what mitigation procedures may be required. Prior to initiation of the proposed Federally funded project, the Advisory Council on Historic Preservation in Washington DC should be notified of the intended undertaking and be provided an opportunity to comment on the proposed project.

4.3.2. Mitigation of Operation Impacts

The majority of potentially adverse operational impacts of the WWTP alternatives are related to the discharge of effluent to surface waters. For the land treatment alternative, the most significant potential adverse effects are impacts on groundwater and possible health risks. Adverse impacts associated with the operation of cluster and on-site systems are primarily related to malodorous conditions which may affect outdoor recreational activities. Measures to minimize these and other operation phase impacts from all the alternatives are discussed below.

Adverse impacts related to the operation of the proposed sewer systems and treatment facilities would be minimal if the facilities are designed, operated, and maintained properly. Aerosols, gaseous emissions, and odors from the various treatment processes could be controlled to a large extent. Above-ground pumps would be enclosed and installed to minimize sound impacts. Concentrations of the effluent constituents discharged from the WWTPs would be regulated by the conditions of the NPDES permits. The effluent quality is specified by the State of Michigan and must be monitored. Proper and regular maintenance of cluster and on-site systems also would maximize the efficiency of these systems and minimize odors released from malfunctioning systems.

Special care to control chlorination and effluent concentrations of chlorine residuals should be taken to minimize adverse impacts to the aquatic biota of study area surface waters. Tsai (1973) documented that depressed numbers of fish and macroinvertebrates were found downstream from outfalls discharging chlorinated effluent. No fish were found in water with chlorine residuals greater than 0.37 mg/l, and the species diversity index reached zero at 0.25 mg/l. A 50% reduction in species diversity index occurred at 0.10 mg/l. Arthur and others (1975) reported that concentrations of chlorine residuals lethal to various species of warm water fish range from 0.09 to 0.30 mg/l. Many wastewater treatment plants have effluents with chlorine residual concentrations of 0.5 to 2.0 mg/l. Furthermore, chlorination of wastewater can result in the formation of halogenated organic compounds that are potentially carcinogenic (USEPA 1976). Rapid mixing of chlorine and design of contact chambers to provide long contact times, however, can achieve the

desired disinfection and the minimum chlorine residual discharge (USEPA and others 1977). Chlorination will require especially careful application and routine monitoring to insure that chlorine residual concentrations are kept to a minimum.

In the document Federal Guidelines for Design, Operation, and Maintenance of Wastewater Treatment Facilities (Federal Water Quality Administration 1970), it is required that:

> All water pollution control facilities should be planned and designed so as to provide for maximum reliability at all times. The facilities should be capable of operating satisfactorily during power failures, flooding, peak loads, equipment failure, and maintenance shutdowns.

4.3.3. Mitigation of Secondary Impacts

As discussed in Section 4.2., few secondary impacts are expected to occur during the operation of any of the ten "build" alternatives. Adequate zoning, health, and water quality regulation and enforcement would minimize these impacts. Local growth management planning would assist in the regulation of general location, density, and type of growth that might occur.

4.4. Unavoidable Adverse Impacts

Some impacts associated with the implementation of any of the "build" alternatives cannot be avoided. The centralized collection and treatment alternatives would have the following adverse impacts:

- Considerable short-term construction dust, noise, and traffic nuisance
- Alteration of vegetation and wildlife habitat along the sewer and force main corridors and at the WWTP sites
- Considerable erosion and siltation during construction
- Discharge of BOD, SS, and phosphorus at greater than ambient levels to Silver Creek and/or the Indian Lake outlet with the waste stabilization lagoon alternatives

- Discharge of increased BOD, SS, phosphorus, and ammonia to Dowagiac Creek from the Dowagiac WWTP for Alternatives 6 and 7
- Significant odors during spring turnover of waste stabilization lagoons
- Significant user fees for wastewater treatment services for the residents within the proposed sewer service areas
- Conversion of agricultural land and, for Section 29 (near Indian Lake), prime farmland to waste stabilization lagoon use.

The decentralized alternatives that include primarily continued use of existing and upgraded on-site systems and either cluster systems or blackwater holding tanks for critical areas would have the following adverse impacts:

- Some short-term construction dust, noise, and traffic nuisance
- Some erosion and siltation during construction
- Alteration and destruction of wildlife habitat at the cluster drainfield sites
- Discharge of percolate with elevated levels of nitrates and chlorides from soil absorption systems to the groundwater
- Occasional ephemeral odors associated with pumping septic tanks and holding tanks and trucking it to disposal sites
- User fees for management and operation of wastewater treatment services for the residents within the proposed service areas.

4.5. Irretrievable and Irreversible Resource Commitments

The major types and amounts of resources that would be committed through the implementation of any of the ten "build" alternatives are presented in Sections 4.1. and 4.2. Each of the alternatives would include some or all of the following resource commitments:

- Fossil fuel, electrical energy, and human labor for facilities construction and operation
- Chemicals, especially chlorine, for Dowagiac WWTP operation
- Tax dollars for construction and operation
- Some unsalvageable construction materials.

For each alternative involving a WWTP, there is a significant consumption of these resources with no feasible means of recovery. Thus, non-recoverable resources would be foregone for the provision of the proposed wastewater control system.

Accidents which could occur from system construction and operation could cause irreversible bodily damage or death, and damage or destroy equipment and other resources. Unmitigated Dowagiac WWTP failure potentially could kill aquatic life in the immediate mixing zone.

The potential accidental destruction of undiscovered archaeological sites through excavation activities is not reversible. This would represent permanent loss of the site.

5.0. LITERATURE CITED

Arthur, J.W., and others. 1975. Comparative toxicity of sewage - effluent disinfection to freshwater aquatic life. Water Pollution Control Research Service, USEPA, Washington DC.

Ayensu, E.S., and R.A. De Filipps. 1978. Endangered and threatened plants of the United States. Smithsonian Institution, Washington DC, 403 p.

Banks, John C. 1977. A limnological study of Pipestone Lake, Berrien County, Michigan. Presented in partial fulfillment of the requirements for the course Biology 466, Limnology, Andrews University, Berrien Springs MI, 19 p.

Beaman, J.H. Unpublished material on threatened and endangered plants in Michigan.

Berrien County Health Department. 1971. Pipestone Lake report. St. Joseph MI, unpaginated.

Braun, E.L. 1950. Deciduous forests of eastern North America. Hafner Press, New York NY, 596 p.

Brown, D.V., and R.K. White. 1977. Septage disposal alternatives in rural areas. Research bulletin 1096. Ohio Agricultural Research and Development Center, Wooster OH, 11 p.

Burt, W.H. 1957. Mammals of the Great Lakes Region. University of Michigan Press, Ann Arbor MI, 246 p.

Cass County Health Department. 1970. Indian Lake survey. Cassopolis MI, 7 p.

Claspy, E. 1966. The Pottowatomi Indians of southwestern Michigan. Dowagiac MI.

Conant, R. 1975. A field guide to reptiles and amphibians of eastern and central North America. Houghton Mifflin Press, Boston MA, 429 p.

Cooley, M.F. 1979. Selected animal distribution maps. Wildlife Division, MDNR, Lansing MI, 40 p. mimeo.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deep water habitats of the United States. FWS/CGS-79/31. US Department of the Interior, Fish and Wildlife Service, Office of Biological Services, Washington DC, 103 p.

Demirjian, Y.A. 1975. Muskegon County wastewater management system. Prepared for Design Seminar for Land Treatment of Municipal Wastewater Effluents sponsored by USEPA Technology Transfer Program. Muskegan MI, 91 p.

Dillon, P.J., and W.B. Kirchner. 1975. The effects of geology and land use on the export of phosphorus from watersheds. Water Research 9: 135-148.

Dillon, P.J., and F.H. Rigler. 1975. A simple method for predicting the capacity of a lake for development based on lake trophic status. Journal of the Fisheries Research Board of Canada 32: 1519-1531.

Dunbar, W.F. 1965. Michigan: A history of the wolverine state. W.B. Eerdmans Publishing Co., Grand Rapids MI.

E.A. Hickok and Associates. 1978. Effects of wastewater stabilization pond seepage on groundwater quality. Prepared for the Minnesota Pollution Control Agency. Wayzata MN, variously paged.

Edwards, H.W., and H.G. Wheat. 1978. Seasonal trends in Denver atmospheric lead concentrations. American Chemical Society, Fort Collins CO.

Ellis, B.G., and A.E. Erickson. 1969. Movement and transformation of various phosphorus compounds in soils. Soil Science Department, Michigan State University and Michigan Water Resources Commission, East Lansing MI, 35 p.

Ellis, B.G., L.W. Jacobs, J.E. Hook, and D.L. Mokma. 1978. Technical handbook for septic drainfield installation. Prepared for South-central Michigan Planning Council. Nazareth MI. Department of Crop and Soil Sciences, Michigan State University, East Lansing MI, 27 p.

Enfield, C.G. 1978. Evaluation of phosphorus models for prediction of percolate water quality in land treatment. In: McKim, Harlan L. (Coordinator), State of Knowledge in land treatment of wastewater, vol. 1. US Army COE Cold Regions Research and Engineering Laboratory, Hanover NH, 436 p. (p. 153-162).

Enfield, Carl G., and Bert E. Bledsoe. 1975. Kinetic model for orthophosphate reactions in mineral soils. EPA 660/2-75-022. USEPA Robert S. Kerr Environmental Research Laboratory, Ada OK, 61 p.

Federal Water Quality Administration. 1970. Federal guidelines for design, operation, and maintenance of wastewater treatment facilities. US Department of the Interior, Washington DC, 29 p.

Giroux, P.R., G.E. Hendrickson, L.E. Stoimenoff, and G.W. Whetstone. 1972. Water resources of Van Buren County, Michigan. US Geological Survey Water Investigation 3, 144 p.

Glover, L.H. 1906. A twentieth century history of Cass County, Michigan. Lewis Publishing Co., Chicago IL.

Gove Associates, Inc. 1977. Facilities Plan for Indian - Sisters Lakes area. Kalamazoo MI, variously paged.

Gove Associates, Inc. 1978a. Sanitary survey questionnaire. Kalamazoo MI, 2 p.

Gove Associates, Inc. 1978b. Sanitary survey questionnaire analysis. Kalamazoo MI, 1 sheet.

Gove Associates, Inc. 1980. Facilities planning document-- Cost-effectiveness analysis for Indian-Sisters Lakes area. Kalamazoo MI, variously paged.

Hartig, J. H., and F. J. Horvath. 1982. A preliminary assessment of Michigan's phosphorus detergent ban. Journal of Water Pollution Control Federation 54(2): 194-197.

Hickey, J.L.S., and P.C. Reist. 1975. Health significance of airborne microorganisms from wastewater treatment processes. Journal of the Water Pollution Control Federation, Volume 47.

Jones, R.A., and G.F. Lee. 1977. Septic tank disposal systems as phosphorus sources for surface waters. EPA 600/3-77-129. Robert S. Kerr Environmental Research Laboratory, Ada OK.

K-V Associates, Inc. 1980. Septic leachate survey Indian Lake - Sister Lakes October, 1979. Falmouth MA, 49 p. plus one appendix.

Kenoyer, L.A. 1930. Ecological notes on Kalamazoo County, Michigan, based on the original land survey. Papers of the Michigan Academy of Sciences, Arts, and Letters 11:211-218.

Lance, J.C. 1978. Fate of bacteria and viruses in sewage applied to soils. Transactions of the American Society of Agricultural Engineers 21:114.

Marsh, W.M., and T. E. Borton. 1974. Michigan inland lakes and their watersheds - an atlas. Prepared for the Michigan Department of Natural Resources. Environmental and Urban Planning Services, Ann Arbor MI, 166 p.

Michigan Department of Commerce. 1976. Summary of the travel product market analysis. Travel Bureau, Lansing MI, 6 p.

Michigan Department of Commerce. 1978. Fuel demand report. Energy Administration, Lansing MI, p. 23, 24, 29, 30, 331, 332.

Michigan Department of Conservation. No date. Well records and water quality records. Geological Survey Division, Lansing MI.

Michigan Department of Natural Resources. 1971. Staff Report - Indian Lake, Silver Creek Township, Cass County. Water Resources Commission, Grand Rapids MI, 2 p.

Michigan Department of Natural Resources. 1972. Pipestone Lake survey. Water Resources Commission, Grand Rapids MI, 5 p.

Michigan Department of Natural Resources. 1973. General Rules, Part 4, water quality standards. Water Resources Commission, Grand Rapids MI, 17 p.

Michigan Department of Natural Resources. 1975. Designated trout streams for the State of Michigan. Lansing MI.

Michigan Department of Natural Resources. 1976. Coldwater lakes of Michigan. Fisheries Division, Lansing MI.

Michigan Department of Natural Resources. 1977a. Air quality report. Air Quality Division, Lansing MI, 49 p. plus 6 appendixes.

Michigan Department of Natural Resources. 1977b. Inland lake self-help program annual report, 1976. Inland Lake Management Unit, Land Resource Programs Division, Lansing MI, 31 p.

Michigan Department of Natural Resources. 1978a. Recreation by Michigan residents, planning region 4. Lansing MI, 101 p.

Michigan Department of Natural Resources. 1978b. Inland lake self-help program annual report, 1977. Inland Lake Management Unit, Land Resource Programs Division, Lansing MI, 34 p.

Michigan Department of Natural Resources. 1978c. STORET polygon retrieval data. Environmental Services Division, Comprehensive Studies Section, Lansing MI.

Michigan Department of Natural Resources. 1979. Inland lake self-help program annual report, 1978. Inland Lake Management Unit, Land Resource Programs Division, Lansing MI, 35 p.

Michigan Department of Natural Resources. 1981. Proposed water quality standards, to amend Act 245, Part 4 of Michigan Water Resources Commission Act. Lansing MI.

Moak, L.L., and A.M. Hillhouse. 1975. Concepts and practices in local government finance. Municipal Finance Officers Association of the US and Canada, Chicago IL.

National Biocentric, Inc. 1978. Southwestern Michigan inland lake watershed study. Prepared for the Southwestern Michigan Regional Planning Commission. St. Paul MN, variously paged plus appendixes.

National Oceanic and Atmospheric Administration (NOAA). 1977. Local climatological data, South Bend, Indiana. Ashville NC, 4 p.

Omernik, J.M. 1977. Non-point source stream nutrient level relationships: a nationwide survey. EPA 600/3-77-105. National Environmental Research Laboratory, Corvalis OR.

Otis, R.J. 1979. Alternative wastewater facilities for small communities - a case study. In: Proceedings of a Workshop on Alternative Wastewater Treatment Systems. UILU-WRC-79-0010. Water Resources Center and Cooperative Extension Service, University of Illinois - Urbana, Urbana IL, p. 44-69.

Otis R.J., and D.E. Stewart. 1976. Alternative wastewater facilities for small unsewered communities in rural America. Annual report to the Upper Great Lakes Region Commission.

Pound, C.E., and R.W. Crites. 1973. Wastewater treatment and reuse by land application, volume 1, summary. USEPA Office of Research and Development, Washington DC, 80 p.

Powers, J.A. 1978. Feasibility study and preliminary site identification for land treatment in Middle Tennessee. In: State of knowledge in land treatment of wastewater, proceedings of an international symposium vol. 2. US Army Corps of Engineers CRREL, August 1978, vol. 2. Hanover NH, 423 p.

Scalf, M.R., and W.J. Dunlap. 1977. Environmental effects of septic tanks. EPA 600/3-77-096. Robert S. Kerr Environmental Research Labratory, Ada OK.

Seigrist, R.L., T. Woltanski, and C.E. Waldorf. 1978. Water conservation and wastewater disposal. In: Proceedings of the second national home sewage treatment symposium (ASAE Publication 5-77). American Society of Agricultural Engineers, St. Joseph MI, p. 121-136.

Shipman, W.L. 1977. Letter, Wayne L. Shipman, Berrien County Health Department to James R. Squire, Gove Associates, Inc., 22 June 1977.

Simmons, J.D., and J. O. Newman. 1979. On-site liquefaction and variable gradient transport lines for rural sewage disposal. Paper No. SER 79-047. American Society of Agricultural Engineers, St. Joseph MI, 16 p.

Smith, V.H., and J. Shapiro. 1981. Chlorophyll - phosphorus relations in individual lakes. Their importance to lake restoration strategies. Environmental Science and Technology 15: 444-451.

Snow, G.E. 1976. A limnological study of Dewey Lake, Cass County, Michigan. Prepared for: Dewey Lake Owners' Association, Inc., Dowagiac MI, 22 p.

Snow, G. E. 1978. Southwestern Michigan inland lakes water quality study. Prepared by Water Testing Laboratory, Andrews University for the Southwestern Michigan Regional Planning Commission. Berrien Springs MI, 35 p.

Soil Conservation Service. 1980a. Prime farmland map units in Michigan. Prepared by State Soil Survey Staff and cooperating agencies, 15 p.

Soil Conservation Service. 1980b. Soil survey of Berrien County Michigan. Prepared in cooperation with the Michigan Agricultural Experiment Station. US Department of Agriculture.

Southwestern Michigan Regional Planning Commission. 1978a. 208 area-wide waste treatment management plan. Appendix B. Population and land use/cover - existing and future conditions. Prepared by SMRPC in cooperation with Lamson-Fisher Associates and Thomas Sinn and Associates. St. Joseph MI, variously paged plus attachments.

Southwestern Michigan Regional Planning Commission. 1978b. District overall economic development plan. Courthouse Printing Department, St. Joseph MI, variously paged, 385 p.

Terwilliger, F.W. 1954. The glacial geology and groundwater resources of Van Buren County, Michigan. Michigan Geological Survey Division, Michigan Department of Conservation, Lansing MI, 94 p.

Transeau, E.N. 1936. The prairie peninsula. Ecology 16:423-437.

Tsai, C. 1973. Water quality and fish life below sewage outfalls. Transactions of American Fisheries Society 102 (281).

Urie, Dean H. 1979. Nutrient recycling under forests treated with sewage effluents and sludge in Michigan. In: Sopper, William E. and Sonja N. Kerr (Editors), Utilization of municipal sewage effluent and sludge on forest and disturbed land. The Pennsylvania State University Press, University Park PA, 537 p. (p.7-17).

Urie, Dean H., John H. Cooley, and Alfred Ray Harris. 1978. Irrigation of forest plantations with sewage lagoon effluents. In: McKim, Harlan L. (Coordinator), State of knowledge in land treatment of wastewater, vol. 2. US Army COE Cold Regions Research and Engineering Laboratory, Hanover NH, 423 p. (p.207-213).

US Bureau of the Census. No date. 1970 census fifth count data for zip codes, counties, and smaller areas. US Government Printing Office, Washington DC, variously paged.

US Bureau of the Census. 1952. US census of population: 1950, volume II, part 22, Michigan. US Government Printing Office, Washington DC, 248 p.

US Bureau of the Census. 1963. US census of population: 1960, volume I, characteristics of population, part 24, Michigan. US Government Printing Office, Washington DC, 675 p.

US Bureau of the Census. 1973. Census of the population: 1970, volume I, characteristics of the population, part 24, Michigan. US Government Printing Office, Washington DC, 1,399 p.

US Bureau of the Census. 1982. 1980 Census of Population. Characteristics of the population: number of inhabitants (final report), part 24, Michigan. US Government Printing Office, Washington DC, 74 p.

USEPA. 1976. Quality criteria for water. Office of Water and Hazardous Materials. Washington DC, 255 p.

USEPA. 1977a. Process design manual - wastewater facilities for sewered small communities. EPA 625/1-77-009. Environmental Research Information Center, Technology Transfer, Cincinnati OH.

USEPA. 1977b. Alternatives for small wastewater treatment systems, on-site disposal/septage treatment and disposal. EPA 625/4-77-011. Technology Transfer, Washington DC, 90 p.

USEPA and others. 1977. Process design manual for land treatment of municipal wastewater. EPA 625/1-77-008. Washington DC, variously paged.

USEPA. 1978a. Funding of sewage collection system projects. Program Requirements Memorandum (PRM 78-9). Office of Water and Hazardous Materials, Washington DC.

USEPA. 1979a. Planning wastewater management facilities for small communities (Draft). Prepared for USEPA Municipal Environmental Research Laboratory, by Urban Systems Research Engineering, Inc., Cincinnati OH, 141 p.

USEPA. 1979b. Management of on-site and alternative wastewater systems (Draft). Prepared for USEPA Environmental Research Information Center, by Roy F. Weston, Inc., Cincinnati OH, 111 p.

USEPA. 1979c. Aerial survey Indian-Sisters Lake Region, Michigan. Office of Research and Development, Las Vegas NV.

USEPA. 1980a. Design manual. On-site wastewater treatment and disposal systems. Office of Research and Development, Municipal Environmental Research Laboratory, Cincinnati OH, 391 p.

USEPA. 1980b. Modeling phosphorus loading and lake response under uncertainty: a manual and compilation of export coefficients. EPA 440/5-80-011. Clean Lakes Section, Washington DC.

USEPA. 1981a. Alternative waste treatment systems for rural lake projects. Draft - generic environmental impact statement. USEPA Region V, Water Division, Chicago IL, 133 p. plus appendixes.

USEPA. 1981b. Facilities planning 1981. Municipal wastewater treatment. EPA 430/9-81-002. Office of Water Program Operations, Washington DC, 116 p.

US Geological Survey. 1978. Water resources data for Michigan: water year 1977. Report MI-77-1.

Uttormark, P.D., and J.P. Wall. 1975. Lake classification for water quality management. University of Wisconsin Water Resources Center.

Veatch, J.O. 1928. The dry prairies of Michigan. Papers of the Michigan Academy of Sciences, Arts, and Letters 8:269-278.

Vollenweider, R.A. 1975. Input - output models with special reference to the phosphorus loading concept in limnology. Schweiz. Z. Hydrol 37:53-83.

WAPORA, Inc. 1979. Affected environment preliminary draft chapter of the Indian Lake - Sister Lakes environmental statement. Submitted to USEPA, Region V, Chicago IL, variously paged.

WAPORA, Inc. 1981. Memorandum to Mr. Charles Quinlan, USEPA, Region V. Revised population projections. Chicago IL.

Zevenboom, W., A.B. deVaate, and L.R. Mur. 1982. Assessment of factors limiting growth rate of Oscillatoria agardhii in hypertrophic Lake Wolderwizd, 1978, by use of physiological indicators. Limnology and Oceanography 27:39-52.

6.0. LIST OF PREPARERS

The Draft Environmental Statement (DES) was prepared by the Chicago Regional Office of WAPORA, Inc., under contract to USEPA Region V. USEPA approved the DES and hereby publishes it as a Draft EIS. The USEPA Project Officers and the WAPORA staff involved in the preparation of the DES/DEIS during the past 4 years include:

USEPA	
Charles Quinlan III	Project Officer
Kathleen Schaub	Project Officer (former)
WAPORA, Inc.	
Robert France	Project Administrator
John Johnson	Project Administrator
E. Clark Boli	Project Administrator
Gerard Kelly	Project Administrator
J. P. Singh	Project Manager, Environmental Engineer and Principal Author
Kenneth Dobbs	Assistant Project Manager and Principal Author
Gerald Lenssen	Project Engineer and Principal Author
Ellen Renzas	Socioeconomist and Editor
Kathleen Brennan	Biologist
Richard C. McKean	Biologist
Rosetta Arrigo	Biologist
William McClain	Biologist
Anita C. Locke	Botanist
Gregg Larson	Demographer
Andrew Freeman	Demographer
Mirza Meghji	Sr. Water Quality Scientist

Steve McComas	Water Quality Scientist
Valarie Krejcie	Graphics Specialist
Peter Woods	Graphics Specialist
Phil Pekron	Environmental Scientist
Kent Peterson	Geologist
John Rist	Engineer
Jan Saper	Editor
Mary Bryant	Production Specialist
Shirley Zingery	Production Specialist

In addition, several subcontractors and others assisted in the preparation of this document. These, along with their areas of expertise, are listed below:

- Aerial Survey
  Office of Research and Development
  USEPA
  Las Vegas NV

- Septic Leachate Analysis
  K-V Associates
  Falmouth MA

- Richard Larson
  Soil Scientist
  Traverse City MI

7.0. GLOSSARY OF TECHNICAL TERMS

Activated sludge process. A method of secondary wastewater treatment in which a suspended microbiological culture is maintained inside an aerated treatment basin. The microbial organisms oxidize the complex organic matter in the wastewater to carbon dioxide, water, and energy.

Advanced secondary treatment. Wastewater treatment more stringent than secondary treatment but not to advanced waste treatment levels.

Advanced waste treatment. Wastewater treatment to treatment levels that provide for maximum monthly average BOD_5 and SS concentrations less than 10 mg/l and/or total nitrogen removal of greater than 50% (total nitrogen removal = TKN + nitrite and nitrate).

Aeration. To circulate oxygen through a substance, as in wastewater treatment, where it aids in purification.

Aerobic. Refers to life or processes that occur only in the presence of oxygen.

Aerosol. A suspension of liquid or solid particles in a gas.

Algae. Simple rootless plants that grow in bodies of water in relative proportion to the amounts of nutrients available. Algal blooms, or sudden growth spurts, can affect water quality adversely.

Algal bloom. A proliferation of algae on the surface of lakes, streams or ponds. Algal blooms are stimulated by phosphate enrichment.

Alluvial. Pertaining to material that has been carried by a stream.

Ambient air. Any unconfined portion of the atmosphere: open air.

Ammonia-nitrogen. Nitrogen in the form of ammonia (NH_3) that is produced in nature when nitrogen-containing organic material is biologically decomposed.

Anaerobic. Refers to life or processes that occur in the absence of oxygen.

Aquifer. A geologic stratum or unit that contains water and will allow it to pass through. The water may reside in and travel through innumerable spaces between rock grains in a sand or gravel aquifer, small or cavernous openings formed by solution in a limestone aquifer, or fissures, cracks, and rubble in harder rocks such as shale.

Artesian (adj.). Refers to ground water that is under sufficient pressure to flow to the surface without being pumped.

Artesian well. A well that normally gives a continuous flow because of hydrostatic pressure, created when the outlet of the well is below the level of the water source.

Bar screen. In wastewater treatment, a screen that removes large floating and suspended solids.

Base flow. The rate of movement of water in a stream channel that occurs typically during rainless periods, when stream flow is maintained largely or entirely by discharges of groundwater.

Bed Rock. The solid rock beneath the soil and subsoil.

Biochemical oxygen demand (BOD). A bioassay-type procedure in which the weight of oxygen utilized by microorganisms to oxidize and assimilate the organic matter present per liter of water is determined. It is common to note the number of days during which a test was conducted as a subscript to the abbreviated name. For example, BOD_5 indicates that the results are based on a five-day long (120-hour)[5] test. The BOD value is a relative measure of the amount (load) of living and dead oxidizable organic matter in water. A high demand may deplete the supply of oxygen in the water, temporarily or for a prolonged time, to the degree that many or all kinds of aquatic organisms are killed. Determinations of BOD are useful in the evaluation of the impact of wastewater on receiving waters.

Biota. The plants and animals of an area.

Chlorination. The application of chlorine to drinking water, sewage or industrial waste for disinfection or oxidation of undesirable compounds.

Clarifier. A settling tank where solids are mechanically removed from waste water.

Coliform bacteria. Members of a large group of bacteria that flourish in the feces and/or intestines of warm-blooded animals, including man. Fecal coliform bacteria, particularly Escherichia coli (E. coli), enter water mostly in fecal matter, such as sewage or feedlot runnoff. Coliforms apparently do not cause serious human diseases, but these organisms are abundant in polluted waters and they are fairly easy to detect. The abundance of coliforms in water, therefore, is used as an index to the probability of the occurrence of such disease-producing organisms (pathogens) as Salmonella, Shigella, and enteric viruses. The pathogens are relatively difficult to detect.

Community. The plants and animals in a particular area that are closely related through food chains and other interactions.

Cultural resources. Fragile and nonrenewable sites, districts, buildings, structures, or objects representative of our heritage. Cultural resources are divided into three categories: historical, architectural, or archaeological. Cultural resources of special significance may be eligible for listing on the National Register of Historic Places.

Decibel (dB). A unit of measurement used to express the relative intensity of sound. For environmental assessment, it is common to use a frequency-rated scale (A scale) on which the units (dBA) are correlated with responses of the human ear. On the A scale, 0 dBA represents the average least perceptible sound (rustling leaves, gentle breathing), and 140 dBA represents the intensity at which the eardrum may rupture (jet engine at open throttle). Intermediate values generally are: 20 dBA, faint (whisper at 5 feet, classroom, private office); 60 dBA, loud (average restaurant or living room, playground); 80 DBA, very loud (impossible to use a telephone, noise made by food blender or portable standing machine; hearing impairment may result from prolonged exposure); 100 dBA, deafening noise (thunder, car horn at 3 feet, loud motorcycle, loud power lawn mower).

Detention time. Average time required to flow through a basin. Also called retention time.

Digestion. In wastewater treatment a closed tank, sometimes heated to 95°F where sludge is subjected to intensified bacterial action.

Disinfection. Effective killing by chemical or physical processes of all organisms capable of causing infectious disease. Chlorination is the disinfection method commonly employed in sewage treatment processes.

Dissolved oxygen (DO). Oxygen gas (O_2) in water. It is utilized in respiration by fish and other aquatic organisms, and those organisms may be injured or killed when the concentration is low. Because much oxygen diffuses into water from the air, the concentration of DO is greater, other conditions being equal, at sea level than at high elevations, during periods of high atmospheric pressure than during periods of low pressure, and when the water is turbulent (during rainfall, in rapids, and waterfalls) rather than when it is placid. Because cool water can absorb more oxygen than warm water, the concentration tends to be greater at low temperatures than at high temperatures. Dissolved oxygen is depleted by the oxidation of organic matter and of various inorganic chemicals. Should depletion be extreme, the water may become anaerobic and could stagnate and stink.

Drift. Rock material picked up and transported by a glacier and deposited elsewhere.

Effluent. Wastewater or other liquid, partially or completely treated, or in its natural state, flowing out of a reservoir, basin, treatment plant, or industrial treatment plant, or part thereof.

Endangered species. Any species of animal or plant that is in known danger of extinction throughout all or a significant part of its range.

Eutrophication. The process of enrichment of a water body with nutrients.

Fauna. The total animal life of a particular geographic area or habitat.

Fecal coliform bacteria. See coliform bacteria.

Floodway. The portion of the floodplain which carries moving water during a flood event.

Flood fringe. The part of the floodplain which serves as a storage area during a flood event.

Flora. The total plant life of a particular geographic area or habitat.

Flowmeter. A guage that indicates the amount of flow of wastewater moving through a treatment plant.

Force main. A pipe designed to carry wastewater under pressure.

Gravity system. A system of conduits (open or closed) in which no liquid pumping is required.

Gravity sewer. A sewer in which wastewater flows naturally down-gradient by the force of gravity.

Groundwater. All subsurface fresh water, especially that part in the zone of saturation.

Groundwater Runoff. Groundwater that is discharged into a stream channel as spring or seepage water.

Holding Tank. Enclosed tank, usually of fiberglass, steel or concrete, for the storage of wastewater prior to removal or disposal at another location.

Hypolimnion. Deep, cold and relatively undisturbed water separated from the surface layer in lakes.

Infiltration. The water entering a sewer system and service connections from the ground through such means as, but not limited to, defective pipes, pipe joints, improper connections, or manhole walls. Infiltration does not include, and is distinguished from, inflow.

Inflow. The water discharged into a wastewater collection system and service connections from such sources as, but not limited to, roof leaders, cellars, yard and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, manhole covers, cross-connections from storm sewers and combined sewers, catch basins, storm waters, surface runoff, street wash waters or drainage. Inflow does not include, and is distinguished from, infiltration.

Influent. Water, wastewater, or other liquid flowing into a reservoir, basin, or treatment facility, or any unit thereof.

Interceptor sewer. A sewer designed and installed to collect sewage from a series of trunk sewers and to convey it to a sewage treatment plant.

Innovative Technology. A technology whose use has not been widely documented by experience and is not a variant of conventional biological or physical/chemical treatment.

Lagoon. In wastewater treatment, a shallow pond, usually man-made, in which sunlight, algal and bacterial action and oxygen interact to restore the wastewater to a reasonable state of purity.

Land Treatment. A method of treatment in which the soil, air, vegetation, bacteria, and fungi are employed to remove pollutants from wastewater. In its most simple form, the method includes three steps: (1) pretreatment to screen out large solids; (2) secondary treatment and chlorination; and (3) spraying over cropland, pasture, or natural vegetation to allow plants and soil microorganisms to remove additional pollutants. Much of the sprayed water evaporates, and the remainder may be allowed to percolate to the water table, discharged through drain tiles, or reclaimed by wells.

Leachate. Solution formed when water percolates through solid wastes, soil or other materials and extracts soluble or suspendable substances from material.

Lift station. A facility in a collector sewer system, consisting of a receiving chamber, pumping equipment, and associated drive and control devices, that collects wastewater from a low-lying district at some convenient point, from which it is lifted to another portion of the collector system.

Limiting Factor. A factor whose absence, or excessive concentration, exerts some restraining influence upon a population.

Loam. The textural class name for soil having a moderate amount of sand, silt, and clay. Loam soils contain 7 to 27% of clay, 28 to 50% of silt, and less than 52% of sand.

Loess. Soil of wind-blown origin, predominantly silt and fine sand.

Macroinvertebrates. Invertebrates that are visible to the unaided eye (those retained by a standard No. 30 sieve, which has 28 meshes per inch or 0.595 mm openings); generally connotates bottom-dwelling aquatic animals (benthos).

Macrophyte. A large (not microscopic) plant, usually in an aquatic habitat.

Melt Water. Water which is formed from the melting of snow, rime, or ice.

Mesotrophic. Waters with a moderate supply of nutrients and no significant production of organic matter.

Mesotrophic Lake. Lakes of intermediate characteristics between oligotrophic and eutrophic. They contain a moderate supply of nutrients and plant life.

Milligram per liter (mg/l). A concentration of 1/1000 gram of a substance in 1 liter of water. Because 1 liter of pure water weighs 1,000 grams, the concentration also can be stated as 1 ppm (part per million, by weight). Used to measure and report the concentrations of most substances that commonly occur in natural and polluted waters.

Moraine. A mound, ridge, or other distinctive accumulation of sediment deposited by a glacier.

National Register of Historic Places. Official listing of the cultural resources of the Nation that are worthy of preservation. Listing on the National Register makes property owners eligible to be considered for Federal grants-in-aid for historic preservation through state programs. Listing also provides protection through comment by the Advisory Council on Historic Preservation on the effect of Federally financed, assisted, or licensed undertakings on historic properties.

Nitrate-nitrogen. Nitrogen in the form of nitrate (NO_3). It is the most oxidized phase in the nitrogen cycle in nature and occurs in high concentrations in the final stages of biological oxidation. It can serve as a nutrient for the growth of algae and other aquatic plants.

Nitrite-nitrogen. Nitrogen in the form of nitrite (NO_2). It is an intermediate stage in the nitrogen cycle in nature. Nitrite normally is found in low concentrations and represents a transient stage in the biological oxidation of organic materials.

Nonpoint source. Any area, in contrast to a pipe or other structure, from which pollutants flow into a body of water. Common pollutants from nonpoint sources are sediments from construction sites and fertilizers and sediments from agricultural soils.

Nutrients. Elements or compounds essential as raw materials for the growth and development of an organism; e.g., carbon, oxygen, nitrogen, and phosphorus.

Outwash. Sand and gravel transported away from a glacier by streams of meltwater and either deposited as a floodplain along a preexisting valley bottom or broadcast over a preexisting plain in a form similar to an alluvial fan.

Oligotrophic. Waters with a small supply of nutrients and hence an insignificant production of organic matter.

Oligotrophic Lakes. Deep lakes that have a low supply of nutrients and thus contain little organic matter. Such lakes are characterized by high water transparency and high dissolved oxygen.

Ordinance. A municipal or county regulation.

Outwash. Drift carried by melt water from a glacier and deposited beyond the marginal moraine.

Outwash Plain. A plain formed by material deposited by melt water from a glacier flowing over a more or less flat surface of large area. Deposits of this origin are usually distinguishable from odinary river deposits by the fact that they often grade into moraines and their constituents bear evidence of glacial origin. Also called frontal apron.

Oxidation lagoon (pond). A holding area where organic wastes are broken down by aerobic bacteria.

Percolation. The downward movement of water through pore spaces or larger voids in soil or rock.

pH. A measure of the acidity or alkalinity of a material, liquid or solid. pH is represented on a scale of 0 to 14 with 7 being a neutral state; 0, most acid; and 14, most alkaline.

Phosphorus. An essential food element that can contribute to the eutrophication of water bodies.

Photochemical oxidants. Secondary pollutants formed by the action of sunlight on nitric oxides and hydrocarbons in the air; they are the primary components of photochemical smog.

Piezometric level. An imaginary point that represents the static head of groundwater and is defined by the level to which water will rise.

Plankton. Minute plants (phytoplankton) and animals (zooplankton) that float or swim weakly in rivers, ponds, lakes, estuaries, or seas.

Point source. In regard to water, any pipe, ditch, channel, conduit, tunnel, well, discrete operation, vessel or other floating craft, or other confined and discrete conveyance from which a substance considered to be a pollutant is, or may be, discharged into a body of water.

Pressure sewer system. A wastewater collection system in which household wastes are collected in the building drain and conveyed therein to the pretreatment and/or pressurization facility. The system consists of two major elements, the on-site or pressurization facility, and the primary conductor pressurized sewer main.

Primary treatment. The first stage in wastewater treatment, in which substantially all floating or settleable solids are mechanically removed by screening and sedimentation.

Prime farmland. Agricultural lands, designated Class I or Class II, having little or no limitations to profitable crop production.

Pumping station. A facility within a sewer system that pumps sewage/effluent against the force of gravity.

Runoff. Water from rain, snow melt, or irrigation that flows over the ground surface and returns to streams. It can collect pollutants from air or land and carry them to the receiving waters.

Sanitary sewer. Underground pipes that carry only domestic or commercial wastewater, not stormwater.

Screening. Use of racks of screens to remove coarse floating and suspended solids from sewage.

Secondary treatment. The second stage in the treatment of wastewater in which bacteria are utilized to decompose the organic matter in sewage. This step is accomplished by introducing the sewage into a trickling filter or an activated sludge process. Effective secondary treatment processes remove virtually all floating solids and settleable solids, as well as 90% of the BOD and suspended solids. USEPA regulations define secondary treatment as 30 mg/l BOD, 30 mg/l SS, or 85% removal of these substances.

Seepage. Water that flows through the soil.

Seepage cells. Unlined wastewater lagoons designed so that all or part of wastewater percolates into the underlying soil.

Septic snooper. Trademark for the ENDECO (Environmental Devices Corporation) Type 2100 Septic Leachate Detector. This instrument consists of an underwater probe, a water intake system, an analyzer control unit and a graphic recorder. Water drawn through the instrument is continuously analyzed for specific fluorescence and conductivity. When calibrated against typical effluents, the instrument can detect and profile effluent-like substances and thereby locate septic tank leachate or other sources of domestic sewage entering lakes and streams.

Septic tank. An underground tank used for the collection of domestic wastes. Bacteria in the wastes decompose the organic matter, and the sludge settles to the bottom. The effluent flows through drains into the ground. Sludge is pumped out at regular intervals.

Septic tank effluent pump (STEP). Pump designed to transfer settled wastewater from a septic tank to a sewer.

Septic tank soil absorption system. A system of wastewater disposal in which large solids are retained in a tank; fine solids and liquids are dispersed into the surrounding soil by a system of pipes.

Settling tank. A holding area for wastewater, where heavier particles sink to the bottom and can be siphoned off.

Sewer, Interceptor. See Interceptor Sewer.

Sewer, lateral. A sewer designed and installed to collect sewage from a limited number of individual properties and conduct it to a trunk sewer. Also known as a street sewer or collecting sewer.

Sewer, sanitary. See Sanitary Sewer.

Sewer, storm. A conduit that collects and transports storm-water runoff. In many sewerage systems, storm sewers are separate from those carrying sanitary or industrial wastewater.

Sewer, trunk. A sewer designed and installed to collect sewage from a number of lateral sewers and conduct it to an interceptor sewer or, in some cases, to a sewage treatment plant.

Shoaling. The bottom effect that influences the height of waves moving from deep to shallow water.

Sinking fund. A fund established by periodic installments to provide for the retirement of the principal of term bonds.

Slope. The incline of the surface of the land. It is usually expressed as a percent (%) of slope that equals the number of feet of fall per 100 feet in horizontal distance.

Sludge. The accumulated solids that have been separated from liquids such as as wastewater.

Soil association. General term used to describe taxonomic units of soils, relative proportions, and pattern of occurrence.

Soil textural class. The classification of soil material according to the proportions of sand, silt, and clay. The principal textural classes in soil, in increasing order of the amount of silt and clay, are as follows: sand, loamy sand, sandy loam, loam, silt loam, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. These class names are modified to indicate the size of the sand fraction or the presence of gravel, sandy loam, gravelly loam, stony clay, and cobbly loam, and are used on detailed soil maps. These terms apply only to individual soil horizons or to the surface layer of a soil type.

State equalized valuation (SEV). A measure employed within a State to adjust actual assessed valuation upward to approximate true market value. Thus it is possible to relate debt burden to the full value of taxable property in each community within that State.

Stratification. The condition of a lake, ocean, or other body of water when the water column is divided into a relatively cold bottom layer and a relatively warm surface layer, with a thin boundary layer (thermocline) between them. Stratification generally occurs during the summer and during periods of ice cover in the winter. Overturns, of periods of mixing, occur in the spring and autumn. This condition is most common in middle latitudes and is related to weather conditions, basin morphology, and altitude.

7-day, 10-day low flow. The lowest average flow that occurs for a consecutive 7-day period at a recurrence interval of 10 years.

Surface water. All bodies of water on the surface of the Earth.

Suspended solids (SS). Small solid particles that contribute to turbidity. The examination of suspended solids and the BOD test constitute the two main determinations for water quality that are performed at wastewater treatment facilities.

Threatened species. Any species of animal or plant that is likely to become endangered within the foreseeable future throughout all or a significant part of its range.

Till. Unsorted and unstratified drift, consisting of a heterogeneous mixture of clay, sand, gravel, and boulders, that is deposited by and underneath a glacier.

Trickling filter process. A method of secondary wastewater treatment in which the biological growth is attached to a fixed medium, over which wastewater is sprayed. The filter organisms biochemically oxidize the complex organic matter in the wastewater to carbon dioxide, water, and energy.

Topography. The configuration of a surface area including its relief, or relative evaluations, and the position of its natural and manmade features.

Trophic level. Any of the feeding levels through which the passage of energy through an ecosystem proceeds. In simplest form, trophic levels are: primary producers (green plants) herbivores, omnivores, predators, scavengers, and decomposers.

Unique farmland. Land, which is unsuitable for crop production in its natural state, that has been made productive by drainage, irrigation, or fertilization practices.

Wastewater. Water carrying dissolved or suspended solids from homes, farms, businesses, and industries.

Water quality. The relative condition of a body of water, as judged by a comparison between contemporary values and certain more or less objective standard values for biological, chemical, and/or physical parameters. The standard values usually are based on a specific series of intended uses, and may vary as the intended uses vary.

Water table. The upper level of groundwater that is not confined by an upper impermeable layer and is under atmospheric pressure. The upper surface of the substrate that is wholly saturated with groundwater.

Wetlands. Those areas that are inundated by surface or ground water with a frequency sufficient to support and under normal circumstances does or would support a prevalence of vegetative or aquatic life that requires saturated or seasonally saturated soil conditions for growth and reproduction.

APPENDIX A

EXISTING ON-SITE SYSTEMS

NOTES ON EXISTING ON-SITE SYSTEMS MEMORANDUM

1. The memorandum is dated 1979 and is consequently outdated with respect to systems that have been upgraded. Also, recent sources have clarified certain information that was unclear.

2. Updated information concerning upgraded systems indicates that during 1980 and 1981 systems have been upgraded at a lesser rate than was typical of earlier in the decade. The number of new systems for new dwellings declined markedly these two years.

3. One unique cluster system has been identified on the west side of Indian Lake in Segment 3 (Figure 2). The Old German Village group of 20 (or 21) houses has a sewage collection system, a common septic tank, and common drain field. The Association maintains the system and, aside from roots plugging the sewers, it functions without problems.

4. Through a variety of sources, primarily the mailed questionnaire prepared by Gove Associates, Inc. but also homeowner comments in local interviews and personal observation, it has been noted that many upgradings do not go through the permit processes of the health departments. In Berrien County permits are rarely filed for an upgrading because none are required in the health code. Restoning dry wells, surely an indication of a failed system, are not subject to permits in Van Buren County. Additionally, many upgradings have reportedly occurred without the direction of the health departments because the homeowner wished to escape the more costly systems designed by a sanitarian.

MEMORANDUM

To: Ms. Kathleen Schaub, Project Officer

Date: 29 January 1980

From: Gregg S. Larson, Project Manager

Ref: (559-C)

Subject: Summary of Existing Treatment and Disposal Systems in the Project Area

Cc:

This memorandum summarizes the results of the field work that was conducted by Mr. G. Lenssen, Associate Agricultural Engineer, during the period from 16 to 19 October 1979. Mr. Lenssen visited the Health Department in Berrien, Cass, and Van Buren Counties to document wastewater treatment system malfunctions and replacements in the project area. Tables that summarize structural characteristics and replacement system characteristics accompany the narrative descriptions of planning segments. Planning segment maps also are attached. The information regarding the 40 planning segments in the Indian Lake and Sister Lakes service areas will be utilized by WAPORA in the development of decentralized alternatives.

EXISTING TREATMENT AND DISPOSAL SYSTEMS

1.0. Introduction

Septic tanks and soil disposal systems of some kind have been utilized for sewage treatment and disposal in the Indian Lake/Sister Lakes area since outdoor toilets were moved indoors. Early systems were "anything that worked" (i.e., that allowed the sink and toilet to continue to function). These generally consisted of cinder block tanks with a short length of tile. As long as the plumbing did not back up, the operation of the system was considered satisfactory. Some of the alternative systems installed consisted of precast concrete septic tanks, open-core concrete block and precast dry wells, drain beds, and hybrid systems of anything that could eliminate wastewater. Sewage disposal was a private concern; the public health department became involved only when a complaint was registered and a distinct public health problem existed. The septic tank and soil absorption system generally were added as an afterthought after a

residence was constructed. Thus, they frequently were installed on the margin of the lakes in a variety of soil material, and often below the groundwater table.

In the late 1960s, State law enjoined each county health department to regulate the installation of septic tanks. Standards for materials and installation were adopted, and a permit program was established for new and/or repaired systems. During the early years of the permit program, permits usually were granted without an examination of the proposed system site. The health departments would prepare a crude sketch, based on the homeowner's verbal property description, and would indicate satisfactory locations for the septic tank and soil absorption system. The homeowner could choose the type of construction; the same alternative systems utilized prior to the permit program were available. Because the health department field inspections were infrequent, actual construction bore little resemblance to what was described in the permit. In the mid 1970s, the health departments began to inspect regularly the system installations to ensure that the regulations were complied with.

Each county health department with jurisdiction in the project area has developed its own standards for soil absorption systems. The Van Buren County Health Department permits block trench and precast concrete dry wells in any location where depth to groundwater is great enough to allow 2 feet of soil below the dry well. Both the Cass County and the Berrien County Health Departments allow precast concrete dry wells only where depth to groundwater is satisfactory and where other replacement systems cannot be installed because prescribed isolation distances are unattainable. Isolation distances, depth to groundwater, and soil material requirements are enforced. Raised drain beds (mound systems) are utilized in all three counties, for new construction and for replacements, on lots where the depth to water table criteria cannot otherwise be met.

Information concerning existing systems has been extracted from the permits filed with each county health department. Although general conclusions can be drawn, the information cannot be used to develop a definitive analysis of existing systems in the project area. Difficulties encountered

in evaluating the permit information included revised standards within individual counties, varying standards between counties, inadequate location descriptions, few as-built sketches, limited field inspections during the early years, and completed repairs without filed permits. The information that was obtained during the reviews of health department permits has been tabulated for each service area by segment in the descriptions and tables that follow.

2.0. Segment Physical Characteristics, Housing and Wastewater Treatment Systems

Segment 1. This area is located along the northwestern shoreline of Indian Lake in Cass County. It consists primarily of four land divisions: the Tice leases, the Love trailer park development, the Lake View Mobile Home Estates, and the Oak Grove subdivision. About 70% of the residences are permanent dwellings, most of which are mobile homes in the Love subdivision. High water table and limited lot sizes are common problems for wastewater disposal. Soils are sands and in some locations are rather silty. Most wastewater treatment systems consist of a septic tank and a dry well, although new and replacement units have included drain beds and raised drain beds with effluent lift pumps. About 25% of the septic tank/soil absorption systems (ST/SAS) have been installed since 1972. About 5% of the total number have been replaced since 1972.

Segment 2. This area is located along the west side of Indian Lake. The Forest Beach subdivision constitutes most of the area. Also included are some apartment buildings, the Indian Lake Golf Course Clubhouse, and some individual parcels. About 50% of the residences are permanent dwellings. The lake margin has a high water table, and the land slopes up rapidly away from that margin. The soil material consists of sands. Most of the residences are old; however, only three soil absorption systems have been replaced in the last 7 years. Drain beds and dry wells have been utilized for replacement systems. A few lots are too limited for drain bed replacement systems.

Segment 3. This area is located along the west side of Indian Lake, south of Segment 2. The Forest Beach subdivision constitutes most of the area. The "Old German Village" area is contained within this segment. About 65% of the housing is seasonal. The broad lake margin and large marsh have high water tables. The land slopes up rather abruptly from the lake margin. Except for the muck soils in the marshy area, the soil material is sand. Most of the residences date back numerous years. Five systems (8%) have been replaced in the last 7 years. Drain beds, raised and conventional, were used for replacement systems. Some lots have restricted areas that preclude drain bed utilization.

Segment 4. This area is located on the south side of Indian Lake. Individual lots make up the bulk of the area; the Ridenour Park and the South Shore subdivisions comprise the remainder. About 65% of the residences are seasonal. This segment also contains the eight commercial structures located around Indian Lake. Most of the segment has a narrow lake margin with a high water table, a steeply sloping strip of land next to the lake margin, and gently sloping land away from the lake. At the southern tip of the lake, the lake margin is much broader and has some muck soils. Many of the lots are too limited to allow for replacement drain bed systems. A small proportion (7%) of the systems have been replaced since 1972.

Segment 5. This segment includes all the leased properties on the east side of Indian Lake and some individual lots on the south side of the lake. Nearly all of the residences are occupied seasonally. The area consists of the lake margin, with a high water table, and gently sloping land away from the lake. Two exceptions to this description include the low-lying land bordering the Indian Lake outlet drain and the steeply sloping land at the southern end of the segment. Only a small percentage (7%) of the systems have been replaced since 1972. Limited lot sizes on the south side of the lake appear to be the only genuine hindrance to drain bed replacement systems, conventional or raised.

Segment 6. This segment is located northeast of Indian Lake. It includes the Loeb's Oakwood and Beachwood subdivisions, as well as numerous individual lots. About 65% of the residences are seasonally occupied.

A restaurant also is located within this segment. Some of the residences are new or have been rebuilt recently. Nearly all of the residences are located on soils with high water tables. About 12% of the soil absorption systems have been replaced since 1972, primarily in the Beechwood subdivision. Raised drain beds have been used extensively for replacements.

Segment 8. This area is located on the south side of Pipestone Lake. Nearly all the residences are located in the Bass Island Park subdivision. A tavern also is located within the segment. About 30% of the residences are occupied seasonally. Nearly all of the residences are located on muck soils that have a high water table. About 10% of the systems have been replaced within the last 8 years. Replacements have been raised drain beds. The Bass Island Tavern has holding tanks for its wastewater.

Segment 9. This area is located on the north side of Pipestone Lake. About 20% of the residences are occupied seasonally. The residences in this area are located on muck soils with high water tables. Concern about lake pollution in the late 1960s led many residents to install raised drain beds. The most recent replacements (since 1972) also have been raised drain beds. The Berrien County Health Department has denied septic tank permits in the muck soils that surround Pipestone Lake. New housing must have either off-site sewage treatment, or the housing must be distant from the lake.

Segment 10. This area is located along Napier Avenue (M152) northeast of Pipestone Lake. The segment includes the Sister Lakes laundromat and some residences. The proposed sewer plans did not include service for these structures, although a sewage lift station was located there. The land is steeply sloping and has a depth to the water table greater than 6 feet. The laundromat recently has installed a small lagoon for waste washwater treatment.

Segment 11. This segment is located on the south side of Dewey Lake and the boat channel. It consists of the Dewey Beach Resort No. 1 and Sandy Beach Estates subdivisions. Many of the residences are newly constructed, and about 50% serve as permanent residences. The land slopes

upward from the shoreline toward the south. Since most of the residences are relatively new, few replacement systems have been installed. Nearly all of the systems recently installed in this segment have been drain beds.

Segment 12. This segment consists of the land on the south side of Dewey Lake between the lake and the channel. Most of the residences are old and about 40% are seasonal. No new residences have been constructed, and no replacement systems have been installed since 1972. Most of the soil area has a high water table, especially at the eastern end of the segment.

Segment 13. This segment consists of western shorelands on Dewey Lake and a 0.5 mile strip along Dixon Street. It includes the Swisher's Landing, Dewey Terrace, Dewey Beach, and Plat of Deweymore subdivisions, as well as numerous individual parcels. About 40% of the residences are occupied seasonally, including several small resorts with leased units. Generally, the segment consists of a narrow lake margin with a high water table and gently sloping land beyond. The southern portion of the segment is steeply sloping away from the lake. About 7% of the systems have been replaced in the last 8 years. Some lots especially toward the southern end, are so limited in size that isolation distances cannot be achieved even with dry wells.

Segment 14. This segment lies between Dewey Lake and Magician Lake, and includes the Dewey Brook, Magician Bay Park, and Supervisor's Plat of South Bay Park subdivisions and parts of the Midway, Orchard Hills, and Currans Beach subdivisions. Most of the residences predate 1972, and 70% are occupied seasonally. Some multiple family dwellings are present in this segment. The land has limited lake margins with high water tables. Most of the land slopes upward away from the lakes. Replacements have been minimal. Limited lot sizes and slopes preclude conventional drain beds on many of the lots.

Segment 15. This segment is located on the east side of Dewey Lake and is comprised of the Sleepy Hollow subdivision and a number of individual parcels. About 50% of the residences are occupied seasonally. Nearly

all the residences predate 1972. With the exception of a low area with a high water table at the southern end of the segment, the land slopes steeply away from the lake. Few replacements have occurred even though most of the residences are rather old. The lots are generally narrow but very long and have adequate replacement area for drain beds.

Segment 16. This area includes a small portion of the west shore of Magician Lake and a wide area along M152. The segment includes the following subdivisions: Magician Lake Park, Lakeview No.1, and portions of Lakeview and Midway. Some individual parcels and the commercial structures along M152 also are included in this segment. Most of the land is gently sloping with a depth to the water table greater than 5 feet. No replacements have been recorded for this segment. Lots in the Magician Lake Park subdivision are small; siting replacement drain beds on these lots would be difficult.

Segment 17. This segment includes virtually all the west and north shorelands of Magician Lake. The Orchard Hills, Midway, Lakeview, Oaklands, Woodlawn, Krohne's Peninsula, and Gregory's Addition to Magician Lake Woods subdivisions are located in this segment. About 30% of the residences are occupied permanently. Nearly all of the structures were built prior to 1972. The lake margin, with a high water table, varies considerably in width. The land slopes gently away from the shore on the west shore and abruptly on the north shore. About 10% of the soil absorption systems have been replaced since 1972. Many of the lots on the north shore have sizes and slopes that preclude replacement systems other than dry wells. However, isolation distances cannot be attained even with dry well installation.

Segment 18. This segment consists of the first tier development on both sides of M152 and Maple Island Road at their intersection. Part of Ina Curran's subdivision is located in the segment. The Gunn Inn also is located in this segment. About 50% of the residences are occupied seasonally. The land is sloping, and the depth to the water table is greater than 10 feet. There has been one replacement system installed in this segment.

Segment 19. This segment includes Maple Island in Magician Lake. About 75% of the residences are occupied seasonally. The island has a broad lake margin, high water table, and an interior knoll. Maintenance of isolation distances, even with dry well soil absorption systems, is difficult because of the lot sizes and shapes. About 15% of the systems have been replaced in the last 8 years. Raised drain beds and dry wells have been used for replacements.

Segment 20. This segment includes most of the lots in the Currans subdivisions on the south shore of Magician Lake. The segment also includes part of the Boathouse Addition. Approximately 65% of the residences are occupied seasonally. The land consists of a narrow to broad lake margin with a high water table. The land rises steeply beyond this margin. The lots are generally narrow and some are also very short; isolation distances are often difficult to attain. Some soil absorption systems have been constructed opposite the residences on the other side of the road. Few soil absorption systems have been replaced in the last 8 years.

Segment 21. This segment is located on the south shore of Magician Lake. The land is owned by the Smith and Polk families and leased for cottages, most of which are occupied seasonally. The majority of the area has a high water table and muck soil material. About 25% of the systems have been replaced in the last 8 years. Nearly all of the new and replacement systems are raised drain beds. Of those, more than half require lift pumps.

Segment 22. This area is located on the southeast shore of Magician Lake. The segment includes part of the Rainbow Park subdivision. Most of the cottages on the shoreline are old, although several have been remodeled. The residences sited away from the lake have been constructed recently. About 60% of the residences are occupied seasonally. The land has a narrow lake margin with a high water table and rises steeply to the gently rolling uplands. Some layers of silty soil material are found in the sands. About 15% of the systems have been replaced in the last 8 years. Many of these replacements are raised drain beds. Land slope and lot size restrict replacement system options on the shoreline lots.

Segment 23. This area is located along the southern shorelands at the eastern end of Magician Lake. It encompasses land in both Cass and Van Buren Counties. Parts of the Rainbow Park and Gilmore Beach subdivisions are included in the segment. About 60% of the residences are occupied seasonally. The land is flat to rolling; the water table depth for nearly all of the segment is less than 6 feet. About 20% of the systems have been replaced in the last 8 years. Most of the new systems and replacement systems in this segment are raised drain beds. Several permit applications for septic tanks and soil absorption systems have been denied in this segment.

Segment 24. This area is located at the northeast end of Magician Lake. The segment includes the Neff rental cottages and others on individual parcels. Nearly all are occupied seasonally. The land is steeply rolling, particularly where the cottages are located. About 20% of the systems have been replaced in the last 8 years. With the exception of areas with steep slopes, soil absorption systems appear suitable for most areas.

Segment 25. The Magician Lake Woods subdivision, on the north side of Magician Lake, comprises this segment. The Blue Fin Marina also is located on the shoreline in this segment. Only 10% of the residences are occupied year-round. The land rises steeply from the lakeshore to the uplands. A small area at the site of the marina has a high water table. About 10% of the systems have been replaced in the last 10 years. Some silty soil material in the segment may limit soil permeability. Inadequately sized dry wells appear to be the primary reason for replacements.

Segment 26. This segment consists of the Cable Park Beach subdivision and some individual parcels on the southwestern shore of Cable Lake. About 65% of the residences are seasonally occupied. The segment is characterized by a steep-sided ridge that parallels the south shore of the lake. The western end of the segment is low-lying land with a high water table. Replacements have been minimal. The steep slopes and narrow lots limit replacement options.

Segment 27. This segment is located on the southeastern shore of Cable Lake and includes the Fitch Foundation Camp, individual parcels, and part of the Wildwood subdivision. About 65% of the residences are occupied permanently, including the camp cabins. The land slopes gently toward the lake. The lake margin, with a high water table, is narrow. No new or replacement systems have been installed in this segment in the last 8 years.

Segment 28. This area encompasses the eastern shorelands of Cable Lake, including a portion of the Wildwood subdivision. About 65% of the residences are occupied seasonally. The land slopes gently away from the lake; a large area near the lake has depths to the water table less than 6 feet. About 5% of the systems have been replaced in the last 8 years. The shallow water table and small lot sizes will preclude standard replacement systems in some areas.

Segment 29. This segment is located on the northern shore of Cable Lake. The land includes portions of the Wildwood and Sister-Cable Lake Shores subdivisions. About 60% of the residences are occupied seasonally. The lands within the segment consist of gently rolling uplands and a steeply sloping shoreline. One small length of shoreline has a wide lake margin with a high water table. About 7% of the systems have been replaced in the last 8 years. Most replacement systems are conventional drain beds, although one raised drain bed was necessary and some dry wells were needed because of limited lot sizes. Although the platted lot sizes in the Wildwood subdivision are small, adjacent lots usually are owned by the same individual and available for replacement systems.

Segment 30. This segment is located in Van Buren County on the eastern shore of lower Crooked Lake. It includes the Adam's Sister Lakes and Spencer's Sister Lakes subdivisions and several individual parcels. About 50% of the residences are occupied seasonally. The segment consists of rolling uplands with a steep slope to the lake shore. There have been two replacement systems installed in the last 8 years. Although the lots are generally narrow and sloping, their length is adequate for replacement systems.

Segment 31. The land between lower Crooked Lake and Cable Lake is included in this segment. The segment encompasses nearly all of the Sister-Cable Lake Shores subdivision. About 65% of the residences are occupied permanently. The area is characterized by rolling uplands sloping, gently to steeply, toward the lake shore. Replacement systems have been installed for about 10% of the residences. Although some of the residences are old, many have been constructed recently (40% in the last 8 years). Lot size and slope prevent installation of drain beds on some lots. Most lots, however, are large enough for replacement systems.

Segment 32. This segment consists of the southwestern shore of lower Crooked Lake. The Supervisor's Plat of Sommer's Beach and the Sister-Cable Lake Shores No. 2 subdivisions in Cass County, in addition to several individual parcels in both Cass and Van Buren Counties, are included in this segment. About 50% of the residences are occupied seasonally. The segment has rolling uplands and a steep slope to the lake shore. About 20% of the systems have been replaced in the last 8 years. Drain beds, half of which require lift pumps, have been used for the replacement systems. Narrow and sloping lots make installation of replacement systems difficult, although the lot sizes are generally adequate.

Segment 33. This segment is located between Round Lake and upper and lower Crooked Lake. It includes the oldest residential and resort area, and the old "downtown" of Sister Lakes. Several small subdivisions are located in the segment; most residences, however, are sited on individual parcels. Approximately 10 commercial structures are located in this segment, as well as several rental cottages. About 50% of the residences are occupied seasonally. The segment is characterized by rolling uplands with steep slopes to the lakeshore. The land between Round Lake and upper Crooked Lake is low-lying and has a shallow water table. Approximately 15% of the systems have been replaced in the past 8 years. Several raised drain beds were installed because of the depth to the water table limitation. Lot sizes and shapes have precluded proper isolation distances in several areas.

Segment 34. This segment is located on the northwest side of upper Crooked Lake. All of Woodland Point subdivision, a portion of the Adam's Hillcrest Shore subdivision, and several individual parcels are in the segment. A large rental cottage complex also is included. About 50% of the residences are seasonally occupied. The point of land on which the Woodland Point subdivision is located is elevated high above the water surface and has steep slopes down to the lake. The remainder of the segment is gently sloping. About 10% of the systems have been replaced in the last 8 years. Most of these have been located on the point, and the replacements have been dry wells that receive pumped effluent. The Adam's Hillcrest Shores subdivision has been platted only recently; systems there are new.

Segment 35. This segment includes a large area on the northeastern shore of upper Crooked Lake, that extends to M152 on the north and east. The Woodland Beach, Kilburland Park, Crooked Lake Park, and Lakeland Terrace subdivisions are in this segment. About 50% of the residences are occupied seasonally, and the majority of these are near the lake. The segment has gently rolling uplands that slope moderately near the lake shore. The lake shore margin, with a high water table, is generally narrow. About 10% of the systems have been replaced in the last 8 years. Some lot sizes and slopes preclude maintenance of isolation distances. Raised drain beds have been required in some areas because of the position of the water table.

Segment 36. This segment encompasses the southern shoreland of upper Crooked Lake. It includes the Woodland Park and Hield's Sister Lakes subdivision. About 50% of the residences are on individual parcels. Several of the parcels are occupied by rental cottages. Three commercial establishments and the Lion's Park also are located within the segment. About 65% of the residences are occupied seasonally. The segment is characterized by rolling uplands that slope steeply to the lake shore. Replacement systems have been installed for about 10% of the residences in the last 8 years. Most replacement systems have been dry wells. Some areas have lot sizes and slopes that preclude standard isolation distances.

Segment 37. This segment is on the south shore of Round Lake. Several individual parcels, the Hampton D. Sill's Sister Lakes subdivision and a cottage rental development are in the segment. Few cottages are occupied year-round. The eastern part is steeply rolling, while the western part is flat and low-lying. The western end of the segment consists of filled land. About 15% of the systems have been replaced within the last 8 years. Raised drain beds have been utilized extensively for new residences in the western end of the segment because of the shallow depth to the water table. Land slopes and narrow lots in the eastern end complicate soil absorption system installation.

Segment 38. This segment encompasses the Oak Park and Oak Island subdivisions on the western shore of Round Lake. These subdivisions contain a number of new residences. Seasonally occupied residences constitute about 45% of the residences. The segment consists of two high ridges; one is located along the lakeshore (the site of the Oak Island subdivision) and the other is located in the middle of the Oak Park subdivision. Between these ridges is marshland designated as Lilly Park. Slopes on these ridges are steep. One area of silty soil material with moderately limited permeability has been identified in the segment. About 10% of the systems have been replaced in the last 8 years. Some raised drain beds have been necessary to meet the depth to the water table standard. Part of the segment has several residences on small lots; a holding tank was the only system that could meet standards in one instance.

Segment 39. This segment is located on the northern shore of Round Lake. The Benton Beach and Pitcher's Acres subdivisions, and numerous individual parcels, are included in this segment. About 20% of the residences are occupied seasonally. The land in the Benton Beach subdivison slopes steeply to the lake. Land in the remainder of the segment slopes to a valley that is oriented north-south. About 10% of the systems have been replaced in the last 8 years. Most of the residences in the Pitcher's Acres subdivision were built within the last 15 years. One parcel with three leased residences has a limited area for replacement systems. Steep slopes in the segment could result in construction difficulties for replacement systems, particularly in the Benton Beach subdivision.

Segment 40. This segment is located on the northeastern shore of Round Lake and extends to the intersection of M152 (Napier Avenue) and CR690 (Sister Lakes Road). The subdivisions included are: Supervisor's Plat of Britton Park, Britton Park, Mariner's Beach, Assessor's Replat of Part of Pitcher's Beach, and Pitcher's Beach. There are also numerous individual parcels. The primary commercial area of Sister Lakes is located in this segment at the intersection of M152 and CR690. About 15 commercial establishments have been identified. The Sister Lakes School also is located in this segment. Seasonally occupied residences constitute about 55% of the residences, and most of these are located near the lake. The land is gently rolling, except along the shoreline of Round Lake, where it is moderately steep. About 10% of the residential and commercial systems have been replaced. The lots on the shoreline are small and sloping; replacement systems have been sited with difficulty.

3.0. Summary

Although the physical characteristics of the planning segments vary with location, all are primarily residential. There were a total of 2,513 residential structures and 56 commercial structures located in the planning segments. Approximately 93% were constructed prior to October 1972. (Generally, two-thirds of the expected flow from collection systems must be for wastewater from residences in existence prior to October 1972 in order to be eligible for Federal funding.) About 2% of the residences were constructed after December 1977. (Federal grant regulations for privately-owned treatment works require that the principal residence or small commercial establishment be constructed and inhabited on or before 27 December 1977.)

Less than 10% of the systems have been replaced over the last 8 years. The numbers and types of replacement systems, however, do not indicate whether systems are operating satisfactorily or whether nutrient enriched effluent is being discharged in the lakes.

The systems that were replaced were primarily dry wells that were too small and sited with less than the required distance above the water table.

Some replacements were necessary because the drain beds or dry wells were insufficiently sized for silty soil material. Lot sizes and shapes and land slopes appear to be the major constraint to installing soil absorption systems that meet the applicable standards of each county. Muck soils around Pipestone Lake, and occassionally along the other lakeshores, are unacceptable for replacement systems and have resulted in permit denials.

The majority of replacement systems have been dry wells or block trenches (42%). Some were installed because lot configurations precluded utilization of drain beds where they were preferred. Dry wells and block trenches that required lift pumps comprised 8% of the replacement systems installed. The lift pumps were needed where the soil absorption systems were installed at higher elevations away from the lake. In Cass County small, congested lots precluded the use of a drain bed.

The conventional drain bed accounted for 18% of the replacements. These were installed wherever possible in Cass County and in locations in Van Buren County where clearance above the water table could not be attained with dry wells. Only a few of the drain bed replacements were standard drain fields. Drain beds that required lift pumps accounted for 7% of the replacements. They were necessary where the drain bed was installed at a higher elevation than the residence because of requirements regarding clearance over the water table, setback from a lake, or lot configuration. Raised drain beds, to provide clearance over a high water table, were necessary for 7% of the replacement systems. On level areas, raised drain beds required lift pumps. Concentrations of raised drain beds with lift pumps were noted in the Gilmore Beach and Beechwood subdivisions, the Polk leases, and the Pipestone Lake area (Segments 23, 21, 6, 8, and 9, respectively), and accounted for 13% of the replacements.

Other replacement systems comprise the remaining 5% of the replacements. They include systems where only the septic tank was replaced, those for which no design information was available, and two holding tank systems.

Table 1. Structural characteristics, by segment, in the Indian Lake/Sister Lakes study area (Gove Associates, Inc. 1979).

Segment	Permanent Housing[1] ■	●	▲	Total Permanent	Seasonal Housing[2] □	○	△	*[3]	Total Seasonal	Total Housing
1	93	27	0	120	49	8	0	0	57	177
2	17	0	0	17	13	0	0	1	13	30
3	19	0	0	19	43	0	0	1	43	62
4	20	0	0	20	36	1	0	8	37	57
5	18	0	0	18	102	0	0	0	102	120
6	27	0	0	27	46	0	1	1	47	74
7	0	0	0	0	0	0	0	0	0	0
8	26	1	0	27	13	0	0	1	13	40
9	37	1	0	38	9	0	0	1	9	47
10	2	0	0	2	0	0	0	1	0	2
11	11	6	1	18	9	9	1	0	19	37
12	21	0	0	21	14	0	0	0	14	35
13	72	0	0	72	44	0	1	0	45	117
14	27	0	3	30	70	2	0	1	72	102
15	13	0	0	13	13	1	0	0	14	27
16	22	2	1	25	15	0	0	4	15	40
17	61	5	0	66	136	2	0	0	138	204
18	3	0	0	3	4	0	0	[illegible]	4	7
19	9	0	0	9	26	0	0	0	26	35
20	19	1	0	20	43	0	0	0	43	63
21	3	1	0	4	28	1	3	0	32	36
22	15	3	0	18	21	4	1	0	26	44
23	26	3	0	29	44	2	0	0	46	75
24	5	0	0	5	19	0	0	0	19	24
25	4	2	0	6	58	2	0	1	60	66
26	11	1	0	12	20	1	0	0	21	33
27	13	0	0	13	8	0	0	0	8	21
28	20	0	0	20	38	2	0	0	40	60
29	17	0	0	17	18	9	0	0	27	44
30	16	0	0	16	16	0	0	0	16	32
31	31	3	0	34	16	2	0	0	18	52
32	15	0	0	15	12	1	0	0	13	28

Table 1. (continued)

Segment	Permanent Housing[1] ■	●	▲	Total Permanent	Seasonal Housing[2] □	○	△	*[3]	Total Seasonal	Total Housing
33	59	1	0	60	62	1	0	9	62	123
34	25	2	0	27	25	0	0	1	25	52
35	103	7	0	110	97	7	1	4	105	215
36	36	2	0	38	56	16	1	4	73	111
37	4	0	0	4	35	1	0	0	36	40
38	38	2	0	40	30	2	0	0	32	72
39	42	8	0	50	10	2	0	3	12	62
40	19	2	0	21	23	3	0	15	26	47
Total	1,019	80	5	1,104	1,321	79	9	56	1,385	2,513

[1] Permanent Housing:
- ■ Building permit issued before October 1972
- ● Building permit issued after October 1972 and before December 1977
- ▲ Building permit issued after December 1977

[2] Seasonal Housing:
- □ Building permit issued before October 1972
- ○ Building permit issued after October 1972 and before December 1977
- △ Building permit issued after December 1977

[3] * Commercial structure.

Table 2. Total and replacement wastewater systems by segment in the Indian Lake/ Sister Lakes study area (Berrien County Health Department 1979, Cass County Health Department 1979, and Van Buren County Health Department 1979).

Segment	DB/DF[1]		DB+L[2]		RDB[3]		RDB+L[4]		DW/BT[5]		DW+L/BT+L[6]		OTHER		TOTAL	
	Total	Repl	Total	Repl	Total	Repl	Total	Repl	Total	Repl	Total	Repl	Total	Repl	Total	Repl
1	24	2	4	1	5	0	4	3	16	1	0	0	0	0	53	7
2	3	2	0	0	1	0	0	0	2	1	0	0	0	0	6	3
3	2	2	0	0	2	1	0	0	1	1	1	1	0	0	6	5
4	6	3	0	0	2	0	0	0	2	1	1	0	0	0	11	4
5	1	1	1	1	1	1	1	0	5	4	1	1	0	0	10	8
6	4	3	0	0	4	3	2	2	3	1	0	0	0	0	13	9
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	2	1	2	2	0	0	0	0	1	1	5	4
9	1	0	0	0	0	0	1	1	0	0	0	0	0	0	2	1
10	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
11	11	1	1	0	2	1	0	0	3	0	0	0	0	0	17	2
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	3	0	0	0	0	0	1	1	7	6	1	1	0	0	12	8
14	7	0	1	1	1	0	0	0	4	0	1	1	1	1	15	3
15	2	1	0	0	1	0	0	0	2	1	0	0	0	0	5	2
16	2	0	0	0	0	0	0	0	3	0	0	0	0	0	5	0
17	7	3	4	4	2	0	1	1	12	8	5	5	0	0	31	21
18	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1
19	1	1	0	0	2	2	0	0	3	2	0	0	0	0	6	5
20	1	1	2	1	1	1	0	0	1	0	0	0	0	0	5	3
21	1	0	0	0	2	0	9	6	2	2	0	0	0	0	14	8

Table 2. (continued)

Segment	DB/DF[1] Total	DB/DF[1] Repl	DB+L[2] Total	DB+L[2] Repl	RDB[3] Total	RDB[3] Repl	RDB+L[4] Total	RDB+L[4] Repl	DW/BT[5] Total	DW/BT[5] Repl	DW+L/BT+L[6] Total	DW+L/BT+L[6] Repl	OTHER Total	OTHER Repl	TOTAL Total	TOTAL Repl
22	7	2	0	0	4	2	2	2	3	1	0	0	0	0	16	7
23	3	1	0	0	5	3	9	8	3	2	0	0	1	1	21	15
24	0	0	0	0	0	0	0	0	6	5	0	0	0	0	6	5
25	0	0	0	0	0	0	1	1	7	4	1	1	0	0	9	6
26	3	1	0	0	0	0	0	0	3	0	0	0	0	0	6	1
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	7	1	0	0	0	0	0	0	2	2	0	0	0	0	9	3
29	10	3	0	0	1	0	0	0	5	0	0	0	0	0	16	3
30	0	0	0	0	0	0	0	0	5	1	0	0	1	1	6	2
31	12	2	1	1	1	0	0	0	7	3	0	0	0	0	21	6
32	5	2	3	3	0	0	0	0	2	0	0	0	0	0	10	5
33	2	0	3	3	0	0	1	1	14	12	1	1	0	0	21	17
34	1	0	0	0	0	0	0	0	1	0	4	4	1	1	7	5
35	8	2	0	0	0	0	1	1	33	17	1	1	1	1	44	22
36	4	2	0	0	0	0	0	0	14	7	1	1	1	1	20	11
37	2	2	1	1	4	0	0	0	2	1	1	1	1	1	11	6
38	1	0	0	0	1	0	1	1	8	3	1	0	5	4	17	8
39	1	1	0	0	0	0	1	1	8	4	0	0	0	0	10	6
40	4	2	0	0	0	0	0	0	12	5	0	0	0	0	16	7
Total	146	41	21	16	44	15	37	31	202	96	20	18	14	12	484	230

[1] DB/DF = Drain Bed/Drain Field

[2] DB+L = Drain Bed + Lift

[3] RDB = Raised Drain Bed

[4] RDB+L = Raised Drain Bed + Lift

[5] DW/BT = Dry Well/Block Trench

[6] DW+L/BT+L = Dry Well + Lift/Block Trench + Lift

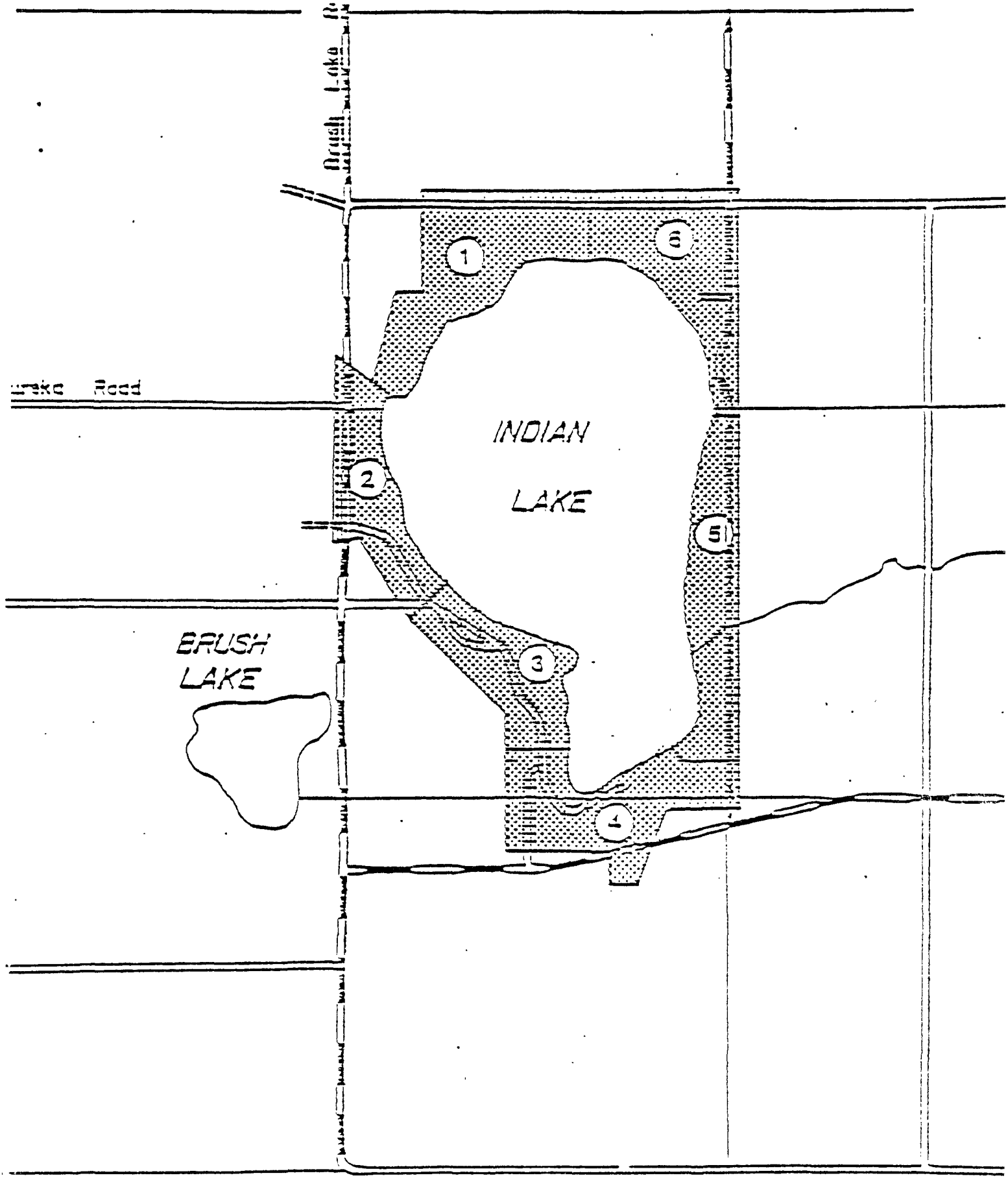


Figure 1. Segment locations in the Indian Lake service area.

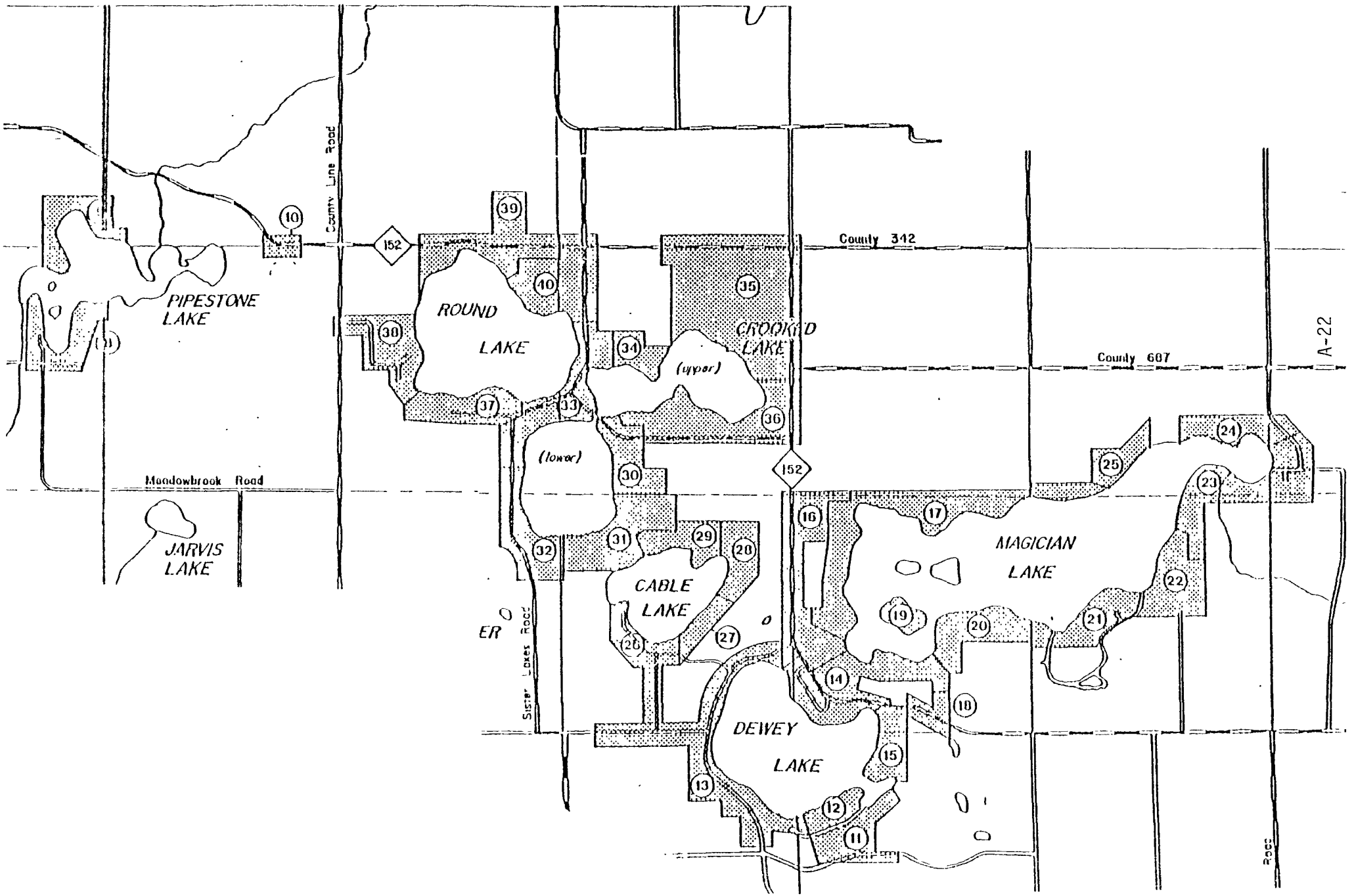


Figure 2. Segment locations in the Sister Lakes service area.

APPENDIX B

SEPTIC LEACHATE SUREVY

INDIAN LAKE - SISTER LAKE

SEPTIC LEACHATE SURVEY

INDIAN LAKE - SISTER LAKES

October, 1979

Prepared for

WAPORA, Inc.
Chicago, Illinois

Prepared by

K-V Associates, Inc.
281 Main Street
Falmouth, Massachusetts 02540

January, 1980

TABLE OF CONTENTS

		Page
1.0	Introduction	1
	1.1 Effluent Plume Theory	1
	1.1.1 Groundwater Plumes	3
	1.1.2 Runoff Plumes	5
	1.2 Special Survey Technique and Equipment	6
2.0	Survey Methodology	9
	2.1 Sample Handling	10
	2.2 Leachate Detector Calibration	10
	2.3 Groundwater Flow Measurements	10
3.0	Plume Locations	12
4.0	Nutrient Analyses	28
5.0	Nutrient Relationships	34
	5.1 Assumed Wastewater Characteristics	36
	5.2 Assumed Background Levels	36
	5.3 Attenuation of Nitrogen and Phosphorus Compounds	37
6.0	Coliform Levels in Surface Waters	38
7.0	Groundwater Flow Patterns	41
8.0	Conclusions	46
	References	48
	Appendix	49

recreational attractiveness of the lakeshore often induces temporary overcrowding of homes leading to hydraulically overloaded septic units. Rather than a passive release from lakeshore bottoms, groundwater plumes from nearby on-site treatment units may actively emerge along shorelines, raising sediment nutrient levels and creating local elevated concentrations of nutrients. The contribution of nutrients from subsurface discharges of shoreline septic units has been estimated at 30 to 60 percent of the total nutrient load in certain New Hampshire lakes, (LRPC, 1977).

The capillary-like structure of sandy, porous soils and horizontal groundwater movement induces a fairly narrow plume from malfunctioning septic units. The point of discharge along the shoreline is often through a small area of lake bottom, commonly forming an oval-shaped area several meters wide when the septic unit is close to the shoreline. In denser subdivisions containing several overloaded units, the discharges may overlap forming a broader increase. (See Figure 2)

1.1.1. Groundwater Plumes

Three different types of groundwater-related wastewater plumes are commonly encountered during a septic leachate survey: 1) erupting plumes, 2) passive plumes, and 3) stream source plumes. As the soil becomes saturated with dissolved solids and organics during the aging process of a leaching on-lot septic system, a breakthrough of organics occurs first, followed by inorganic penetration (principally chlorides, sodium, and other salts). The active emerging of the combined organic and inorganic residues into the shoreline lake water describes an

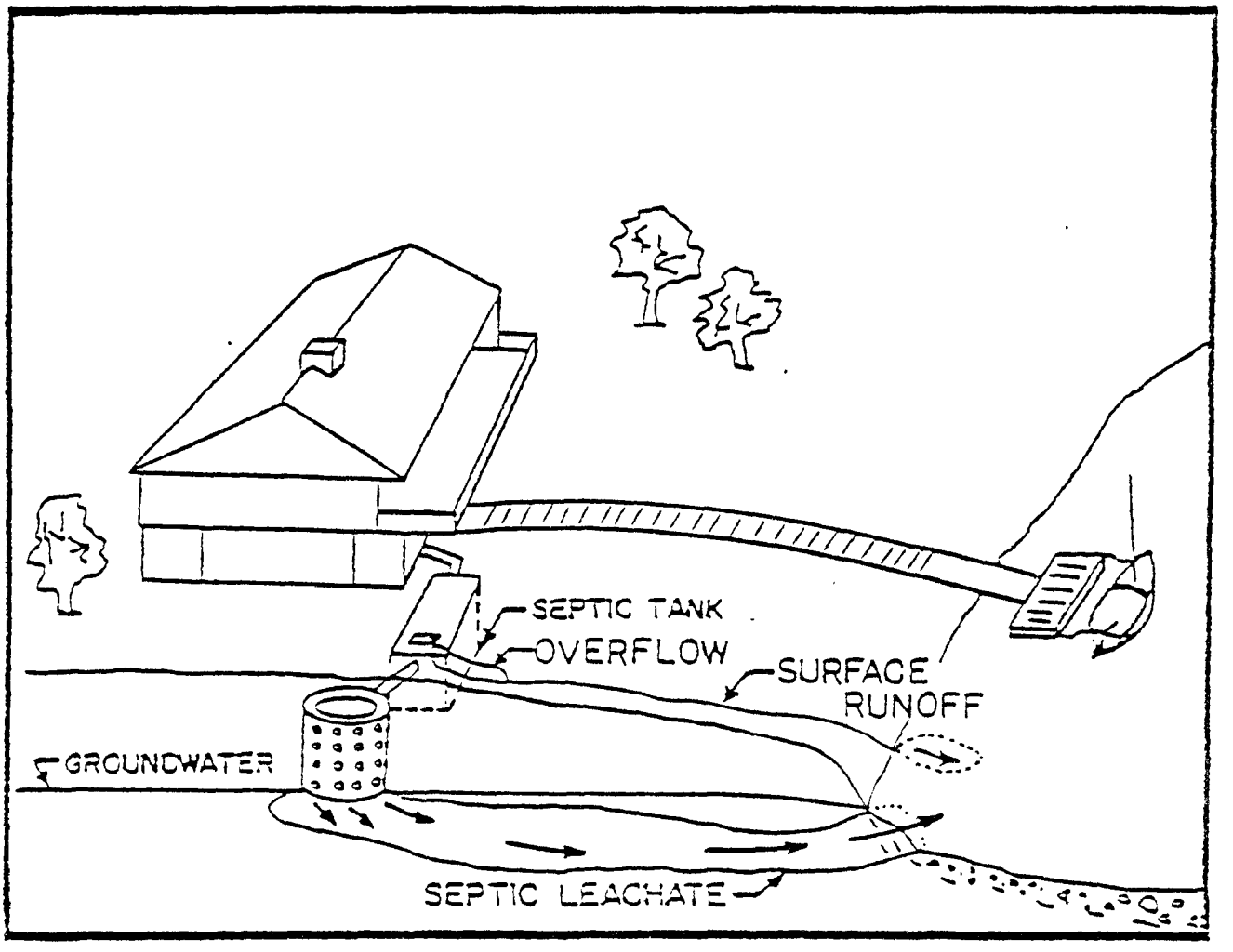


Figure 2. Excessive loading of septic systems causes the development of plumes of poorly-treated effluent which may 1) enter nearby waterways through surface runoff or which may 2) move laterally with groundwater flow and discharge near the shoreline of nearby lakes.

erupting plume. In seasonal dwellings where wastewater loads vary in time, a plume may be apparent during late summer when shoreline cottages sustain heavy use, but retreat during winter during low flow conditions. Residual organics from the wastewater often still remain attached to soil particles in the vicinity of the previous erupting plume, slowly releasing into the shoreline waters. This dormant plume indicates a previous breakthrough, but sufficient treatment of the plume exists under current conditions so that no inorganic discharge is apparent. Stream source plumes refer to either groundwater leachings or near-stream septic leaching fields which enter into streams which then empty into the lake.

1.1.2 Runoff Plumes

Traditional failures of septic systems occur in tight soil conditions when the rate of inflow into the unit is greater than the soil percolation can accomodate. Often leakage occurs around the septic tank or leaching unit covers, creating standing pools of poorly-treated effluent. If sufficient drainage is present, the effluent may flow laterally across the surface into nearby waterways. In addition, rainfall or snow melt may also create an excess of surface water which can wash the standing effluent into water courses. In either case, the poorly-treated effluent frequently contains elevated fecal coliform bacteria, indicative of the presence of pathogenic bacteria and, if sufficiently high, must be considered a threat to public health.

1.2 Special Survey Technique and Equipment

Wastewater effluent contains a mixture of near-UV fluorescent organics derived from whiteners, surfactants and natural degradation products which are persistent under the combined conditions of low oxygen and limited microbial activity. Figure 3 shows two samples of sand-filtered effluent from the Otis Air Force Base, Massachusetts, sewage treatment plant. One was analyzed immediately and the other after having been held in a darkened bottle for six months at 20°C. Note that little change in fluorescence was apparent, although during the aging process some narrowing of the fluorescent region did occur. The aged effluent percolating through sandy loam soil under anaerobic conditions reaches a stable ratio between the organic content and chlorides which are highly mobile anions. It is this stable ratio (conjoint signal) between fluorescence and conductivity that allows ready detection of leachate plumes by their conservative tracers. Such identified plumes are an early warning of potential nutrient breakthrough or public health problems. The septic leachate detector instrument utilizes this principal.

Septic surveys for shoreline wastewater discharges are conducted with a septic leachate detector, ENDECO® Type 2100 "Septic Snooper"™, and the K-V Associates, Inc. "Dowser"™ Groundwater Flow Meter. The leachate detector unit can be operated out of any small rowboat. It consists of the subsurface probe (water intake system), the analyzer control unit, and an analog stripchart recorder. Initially the unit is calibrated against incremental additions of wastewater effluent of

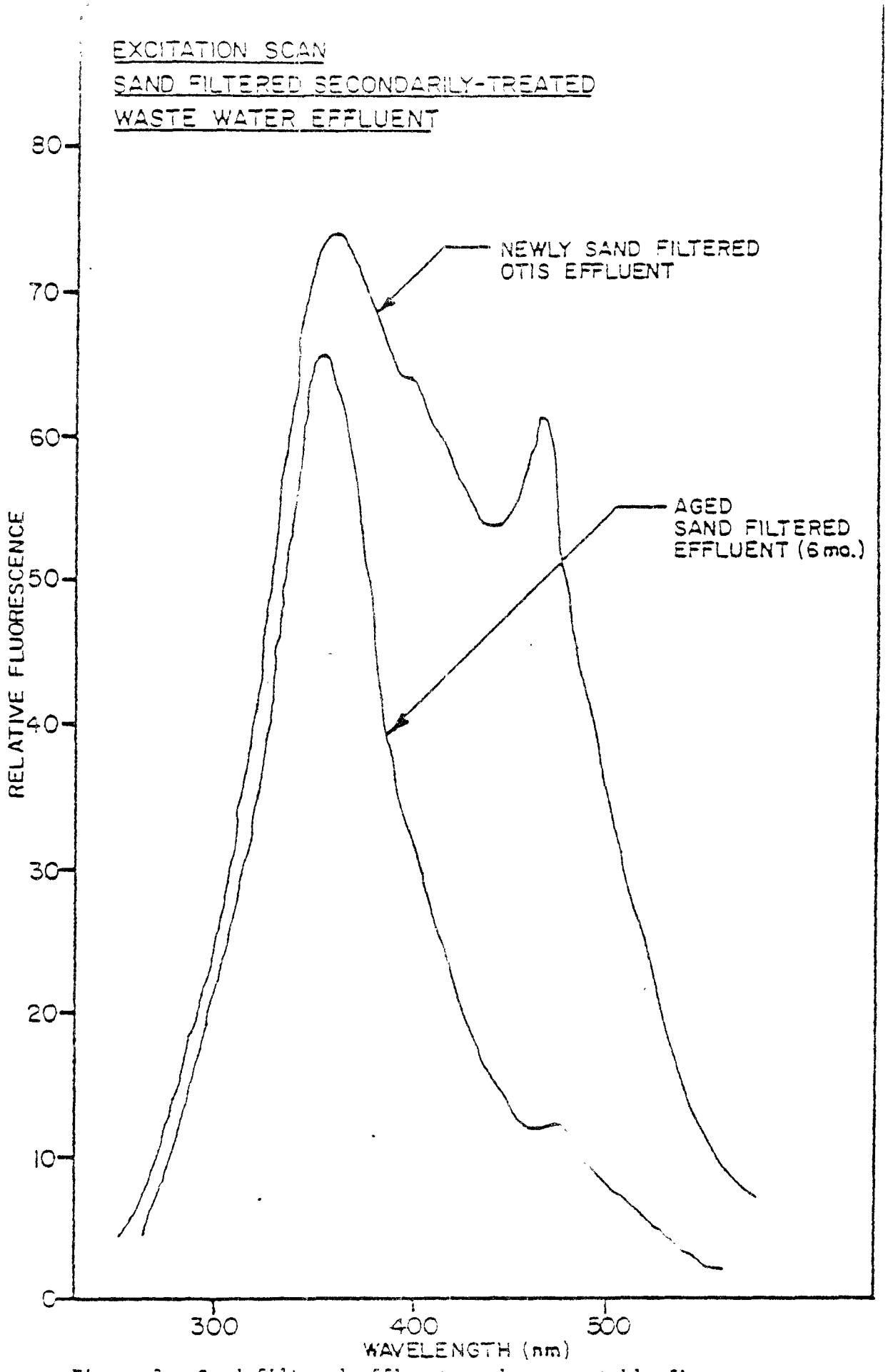


Figure 3. Sand-filtered effluent produces a stable fluorescent signature, here shown before and after aging.

the type to be detected to the background lake water. The pump end of the probe unit is then submerged in the lake water along the near shoreline. Groundwater seeping through the shoreline bottom is drawn into the screened intake of the probe and travels upwards to the analyzer unit. As it passes through the analyzer, separate conductivity and fluorescence signals are generated. The responses are sent to the signal processor which registers the separate signals on a strip chart recorder as the boat moves forward. The analyzed water is continuously discharged from the unit back into the receiving water. The battery-powered unit used for field studies can record individual fluorescence and conductivity or a combination signal. It has also been modified to operate under the conductivity conditions encountered in the field.

Well-point sampling of groundwater and bacterial sampling of surface run-off complement the leachate detector scan, surface water sampling and groundwater flow vector measurements for the complete survey.

2.0 SURVEY METHODOLOGY

Continuous leachate scans were performed on all lakes in a counter-clockwise direction around their shallow periphery (in less than 1 meter deep water) identifying the location of any plume discharges. The survey team consisted of two field scientists and lightweight mobile survey gear. The basic equipment platform was a 12-foot aluminum skiff with small outboard. Portable equipment included the battery-powered leachate detector instrument, hand-driven wellpoints and plastic water sampling and filtration apparatus.

As a routine, the team first surveyed each lake with the leachate detector gear, taking appropriate center and background discrete water samples from areas showing no obvious indications of pollution. At those points along the shore where the instrument recorded a significant event above background, the crew secured surface and groundwater samples while charting location and logging any supporting visual observations of the local surroundings. The team walked or motored the boat around the lakes within 15 feet of shore in shallow water. Specific conductance of each sample was measured on the boat as each sample was prefiltered and bottled. The team usually checked at least two groundwater sampling depths for each plume in search of a local maximum conductivity level. Relative fluorescence and conductivity were continuously plotted on separate strip recorders with positional cross-references to sewer planning maps of the lakes.

After completing the leachate survey of a lake, the team returned for bacterial sampling of selected plumes and surface flows, and took groundwater flow data in the beach sand at distributed points around the lake.

2.1 Sample Handling

Both ground and surface water samples for nutrient analysis were prefiltered on the boat and later final-filtered through .45 μm membrane filters. The samples were acidified with sulfuric acid (to less than pH 2) at the close of each sampling day, following procedures outlined by EPA Standard Methods.

Berrien County Health Department provided sterile bacteria sampling bottles and performed the fecal coliform analyses.

2.2 Leachate Detector Calibration

The shoreline scanning work day began with a calibration of the septic leachate instrument. Two solutions were required: the first, a blank sample drawn from an unaffected central portion of the lake; and the second, a sample of Dowagiac Municipal Treatment Plant effluent. Calibration was by method of additions, a 2% addition of effluent to center water being scaled to cover 40% of full meter span for each channel. Dynamic recirculating flow-through was employed to introduce solutions to the sensing chamber.

2.3 Groundwater Flow Measurements

The survey team utilized the K-V Associates, Inc. Model 10 Dowser groundwater flow meter to obtain flow measurements. The team dug shallow

holes to groundwater along sandy shores at spaced intervals around the lake. The instrument probe head was inserted about three inches into the groundwater-saturated loose sand substrate. The battery-powered unit required about three minutes to give a digital indication of flow velocity and direction. The unit was calibrated in a simple flow chamber using local beach sand.

3.0 PLUME LOCATIONS

The Indian Lake - Sisters Lake project proposed service area encompasses the entire shorelines of eight inland lakes lying within Berrien, Cass and Van Buren counties in the southwestern corner of Michigan. Vegetated wetlands occur adjacent to each of these lakes which are fed primarily by groundwater recharge or surface runoff, there being no major tributary inlets or stream linkages between one lake and another.

Soils that overlie the glacial landforms of the study area vary from mucks through loams to fine sand. The predominant soil association surrounding Sister Lakes in Cass County is Oshtemo-Kalamazoo-Hillsdale association. This association is characterized by deep, well-drained soils of undulating to rolling topography found on outwash plains and moraines. These soils are of moderately coarse to coarse textures. Some of the rolling areas are covered by croplands and orchards, others by pastureland or forest.

For purposes of evaluation consistent with our historical practice, a wastewater plume was judged to be a leachate detector signal excursion of at least 1% effluent equivalent of fluorescence and ½% of conductivity.

Dewey Lake

This small lake in Cass County has a surface of nearly 190 acres and a maximum depth of less than 14 meters. While populated around most of its shoreline, it abuts a wetland to the south. It has previously

been classified as eutrophic. No active wastewater plumes were revealed around the lake perimeter. Several small organic (fluorescence) rises were detected along the northern shore, but were unaccompanied by any inorganic (conductivity) changes. Sample #4 is clearly bog as revealed by its very strong fluorescence with no coincident conductivity rise, and also by lab analysis showing fluorescent spectral wavelength shift and high levels of ammonia-nitrogen characteristic of anaerobic reducing conditions. Sample #3 from a canal leading to wetlands also shows bog characteristics. No fecal coliform bacteria contamination was evident, nor was there any indication of high nitrate levels in two well water samples taken, though the Shady Shores well showed high dissolved solids loading.

Keeler Lake

This very small, outlying lake is to the northeast of the Sisters Lakes. A single tier of dwellings surrounds its shore, with the exception of a wetlands expanse to the west. The continuous shoreline survey did not identify any effluent plume sources. However, each of the sediment groundwater samples had elevated levels of total phosphorous or ammonia retained in soft material.

Cable Lake

This scenic little lake, smallest of the group, also lies in Cass County and has a surface area of 91 acres. Along with Round Lake, Cable Lake has the smallest watershed (685 acres) of any of the Sister Lakes. Wooded swamp confronts a small section of the western shore and constitutes about 22% of the watershed acreage. No erupting effluent plumes were found

here. Nitrate levels in surface and groundwater samples were consistently very low (<.04 ppm). One routinely sampled background location (#15) did show a moderately high phosphorous level (.192 ppm) in the sediment waters. Indications of surfactants and whiteners were not apparent on Cable Lake.

Magician Lake

Magician Lake is second in surface area (468 acres) only to Indian Lake and has over 11 km of well-developed shoreline. Swamps lie to the south and east. Of three islands on the lake, two are inhabited: Maple Island, accessible by causeway; and Hemlock Island, reachable only by boat.

Traces of several wastewater plumes were located in the southwest corner of Magician Lake which includes two narrow canal extensions. However, nutrient concentrations were not high. Interestingly, the groundwater sample of a nominal background location (#25) revealed high conductivity (820 µmho/cm) and ammonia-nitrogen (31 ppm). This site was along the southern shore of Maple Island. The bottom was a mucky bed of organic debris and the surface water became unnavigable because of the heavy plant growth. Strong reducing conditions were present.

Elsewhere around the lake, nitrate levels were high in plume samples drawn along the northern shore. Broad rolling croplands approach the shorefront residential lots. Owners report numerous springs underly the soft silty bottom. The plume source is likely a mix of domestic and agricultural products.

Sample #27 represented fresh, soapy effluent believed to originate from a shower drain piped directly to the lake's edge. The pipe end was

algae covered, and the total phosphorous level was high (.144 ppm).

Pipestone Lake

An irregularly shaped lake, Pipestone has the lowest ratio of water surface area to wetted shoreline. As the lowest lake in elevation in the entire study area, its watershed includes the highest percentage of both orchards (23%) and wooded swamp (29%). The diversity of fish species is high in this lake as it is connected to the St. Joseph River by the outflowing Pipestone Creek. Large salmon were running upstream to spawn during the period of this October survey. For a low-lying lake surrounded by such extensive wetlands, Pipestone has logically been classified as mesotrophic, tending towards eutrophic. Plume discoveries were numerous and included high total phosphorous (.843 ppm) and ammonia-nitrogen (13 ppm) levels in both surface drainpipe and groundwater samples. While these stream sources originate from bog areas, the potential runoff for leachfield wastewater entrainment is very strong, given the high water table and frequent flooding conditions. The high fecal coliform bacteria count at code B32 (7,600 colonies/100 ml water) from a pipe running through the yard of a permanent resident underscores the septic leaching implications. The lake bottom was mucky organic debris and the waterways were often choked with rooted aquatic vegetation.

Indian Lake

Located well to the south of the Sister Lakes, Indian Lake is the largest in area and most nearly regular in shape. Some wetlands append Indian Lake along its southern boundary, but over 50% of the watershed area

is under agricultural use. A 1975 Cass County Health Department survey declared this lake to be experiencing accelerated eutrophication related to nutrient leakage from on-site sewage systems.

Our septic survey found very few distinct septic problems on a lake of this size. Fewer than 10 plumes were reported; virtually all were along the northern shore. Of samples taken, all nitrate levels but one were less than .06 ppm and total phosphorous <.03 ppm. Sample #54 was taken in the vicinity of a very discrete patch of Cladophora capping some submerged cinder blocks near a concrete breakwall. Cladophora occurrences were not widespread but did crop up elsewhere in isolated patches. Sample #55 corresponds to a large pipe bearing stream drainage from the northeast shore region. Sample #56 was drawn from a broad plume source along this same northeastern shore. Autumn leaves collected by the wind and waves matted the near shore to a depth of about .3m. The higher than usual nitrate and conductivity value from the groundwater sample beneath the leaves suggests a wastewater plume source possibility. Prevailing groundwater flow was found to be into the lake along this north shore. Many homes on the north shore are situated no more than 15-20 feet from their neighbors, and have a set-back of 25-30 feet from the water. Mucky bottom sediments prevail in proximity to the northwest corner canal area. A surface sample (#57) in the canal showed significant inorganic breakthrough, though no apparent increase in nominal nutrient levels. Attempts to pull groundwater from the bottom mucks were unsuccessful.

Crooked Lake

A lake in two major sections, Crooked Lake has bottom sediments composed of organic debris and sand. Crooked Lake is notable in that 50% of its watershed area is residentially developed, with another 32% under forestation. Most of the north and south shores of upper Crooked Lake are hilly, with housing sitting well above the water. At the east end of the upper basin, houses are located close together (~20 ft.) and only 30 ft. back from water's edge. The terrain at this end is quite level and has a shallower depth to groundwater. Fourteen plume occurrences were plotted around the entire lake, half being more of the dormant type leaching without inorganic breakthrough. Neither total phosphorus nor total nitrogen was notably high for any of the sample sites. Groundwater appeared to flow from the northeast which would be consistent with the plume patterns developed.

Round Lake

Nested close to Crooked Lake, Round Lake has a lower total hardness (44 ppm) and specific conductance (~100 µmho/cm) typical of the smaller lakes and streams. Swampland appears on the far western shore. Remarkably, only one solid plume indication was noted (#76, 1403 Rays Court). This site showed high conductivity (840 µmho/cm) and highest of otherwise very low nitrate levels. Bacterial contamination was not a problem from the four sampling stations examined.

Figures 4a through 4i. Mapping of Dewey, Keeler, Cable, Magician, Indian, Pipestone, Crooked, and Round Lakes survey along their complete shorelines. Sample stations for bacteria, well water and nutrients are shown, using the following symbols:

Nutrient sample station

Bacteria sample station

Well water sample station

Dormant groundwater plume

Dormant stream source plume

Erupting groundwater plume

Erupting stream source plume

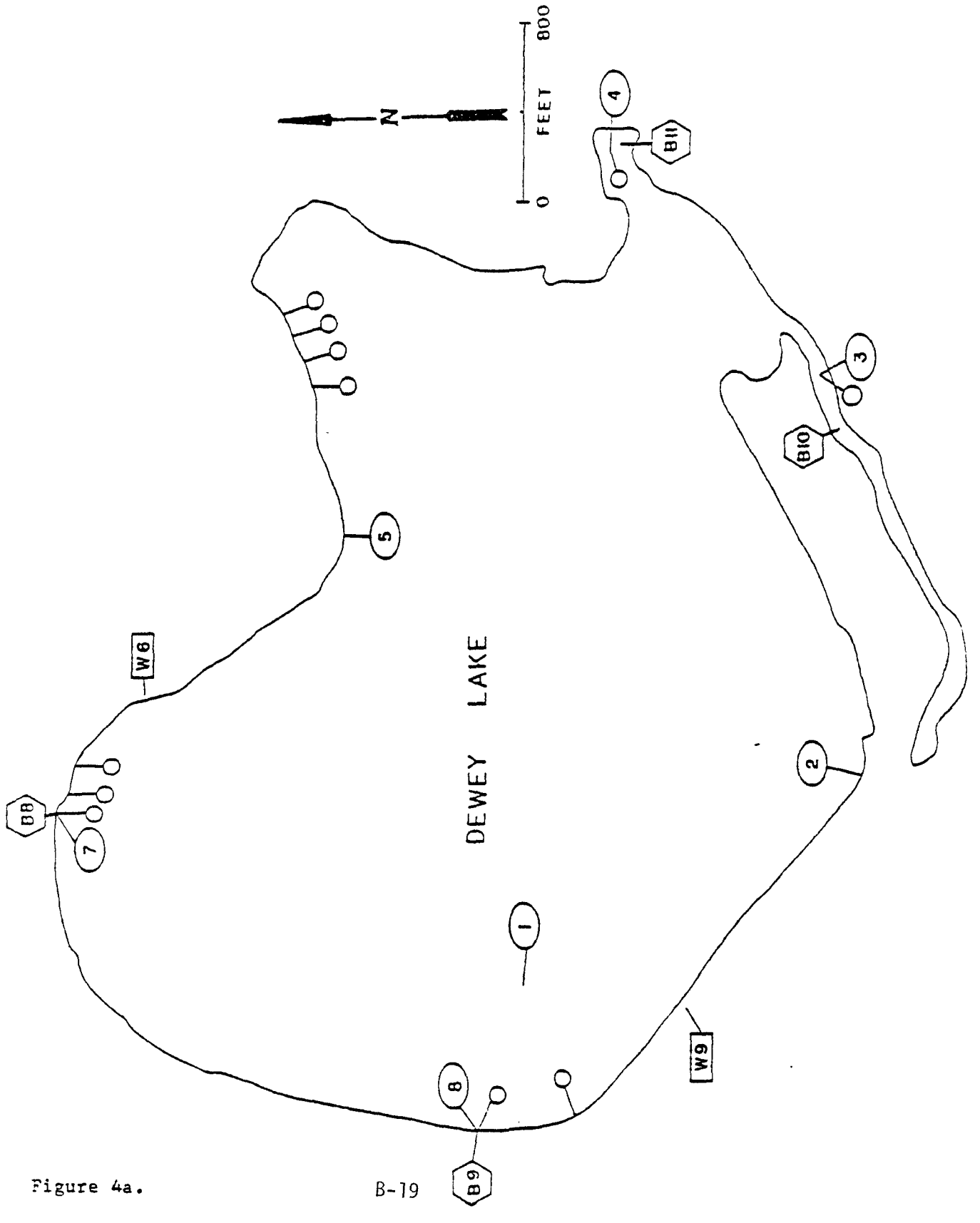


Figure 4a.

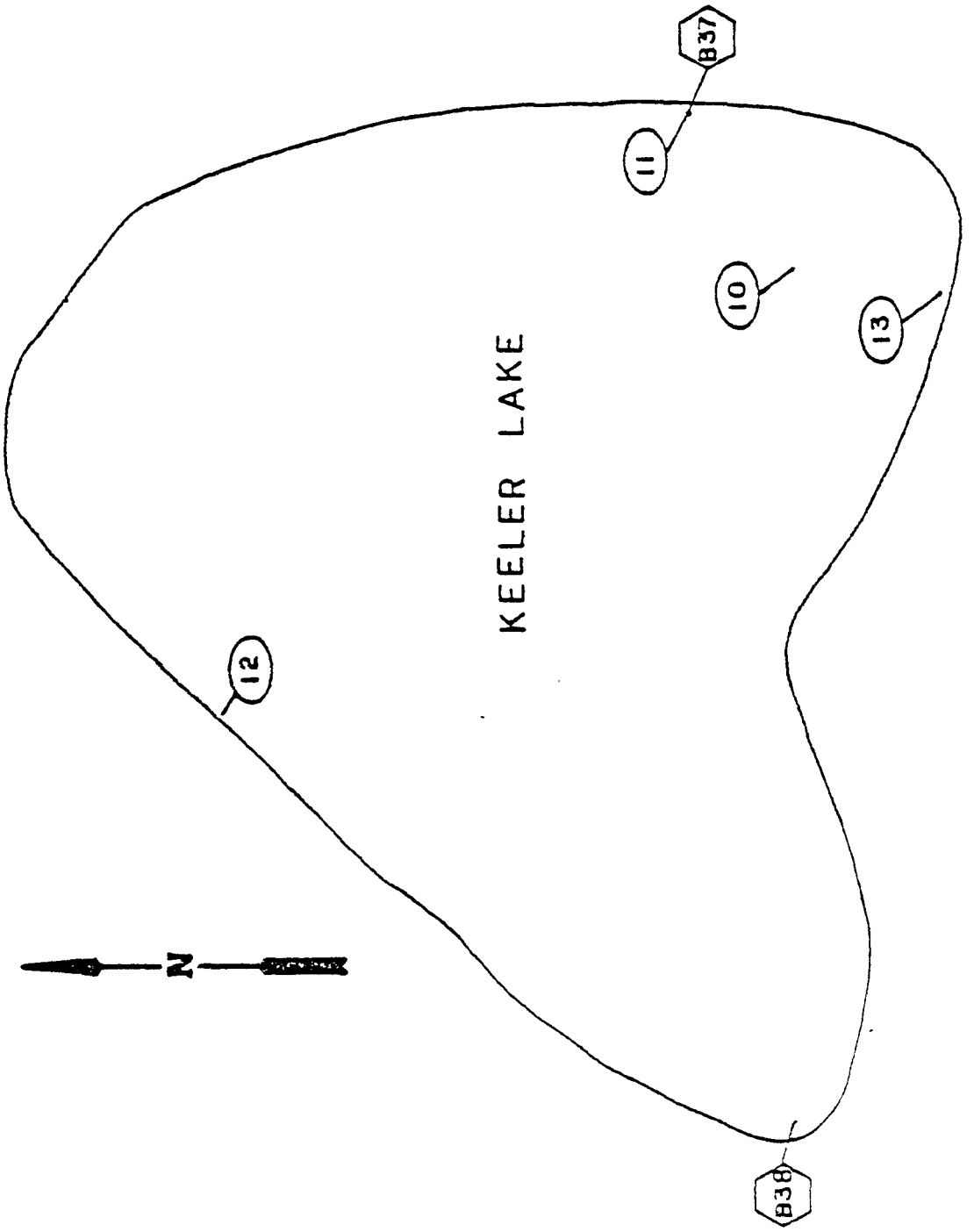


Figure 4b.

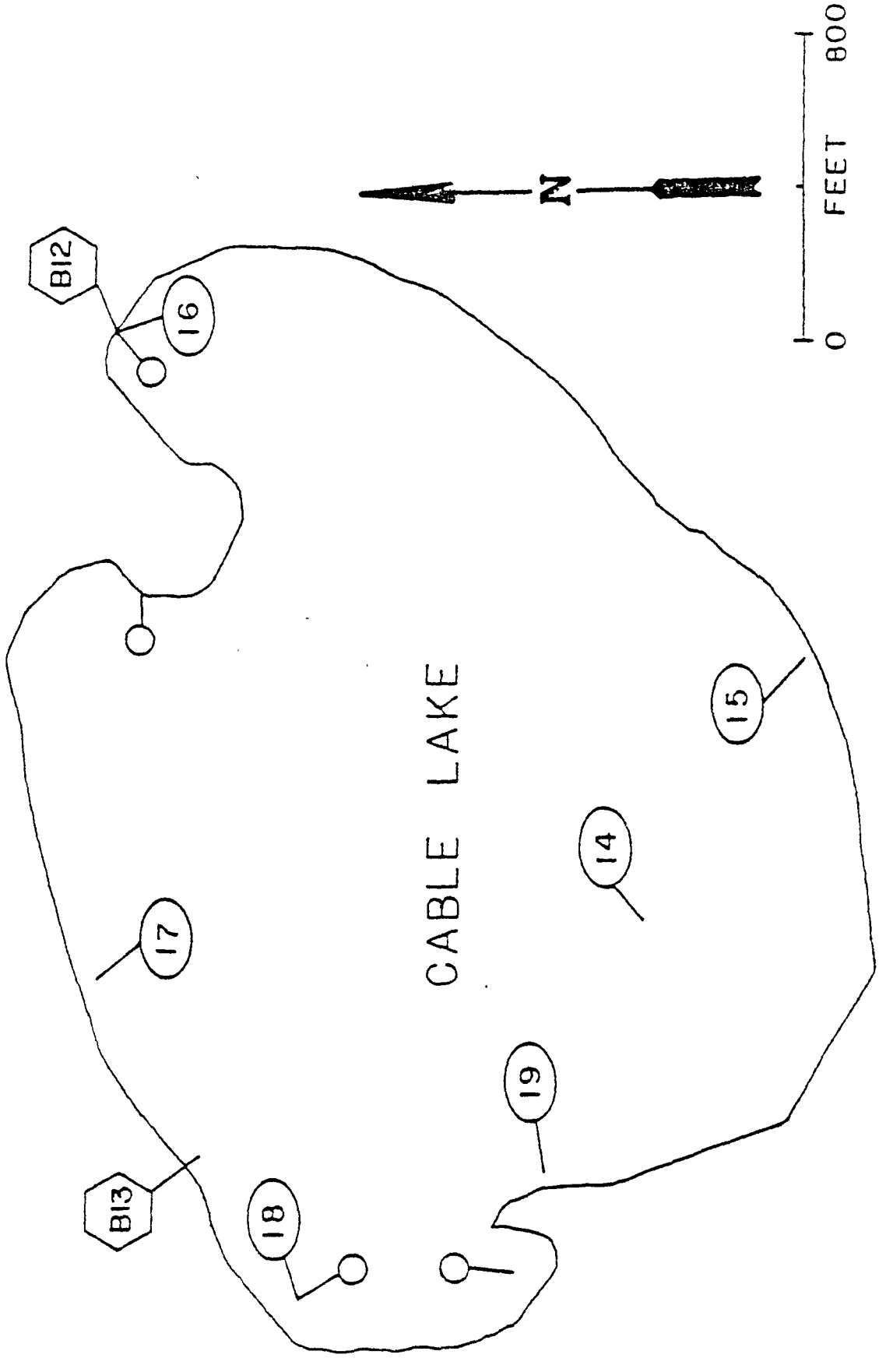


Figure 4c.

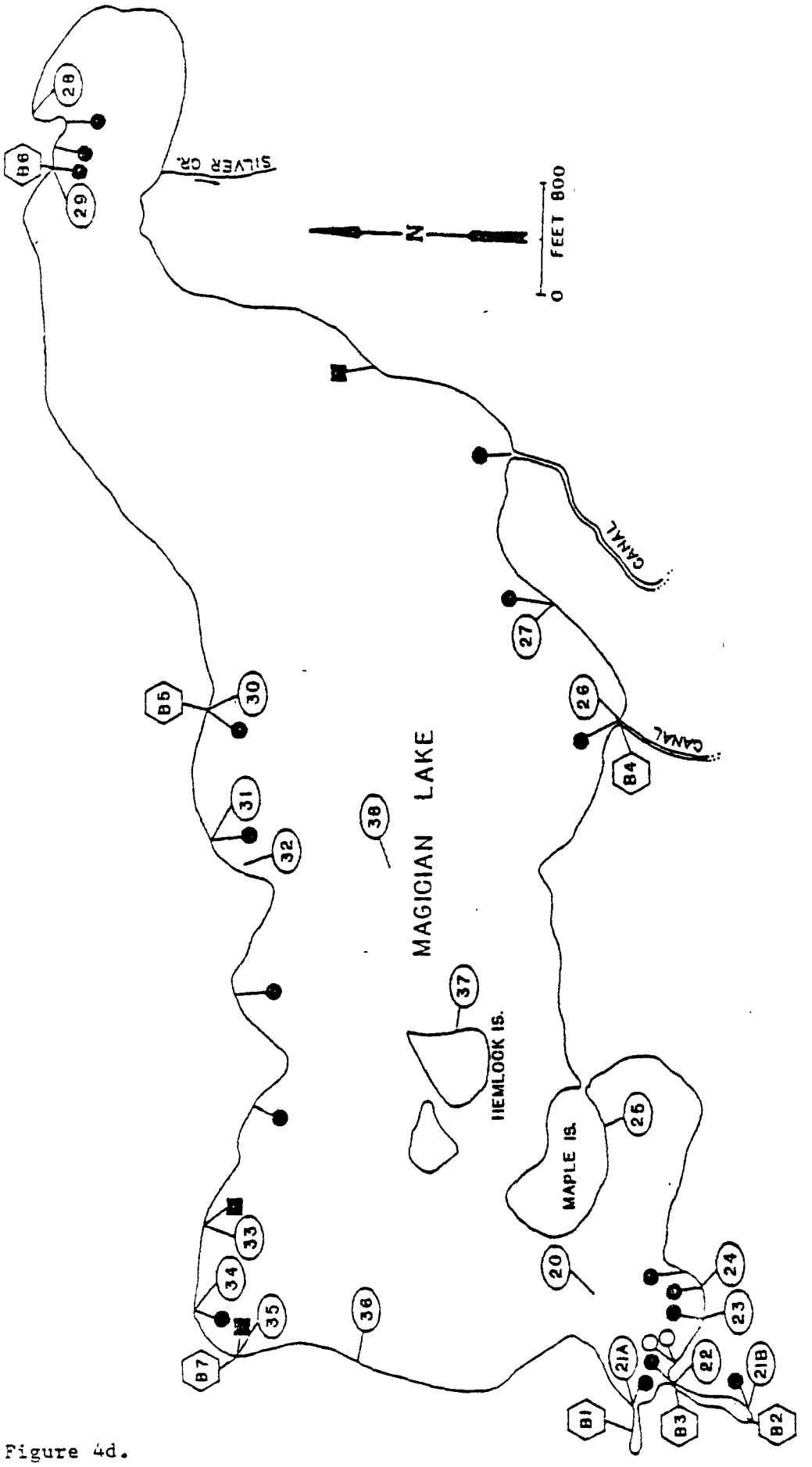

SILVER CR.
N
0 FEET 800
CANAL
CANAL
MAGICIAN LAKE
HEMLOCK IS.
MAPLE IS.
B1
B2
B3
B4
B5
B6
B7
20
21A
21B
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38

Figure 4d.

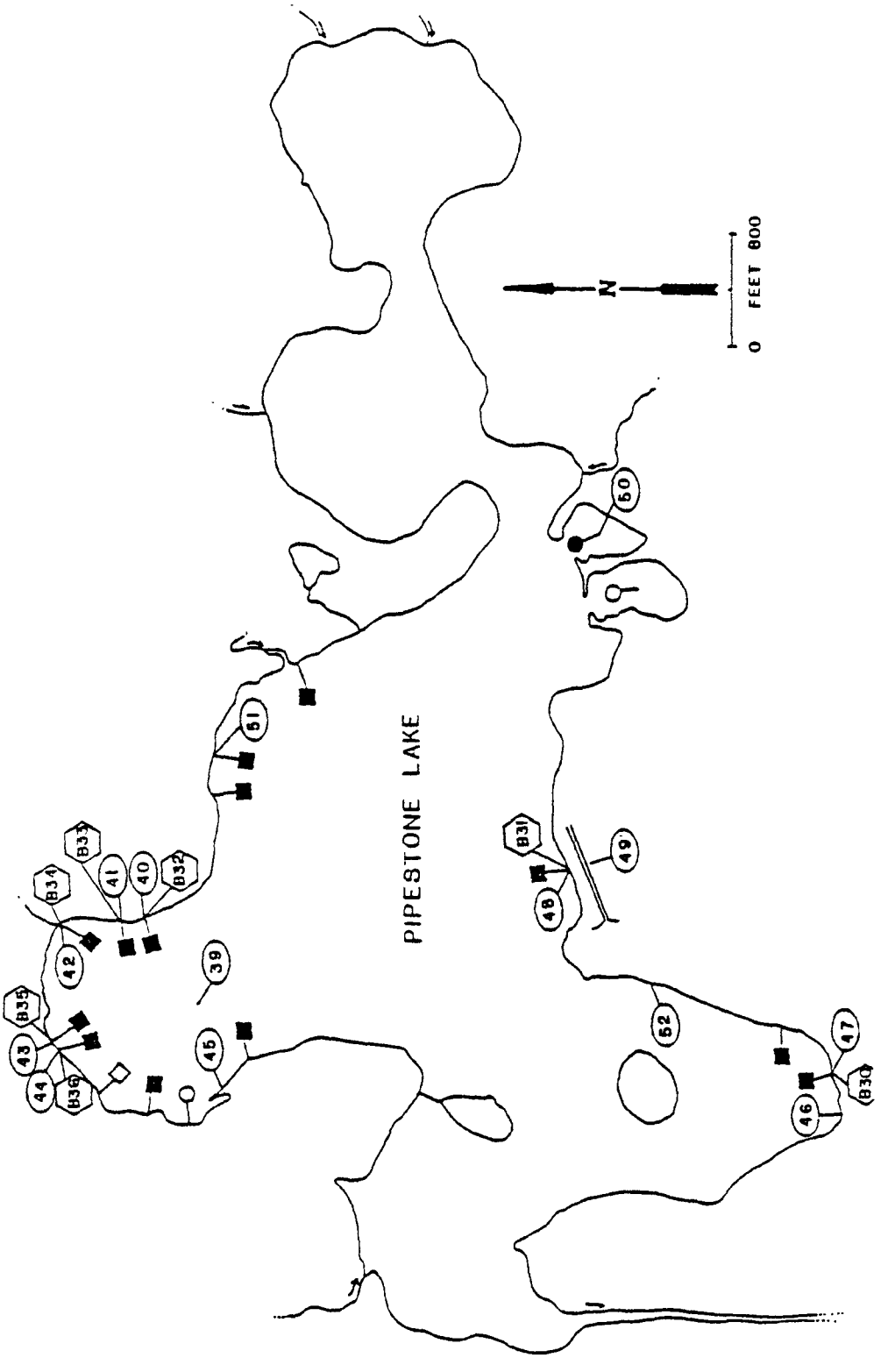

PIPESTONE LAKE
N
0 FEET 800
60
61
B33
B34
41
40
B32
42
39
B35
43
44
B36
45
B31
49
48
52
47
B30
46

Figure 4e.

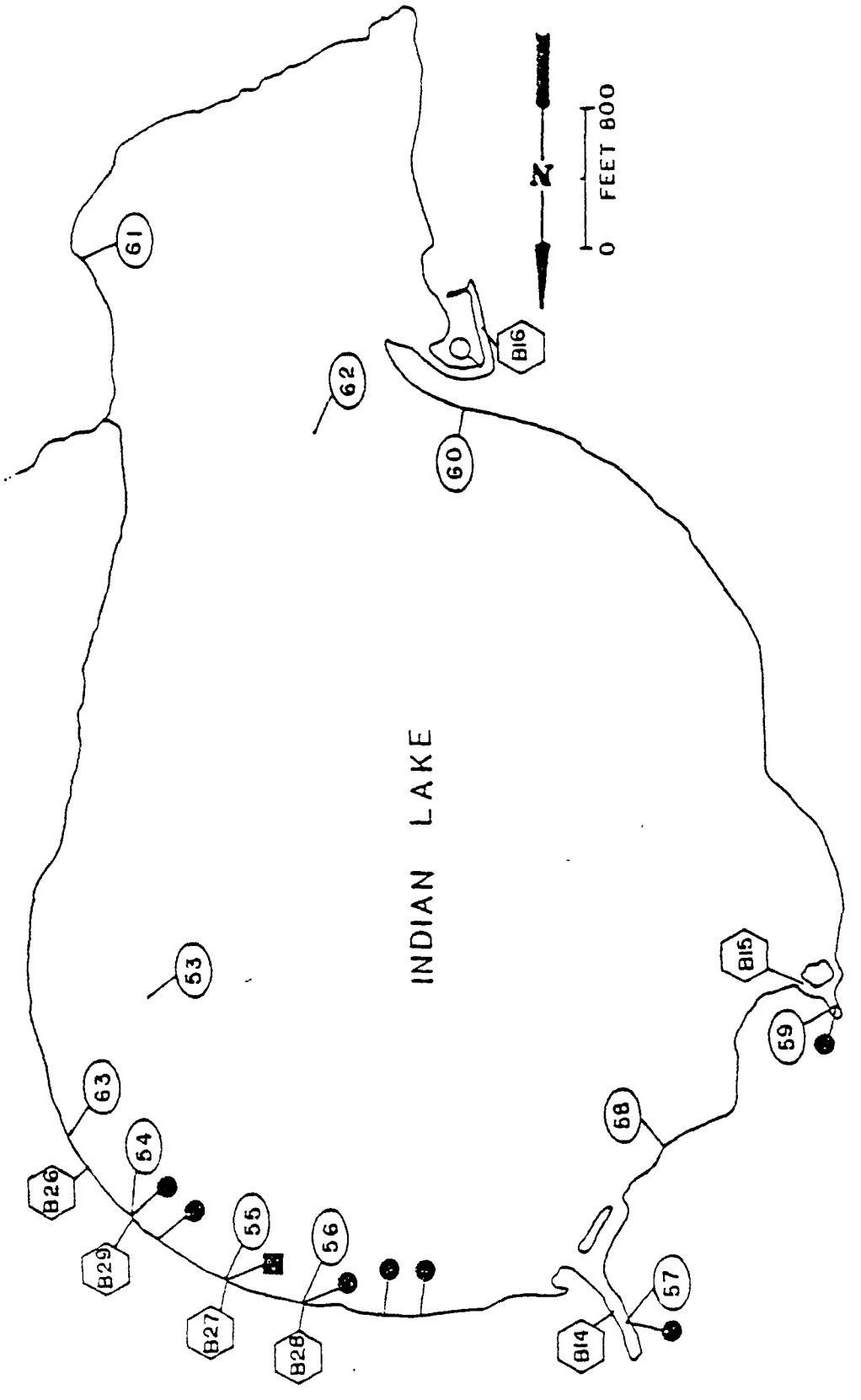

INDIAN LAKE
N
0 FEET 800
61
62
60
B16
53
63
54
B26
B29
55
56
B27
B28
68
B15
59
57
B14

Figure 4f.

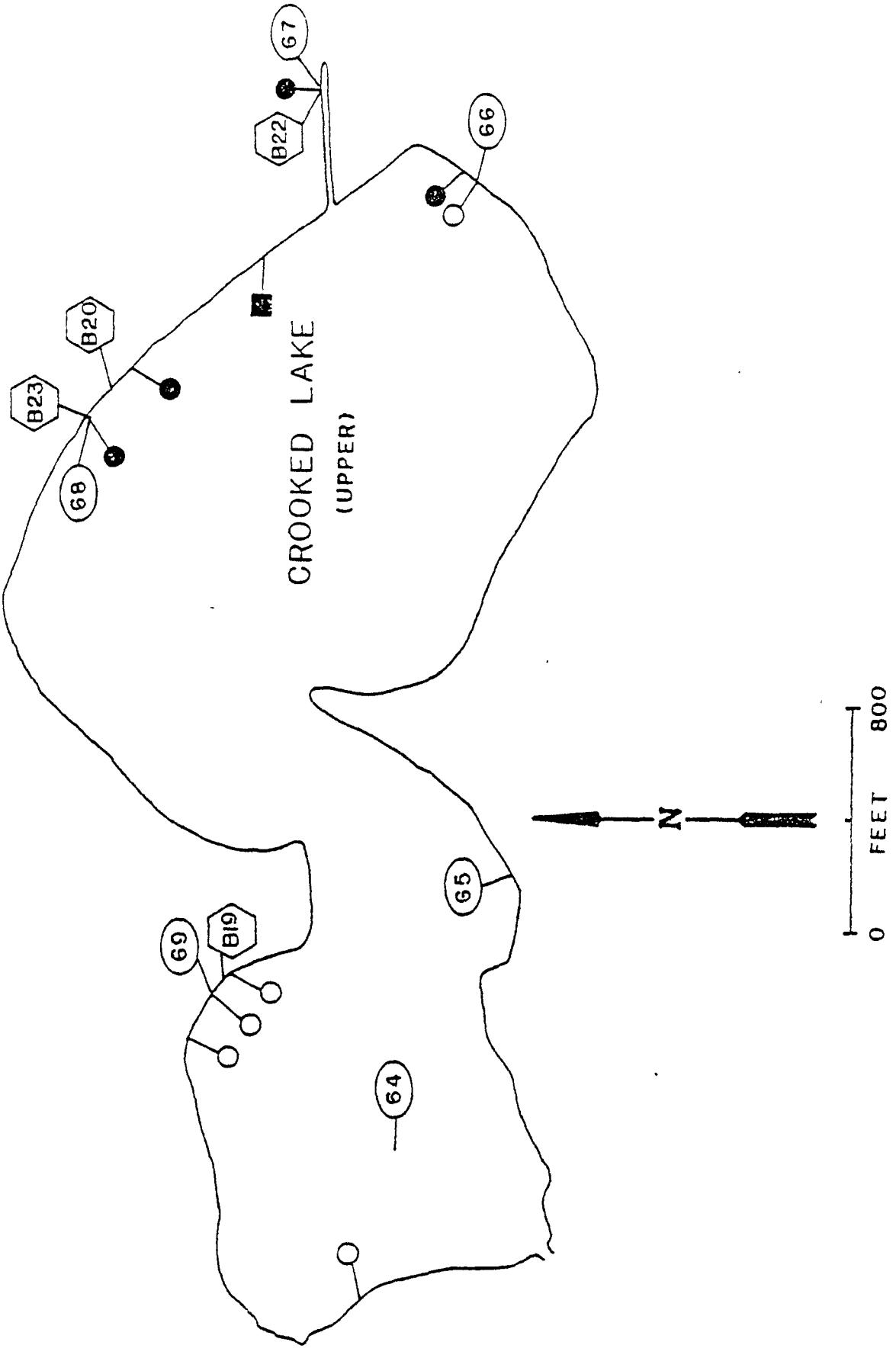


Figure 4g.

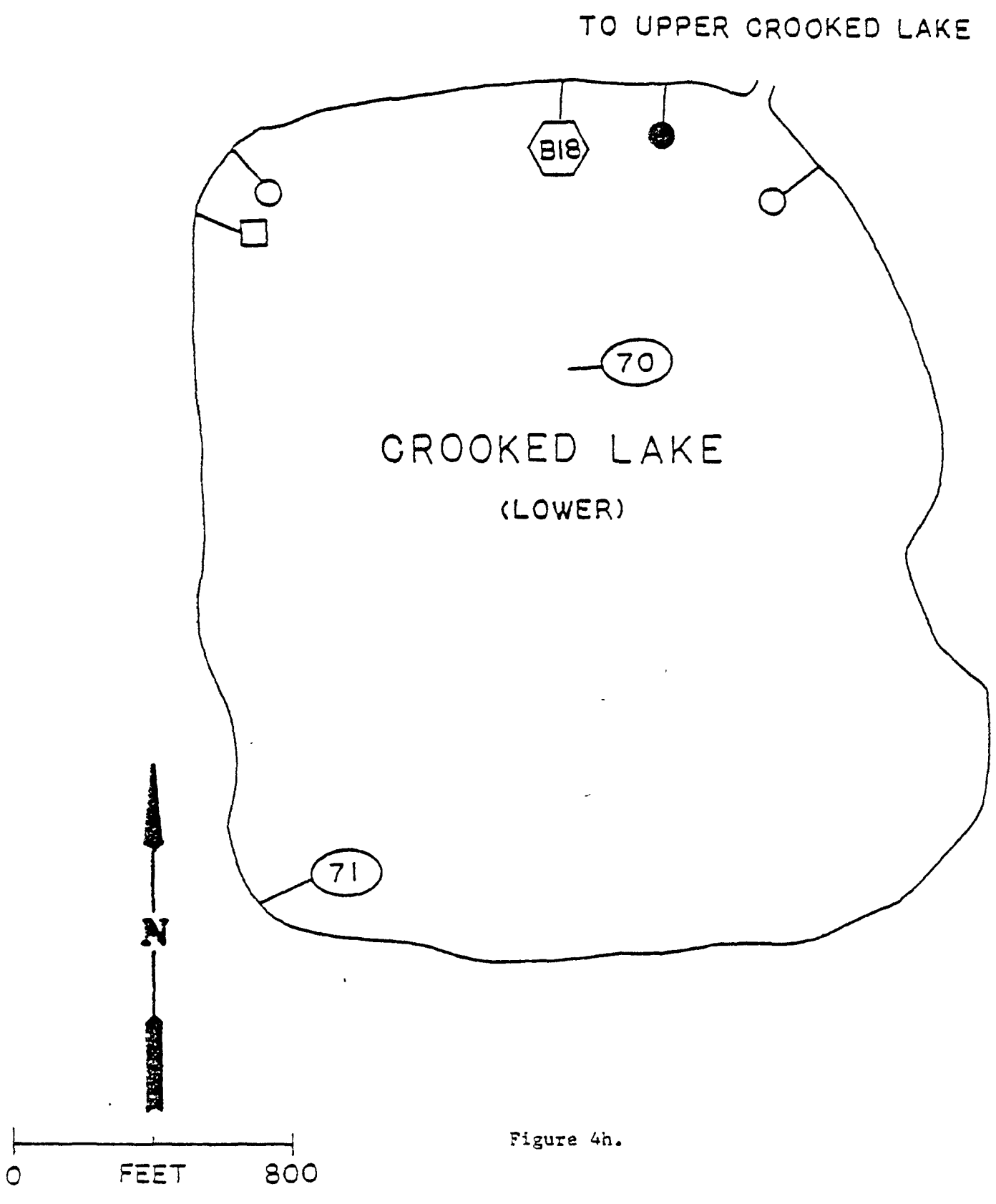
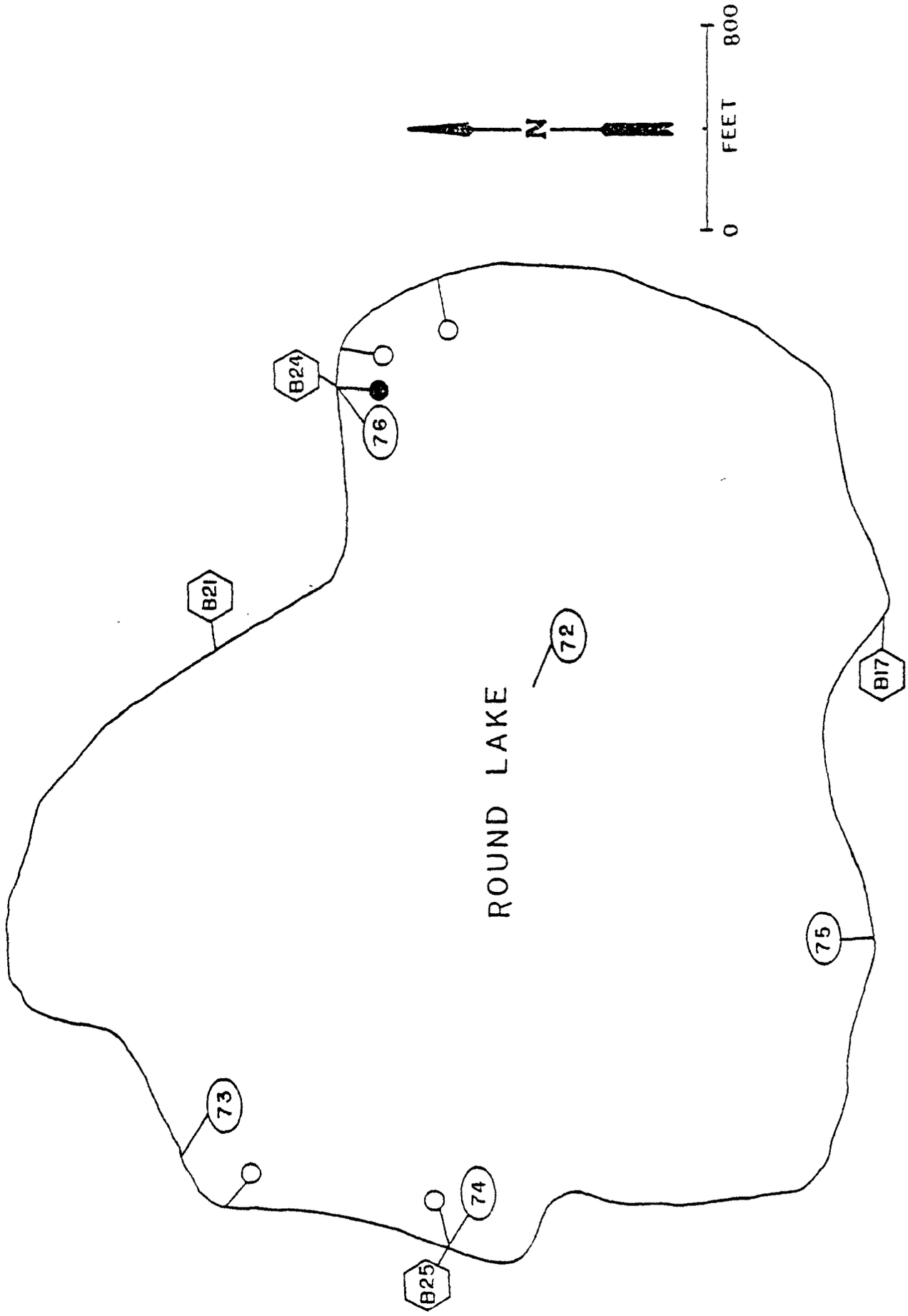

TO UPPER CROOKED LAKE
B18
70
CROOKED LAKE
(LOWER)
71
N
0
FEET
800

Figure 4h.



B-27

Figure 4i.

4.0 NUTRIENT ANALYSES

Completed analyses of the chemical content of 116 samples taken from the Indian Lake - Sister Lakes region are presented in Table 1. The samples are grouped by lake area. The numerical sample codes refer to the shoreline sampling locations as seen on individual area maps (Figure 4a through 4i).

The conductivity of the water samples as specific conductance (μmho/cm) was generated by a portable Horizon Ecology conductivity meter. Nutrient analyses for total phosphorus (TP), combined nitrate-nitrite nitrogen (NO_3-NO_2-N) and ammonia nitrogen were measured on a spectrophotometric auto-analyzer by EPA approved methods. Units of measure are parts-per-million (ppm) or milligram per liter (mg/1).

Table 1. Analysis of surface water (S), groundwater (G) and well water (W) samples taken around the periphery of Indian Lake - Sister Lakes, Michigan, October, 1979.

Sample Number		Bkg/Ctr		Cond.	Total P ppm	NH_4-N ppm	NO_3-N ppm	Δ^C	Δ^{TP}	Δ^N	% Breakthrough P	% Breakthrough N	Comments
Dewey Lake													
1	S		●	70	.007	.077	.016						
2	S	●		66	.007	.044	.016						
	G	●		115	.023	.848	.029						
3	S			67	.007	.045	.017						Canal, bog
4	S			66	.010	.055	.021						Swampy cove
	G			155	.170	5.696	.010	85	.16	5.55			
5	S	●		68	.006	.054	.017						
	G	●		67	.019	.403	.019						
W6	G			200	.053	.999	.016	130	.04	.85	9	39	Mr. Morrow's well
7	S			69	.010	.053	.015						
	G			107	.011	.792	.033	37	<.01	.67			
8	S			70	.006	.039	.055						#5015 Garret Rd.
	G			310	.012	.322	.026	240	<.01	.20	<1	5	
W9	G			890	.009	.079	.060	820	<.01	<.01	<1	<1	Shady Shores Rd.
Keeler Lake													
10	S		●	50	.007	.087	.013						
11	S	●		50	.006	.071	.013						
	G	●		50	.227	.442	.033						
12	S	●		50	.012	.084	.008						
	G	●		70	.883	.690	.077	20	.87	.62			
13	S	●		50	.015	.087	.017						
	G	●		165	.014	3.109	.017	115	<.01	2.98			

Table 1 (continued)

Sample Number		Bkg/Ctr		Cond.	Total P ppm	NH_4-N ppm	NO_3-N ppm	Δ^C	Δ^{TP}	Δ^N	% Breakthrough P	% Breakthrough N	Comments
Cable Lake													
14	S		●	44	.006	.086	.017						
15	S	●		45	.009	.122	.018						
	G	●		80	.192	.437	.019						
16	S			47	.014	.070	.015						Filled in swamp
	G			82	.010	.489	.010						
17	S	●		45	.006	.077	.012						
	G	●		45	.019	.573	.022						
18	S			45	.015	.110	.014						Swampy area
19	S	●		45	.006	.100	.040						
	G	●		54	.011	.211	.026						
Magician Lake													
20	S	●		350	.009	.220	.038						
21A	S			400	.015	.119	.040						Canal
	G			360	.014	.960	.008						
21B	S			400	.015	.312	.044						
	G			900	.023	.198	.237	540	.01	.30	<1	2	
22	S			350	.011	.280	.027						Canal entrance
	G			500	.016	.404	.009	140	<.01	.36	<1	10	
23	S			350	.024	.184	.066						
	G			540	.011	.242	.036	180	<.01	.13	<1	3	
24	S			350	.006	.262	.054						
	G			360	.009	.433	.011						Artesian groundwater
25	S	●		350	.005	.265	.058						Marl bottom
	G	●		820	.012	31.243	.011	460	<.01	31.1			
26	S			350	.008	.146	.557						Mouth of canal
	G			640	.010	3.004	.009	280	<.01	2.85	<1	41	
27	S			350	.144	.440	.128						Soapy water from shower bath
28	S			350	.008	.144	.570						Swampy area
29	S			350	.006	.097	.464						Old campground
	G			540	.008	.106	6.778	180	<.01	6.73	<1	150	
30	S			350	.006	.118	.557						Near block boathouse

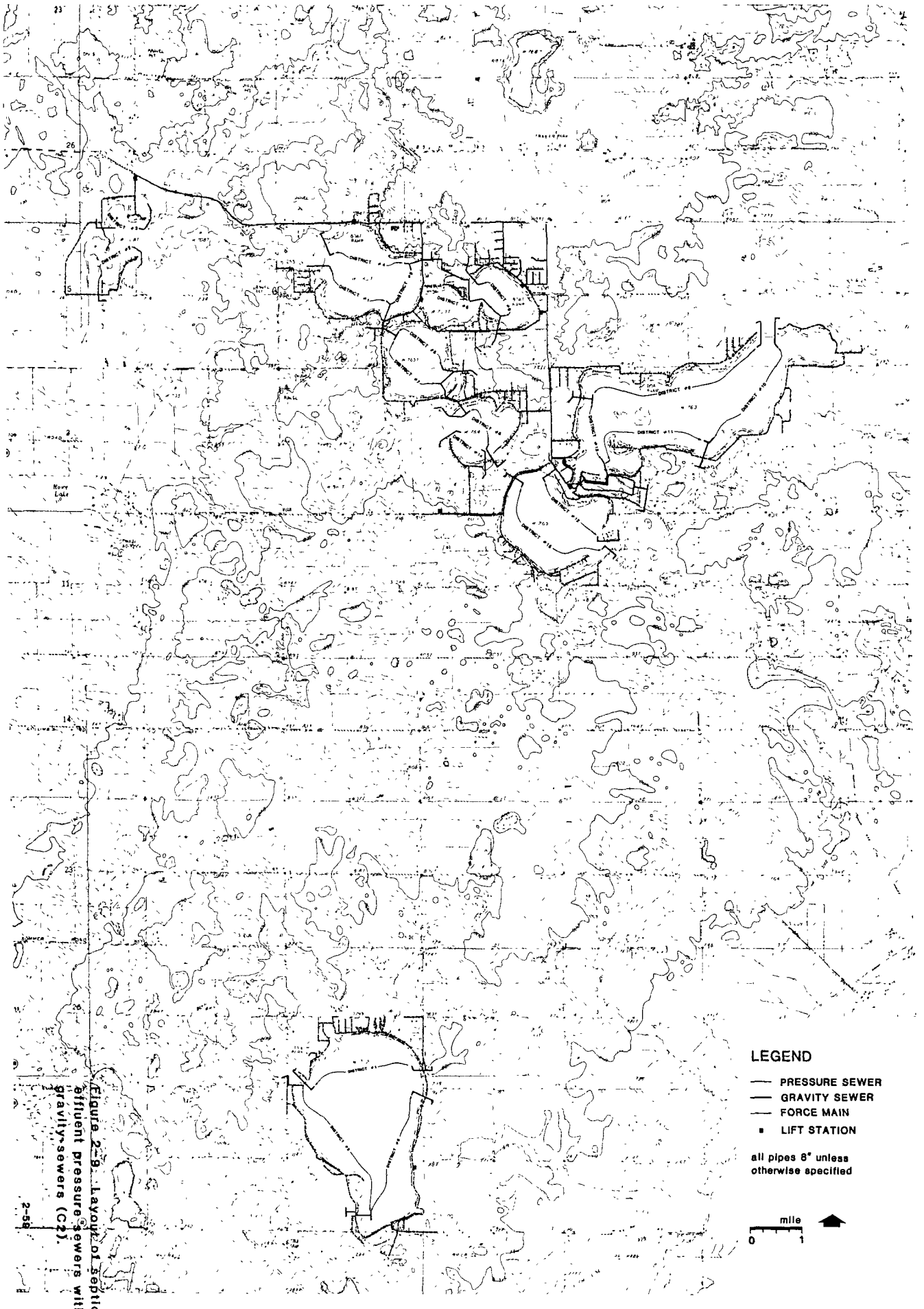


Figure 2-9. Layout of septic tank effluent pressure sewers with some gravity sewers (C2).

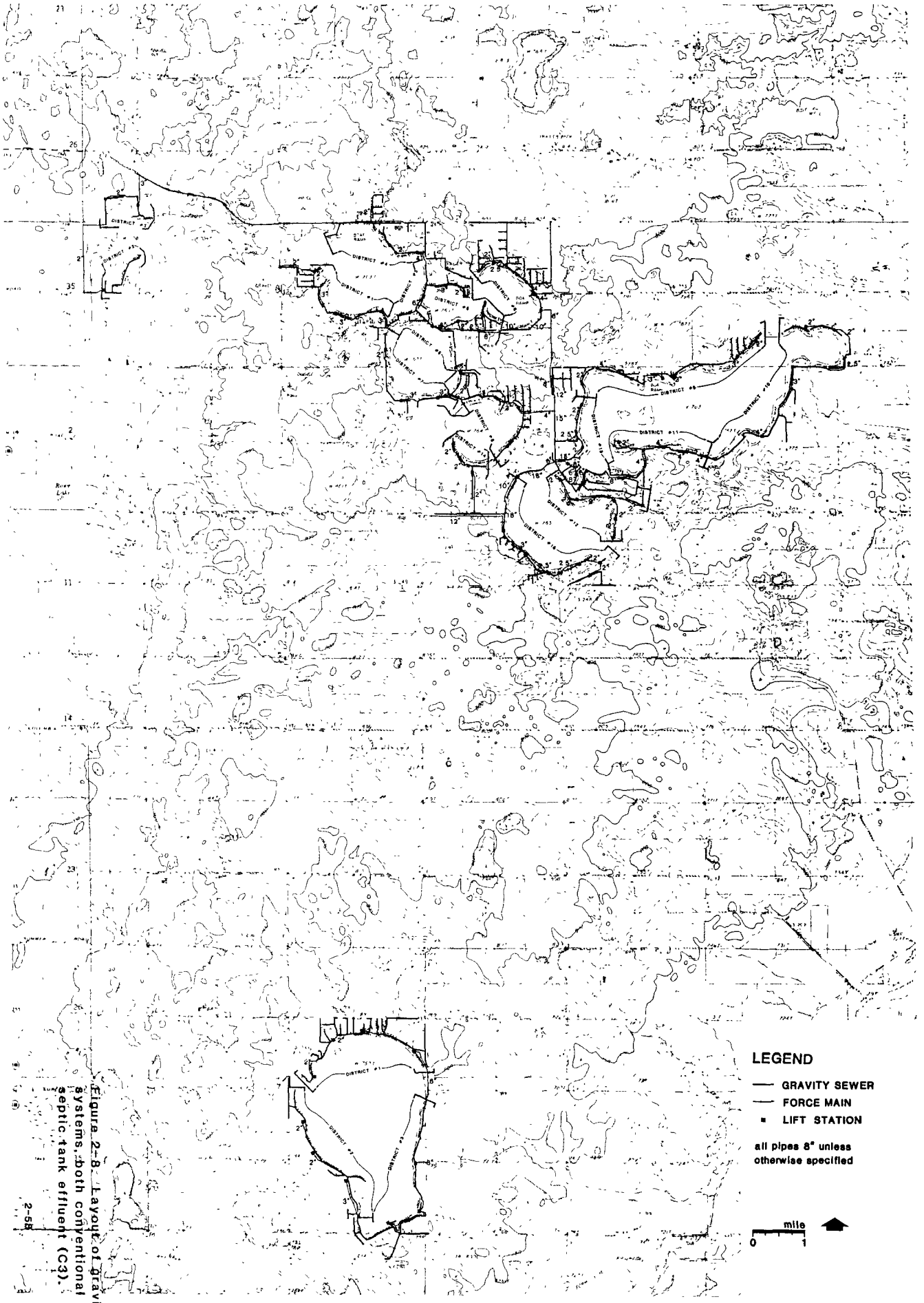


Figure 2-8. Layout of gravity collection systems, both conventional (C1) and septic tank effluent (C3).

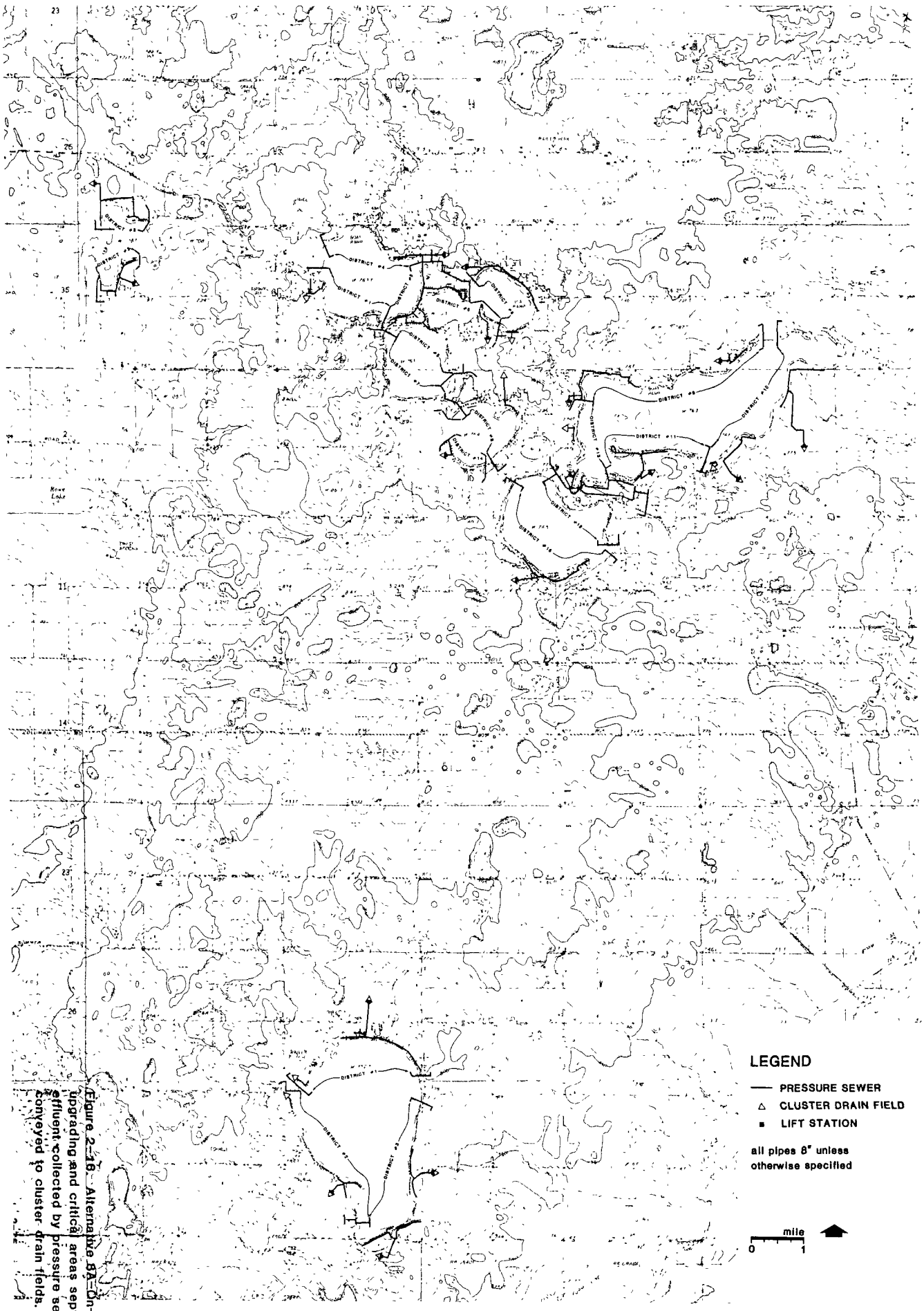


Figure 2-16. Alternative 8A - On-site systems upgrading and critical areas septic tank effluent collected by pressure sewers and conveyed to cluster drain fields.

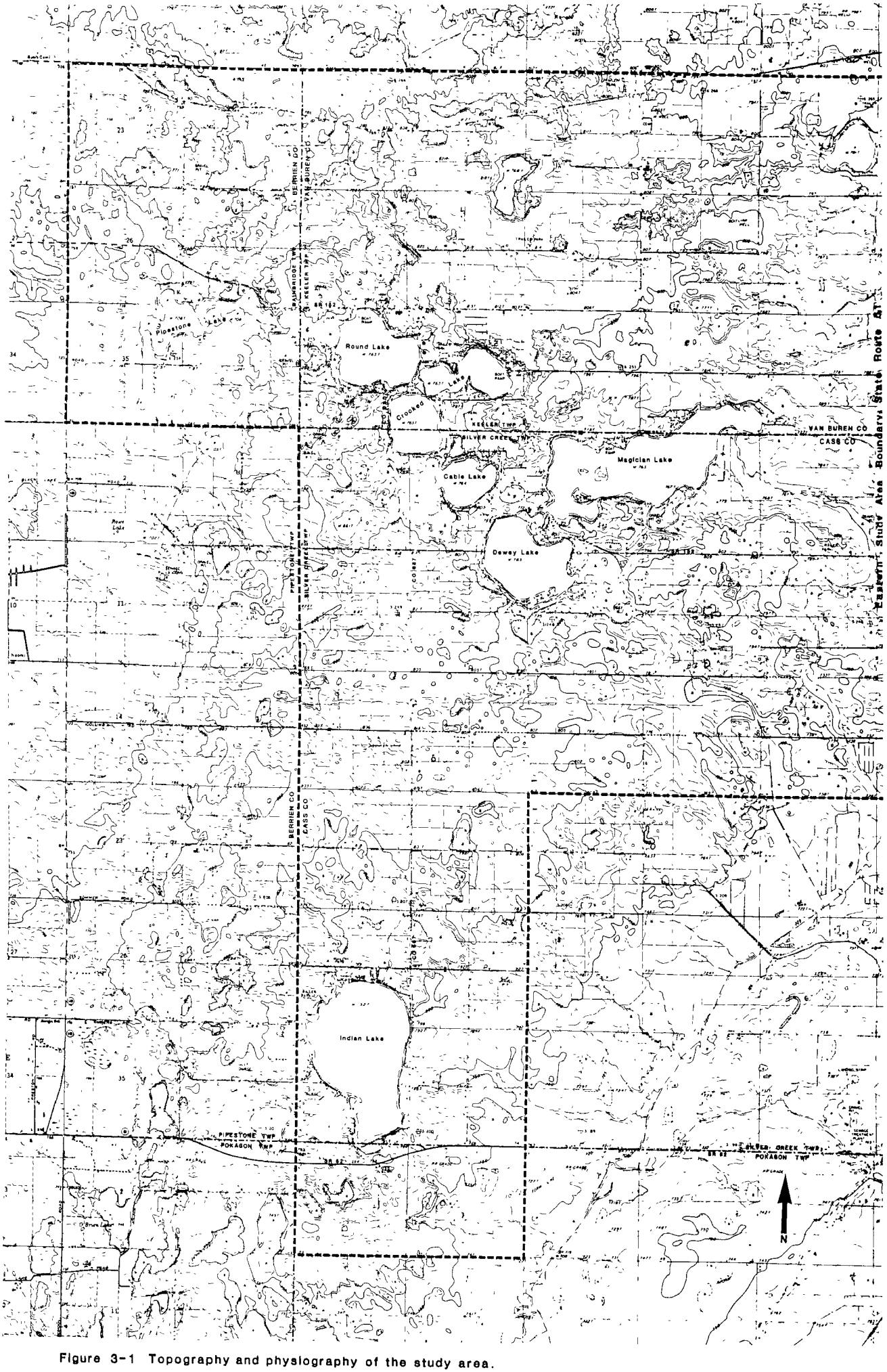


Figure 3-1 Topography and physiography of the study area.

Table 1 (continued)

Sample Number		Bkg/Ctr	Cond.	Total P ppm	NH_4-N ppm	NO_3-N ppm	Δ^C	Δ^{TP}	Δ^N	% Breakthrough P	% Breakthrough N	Comments
Magician Lake												
31	S		370	.007	.114	1.066						
32	S	●	340	.008	.244	.278						
	G	●	500	.008	.135	2.202	140	<.01	2.16			
33	S		350	.007	.178	.783						10" storm drain
34	S		380	.010	.265	.542						
35	S		500	.015	.265	1.777						Conduit Waheska house
36	S		325	.007	.181	.098						
	G		360	.012	.176	.014						
W37	G		460	.006	.273	.014	100	<.01	.14	<1	6	
38	S	●	350	.006	.280	.094						
Pipestone Lake												
39	S	●	380	.017	.379	.017						
40	S		760	.262	9.077	.180	380	.25	8.70	13	92	Slimy drainpipe
41	S		520	.050	1.154	.061	140	.04	.7	6	20	Pipe w/ Cladophora
42	S		550	.038	1.142	.053	170	.03	.7	4	16	Pipe
43	S		450	.058	2.353	.042	70	.06	1.9			Pipe
44	S		520	.843	13.351	.048	140	.83	12.9	119	369	Pipe
45	S	●	400	.015	.399	.017						
	G	●	830	.010	7.046	.011						
46	S	●	380	.012	.233	.015						
	G	●	550	.030	4.419	.020						
47	S		420	.010	.454	.112						Water seeping from shore bank
48	S		540	.066	.390	.129	160	.05	<.01	6	<1	Drainpipe, bad odor
49	S		440	.206	.158	.010						Ditch across road
50	S		400	.009	.233	.028						Bay, end of lake
51	S		440	.011	.380	.031	80	<.01	<.01	<1	<1	Boggy area
52	S		460	.014	.169	.012						Boggy area

Table 1 (continued)

Sample Number		Bkg/Ctr		Cond.	Total P ppm	NH_4-N ppm	NO_3-N ppm	Δ^C	Δ^{TP}	Δ^N	% Breakthrough P	% Breakthrough N	Comments
Indian Lake													
53	S		●	300	.009	.179	.010						
54	S			300	.009	.157	.015						Cladophora, FN 325
	G			500	.017	.293	.029	140	<.01	.17	<1	5	
55	S			415	.031	.177	.020						Pipe from stream
56	S			320	.009	.248	.052						Submerged leaves, 50 yrds
	G			1940	.012	.239	.284	1800	<.01	.37	<1	<1	33326 Lakeview
57	S			340	.008	.130	.058						Canal
58	S	●		300	.007	.126	.057						
	G	●		650	.021	.404	.047	290	.01	.30			
59	S			325	.007	.166	.010						
60	S	●		300	.007	.176	.007						
	G	●		435	.012	2.514	.014	75	<.01	2.37			
61	S	●		300	.012	.179	.006						
	G	●		360	.023	1.504	.017						
62	S		●	300	.007	.155	.008						
63	S			320	.006	.178	.026						
	G			700	.014	.675	.012	340	<.01	.54	<1	6	
Crooked Lake													
64	S		●	320	.005	.123	.017						
65	S	●		320	.009	.177	.012						
	G	●		340	.019	.703	.024						
66	S			320	.023	.135	.010						Tall grassy area front, vacant lot
66	G			720	.007	.680	.010	360	<.01	.54	<1	6	
67	S			330	.009	.160	.010						Canal
68	S			330	.009	.129	.078						#2223
	G			750	.006	.150	.008	390	<.01	<.01	<1	<1	
69	S			315	.009	.094	.015						2019 Victory Shore Dr.
70	S		●	190	.007	.123	.013						
71	S	●		185	.006	.140	.010						
	G	●		165	.008	2.130	.011						

Table 1 (continued)

Sample Number		Bkg/Ctr		Cond.	Total P ppm	NH_4-N ppm	NO_3-N ppm	Δ^C	Δ^{TP}	Δ^N	% Breakthrough P	% Breakthrough N	Comments
Round Lake													
72	S		●	104	.006	.116	.009						
73	S	●		104	.007	.135	.010						
	G	●		210	.020	1.918	.038						
74	S			105	.017	.217	.010						Swampy area, with apple orchards beyond
	G			123	.017	.324	.020						
75	S	●		104	.019	.152	.007						
	G	●		360	.009	.884	.011						
76S	S			123	.011	.136	.013						#403 Rays Court
	G			840	.017	.146	.240						
Effluent				960	.885	.421	15.59						Dowagiac Treatment Plant.

5.0 NUTRIENT RELATIONSHIPS

By the use of a few calculations, the characteristics of wastewater plumes can be described. First, a general background groundwater concentration for conductivity and nutrients is determined. The concentration of nutrients found in a plume is then compared to the background and to municipal wastewater effluent from the lake region to determine the percent breakthrough of phosphorus and nitrogen to the lake water. Because the wellpoint sampler does not always intercept the center of the plume, the nutrient content of the groundwater plume is always partially diluted by surrounding ambient background groundwater or seeping lakewater concentrations. In an attempt to correct for the sampling uncertainty in pinpointing the peak of the groundwater plume, the nutrient concentrations of the sampled plume are corrected to a concentration proportional to adjustment of plume conductivity to the level of undiluted municipal effluent. (Recall section 1.1.1 explained that effluent-saturated soils will likely pass 100% conductivity of any newly-charged effluent.) The percentage of location-corrected nutrient concentration to raw municipal effluent nutrient levels is referred to as "nutrient breakthrough."

For the difference between background (C_o) and observed (C_i) values:

$C_i - C_o = \Delta C_i$ conductivity

$TP_i - TP_o = \Delta TP_i$ total phosphorus

$TN_i - TN_o = \Delta TN_i$ total nitrogen (here, sum of NO_3-N and NH_4-N)

For attenuation during soil passage:

$$100 \times \left(\frac{\Delta C_{ef}}{\Delta C_i}\right) \frac{\Delta TP_i}{TP_{ef}} = \% \text{ breakthrough of phosphorus}$$

$$100 \times \left(\frac{\Delta C_{ef}}{\Delta C_i}\right) \frac{\Delta TN_i}{TN_{ef}} = \% \text{ breakthrough of nitrogen}$$

where: C_o = conductivity of background groundwater (µmho/cm

C_i = conductivity of sampled plume groundwater (µmho/cm)

C_{ef} = conductivity of sand-filtered effluent minus the conductivity of background (well) water (µmho/cm)

TP_o = total phosphorus in background groundwater (ppm)

TP_i = total phosphorus of sampled plume ground (ppm)

TP_{ef} = total phosphorus concentration of standard effluent (ppm)

TN_o = total nitrogen content of background (well) groundwater, here calculated as NO_3-N + NH_4-N (ppm)

TN_i = total nitrogen content of sampled plume groundwater, here calculated as NO_3-N + NH_4-N (ppm)

TN_{ef} = total nitrogen content of standard effluent (ppm)

TN_o and TP_o are considered insignificantly small compared to TP_{ef} and TN_{ef}.

5.1 Assumed Wastewater Characteristics

Samples of effluent were taken from the designated "secondary treatment" sampling station in the new Dowagiac Municipal Sewage Plant. This plant has tertiary treatment capability and it is important to mention that phosphorus removal is likely carried out at several stages in the process: i.e., a sizeable percentage of total phosphorus (TP) is removed prior to the "secondary" stage and ~98% of phosphorus is removed following tertiary treatment. This would be a reasonable explanation for the low total phosphorus (.885 ppm) found in our sewage sample. Characteristics of the effluent formed the basis of comparison for all sampled plumes in the Indian Lake - Sister Lakes study area. A conductance : total phosphorus : total nitrogen ratio of 600:3:15 was used. Please note the substitution, for purposes of comparison, of 3 ppm for TP; this is the expected value of sand-filtered effluent as opposed to the phosphorus depleted level of .88 ppm in this case of tertiary-treated effluent.

5.2 Assumed Background Levels

One or more background pair samples were taken from each lake shore. Background levels of surface water conductivity, total phosphorus and total nitrogen were derived from lake center samples. Likewise, background levels of conductivity, total phosphorus and total nitrogen for groundwater were derived judgementally from consideration of local well water and background station samples. The common value chosen was: conductivity, 360 µmho/cm; TP, .010 ppm; TN, .15 ppm. The 360 µmho/cm value best fit the four largest lakes (Magician, Crooked, Pipestone and Indian), whereas the smaller lakes had a much lower background conductivity, on the order of 50-100 µmho/cm.

5.3 Attenuation of Nitrogen and Phosphorus Compounds

Complex soil conditions including marl and muck bottoms typical of the Indian Lake - Sister Lakes group make evaluation of nutrient breakthrough somewhat difficult. Some patterns do emerge. On heavily-vegetated Pipestone Lake where reducing conditions must certainly exist in the organic bottom and elevated nutrients in the free water, we find that 8 of 14 (57%) surface samples taken exceed .015 ppm TP, whereas on all other lakes only 10% of surface samples exceed this value. Also, 21 of 30 cases of elevated groundwater conductivity were not accompanied by any detectable breakthrough of total phosphorus.

High nitrate (>1.0 ppm) occurred only on Magician Lake, while high ammonia nitrogen (1-30 ppm) was found more frequently on several lakes. Major transporters of nutrient loading appear to derive more from surface runoff streams (such as at Pipestone Lake) than from the low frequency of observed groundwater plumes.

6.0 COLIFORM LEVELS IN SURFACE WATERS

A series of water samples from around the different lakes was analyzed for fecal coliform count to confirm the presence of surface runoff or soil short-circuiting from malfunctioning septic systems. The membrane filter coliform count indicates the density of coliform organisms. Since these organisms may be of intestinal origin and are numerous in sewage, high numbers are indicative of sewage pollution with its possible hazards to public health through the potential presence of pathogenic organisms. Here, the fecal coliform count was used as a more specific test of recent sewage pollution.

Historical bacteria data is limited to Dowagiac River, Pipestone Creek, and Crooked Lake, the two streams having documented high fecal counts and Crooked Lake not showing any problem. In this survey, we obtained four to seven bacteria samples from each of the six major lakes, and two from outlying Keeler lake.

We found significant fecal coliform contamination only in Pipestone Lake. Sample B32 (7600 colonies/100 ml water) was drawn from a 4" drain pipe flowing into Pipestone Lake from a lot along the cottage-lined northern lobe of the lake. Sample B33 (<100 colonies/100 ml water), also taken from a drain pipe in the northern lobe, is only an estimate as it was too debris-laden for an accurate count. All other sampling stations at the various lakes registered less than 75 colonies/100 ml water,

indicating no particular bacterial problems inside the lake at this time (autumn) of the year. The canals surrounded by housing units on Magician, Dewey, Indian, and Crooked Lakes showed only safe levels of fecal bacterial activity. See Table 2 for specific values.

Berrien County Health Department laboratory provided the bacterial analysis.

Table 2. Bacterial content of shoreline water samples of Indian Lake - Sister Lakes, Wisconsin.

Lake	Station	Fecal Coliform No/100 ml	Location
Magician Lake	B1	62	Middle of Canal #1
	B2	22	End of Canal #2
	B3	12	Beginning of Canal #2
	B4	60	Mouth of Big Canal
	B5	19	Middle of north shore
	B6	28	Camp - northeast shore
	B7	0	Pipe - northwest shore
Dewey Lake	B8	6	North corner
	B9	10	West shore
	B10	4	Canal - southeast shore
	B11	4	Swamp - southeast corner
Cable Lake	B12	2	Northeast corner
	B13	75	Near swamp - northwest corner
Indian Lake	B14	25	#20 Love Lane
	B15	12	Cove - Highland Drive
	B16	9	Canal - southwest shore
	B26	0	Near #313 Lakeview Ave.
	B27	11	3' stream - Lakeview Ave.
	B28	26	#33341 Lakeview Ave.
	B29	0	Near #327 Lakeview Ave.
Round Lake	B17	25	Sister Lakes Rd.
	B21	1	#1319 Mariner Lane
	B24	0	#1403 Rays Court
	B25	3	Madison Ave. - South corner
Crooked Lake	B18	1	#3107 Lakeview Court
	B19	8	#2022 Victory Shore Dr.
	B20	17	#2306 Lakeshore Dr.
	B22	14	Canal - east end of lake
	B23	47	#2215 Lakeshore Dr.
Pipestone Lake	B30	0	South end Bass Isl. Prk. Dr.
	B31	50	Pipe - 1980 Bass Isl. Prk. Dr.
	B32	7,600	Pipe - 1st house N. of steimle's
	B33	100	Drain pipe - Tennisson's house
	B34	3	Drain pipe - Potter's house
	B35	0	Drain pipe - 8768 Lakeview
	B36	20	#8760 Lakeview
Keeler Lake	B37	4	Fire Lane - east shore
	B38	2	Swampy area - west shore

7.0 GROUNDWATER FLOW PATTERNS

Precipitation provides the primary supply to groundwater aquifers in Cass, Van Buren and Berrien Counties surrounding the lakes study area. Percolation and down-gradient transmission of this groundwater through the glacial drift provides the basic recharge for Indian Lake and the Sister Lakes. Only Indian Lake, Magician Lake and Pipestone Lake have significant surface outflows. Surface inflows for the lake group are confined to very low volume streamlets and drain tiles. Saturated wetlands surrounding many of the lakes must also facilitate groundwater movement through the lake boundaries.

To look for relationships between plume breakout frequency and localized groundwater flow patterns, we employed the Dowser™, a groundwater flow instrument (K-V Associates, Inc.). This device is most effective in shallow saturated soil of uniform grain and porosity (fine sands to fine gravel), but can also generate useful directional indications, if less precise, in coarser, non-homogeneous soils. In digging our test holes, we encountered a wide variety of difficult conditions around the eight lake shorelines. While a veneer of uniform medium beach sand was prevalent around such lakes as Dewey, Indian, Crooked, Magician and Round, the frequently-encountered underlying coarse gravel and stone soil composition there added to the variability of the results. Flow restrictive muck, marl, and clay layers are typically less easy to interpret vectorally; such tight soils were common around portions of Magician and Pipestone, yielding several undecipherable slow flow indications.

Figure 5 gives an overview of specific flow determinations around the various lake perimeters. Groundwater direction is generally into the lakes along northern and eastern shores, correlating well with plume densities seen along Indian, Crooked, and Pipestone Lakes. See Table 3 for details of individual site vectors.

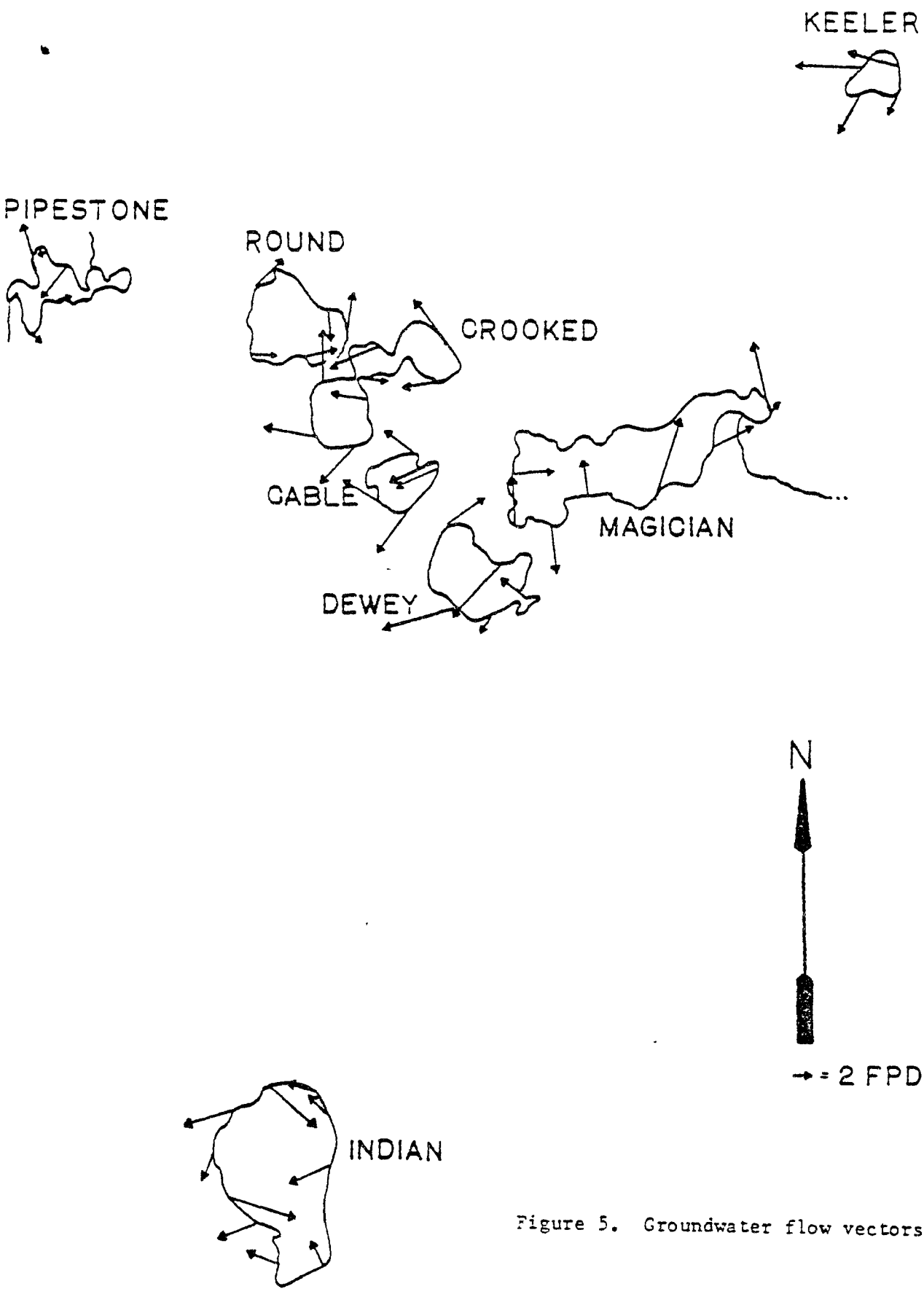


Figure 5. Groundwater flow vectors.

Table 3. Observed rates of groundwater flow in Indian Lake and Sisters Lake, Michigan

Station	Location	Flow Direction	Flow Rate FPD
DEWEY			
1	Shady Shores	250° W	8.5
2	#31916	213° SW	3
3	Ashcraft - Bancock	41° NE	5
4	At Point of Noah Shore	233° SW	7.5
5	South of Sleepy Hollow	305° NW	3.5
Keeler			
6	ENE Shore	287° W	6
7	Haskin	273° W	7.5
8	SSE Shore	218° SW	5
9	Oak Pts. subdivision-#2	213° SW	3
Cable			
10	Lawn below wooded hill S.E. Shore	213° SW	6
11	#4294	244° W	5
12	#50229 Park Rd.	248° W	5.5
13	#32475 Wildwood	303° NW	4
14	#4514 Cable Lake Rd.	297° W	5
Magician			
15	S.W. end	354° N	5.5
47	#31500 S. Lakeshore Dr.	165° S	5.5
48	#31290 Currans Beach	346° N	4
49	Cobbens	18° N	10
50	Rainbow Park	59° NE	5
51	#50317 Lake Shore Drive	84° E	4.5
52	#31339	-	No Flow
53	East of Blue Fin Marina	-	No Flow
54	East end	34° NE	2
55	East end	342° N	7.5
Pipestone			
16	#8970 Hamilton Dr.	215° SW	5
17	#8830	262° W	1
18	Skibbe Dr.	331° N	5.5
19	South end of Bass Island Park Drive	115° E	1.5
20	#2030	-	No Flow
21	South east end	75° E	1.5

Table 3. (Continued)

Station	Location	Flow Direction	Flow Rate FPD
Indian			
22	Washington Rd.	130° SE	7
23	Golf Course	109° E	8
24	South end	207° S	3.5
25	South of canal - West shore	245° W	6
26	#33203 Lakeview Ave.	290° N	3.5
27	East of Schusters	313° N	3
28	North shore - east of road section	242° W	5
29	Yacht club	318° NW	3.5
30	Forest Beach Rd.	292° W	3.5
31	N of #685 Forest Beach Rd.	245° W	5
Upper Crooked			
32	R 6 Box 514	93° E	2.5
33	Near #2019 Victory Shore Dr.	258° W	6
34	#2310	323° NW	5.5
35	#2699	257° W	5
Lower Crooked			
36	Schroeder	356° N	6
37	#50077 Sister Lakes Rd.	282° W	6
38	#32826 Haley Rd.	222° SW	6
39	House, north end of Wildwood Dr.	280° W	4
Round			
44	#1403 Clark	171° S	4
45	Center of South Shore	79° E	3.5
46	North of swamp - west shore	39° NE	4
56	South west corner	92° E	2.5
57	North of "The Wharf"	9° N	4

8.0 CONCLUSIONS

A continuous septic leachate survey was conducted in the autumn of 1979 along the shorelines of Indian Lake, Crooked Lake, Magician Lake, Dewey Lake, Cable Lake, Keeler Lake, Pipestone Lake and Round Lake, all located in southwestern Michigan. The following conclusions were drawn from the shoreline profiles, fluorescence scans, nutrient and inorganic analyses of surface and groundwater samples, and groundwater flow measurements:

1) A total of 47 locations exhibited noticeable erupting effluent plume characteristics, specifically occurring on Crooked Lake, Magician Lake, Indian Lake and Pipestone Lake. The other (smaller) lakeshores had far fewer potential point source problem sites and had water quality more resembling that of wetlands influence.

2) At least 16 of the principal plumes are associated with stream inlets, with 12 such inputs on Pipestone Lake alone. Plume occurrence was predominantly along northern shores, corresponding quite well with observed groundwater flow intrusion.

3) Fecal coliform bacterial contamination has not reached a level of major concern with the possible exception of levels found in Pipestone Lake. Of 38 locations sampled around the eight lakes, only one (a drainpipe on Pipestone Lake) exceeded 75 colonies/100 ml of water.

4) Nutrient levels were lower as a group than might be expected for lakes with anticipated water quality problems. A total of 115 discrete water samples were analyzed: 84% of the samples showed NO_3 values <.100 ppm (72% of the higher readings occurred at Magician Lake); 90% of the samples did not exceed .040 ppm TP, the maximum being .883 ppm.

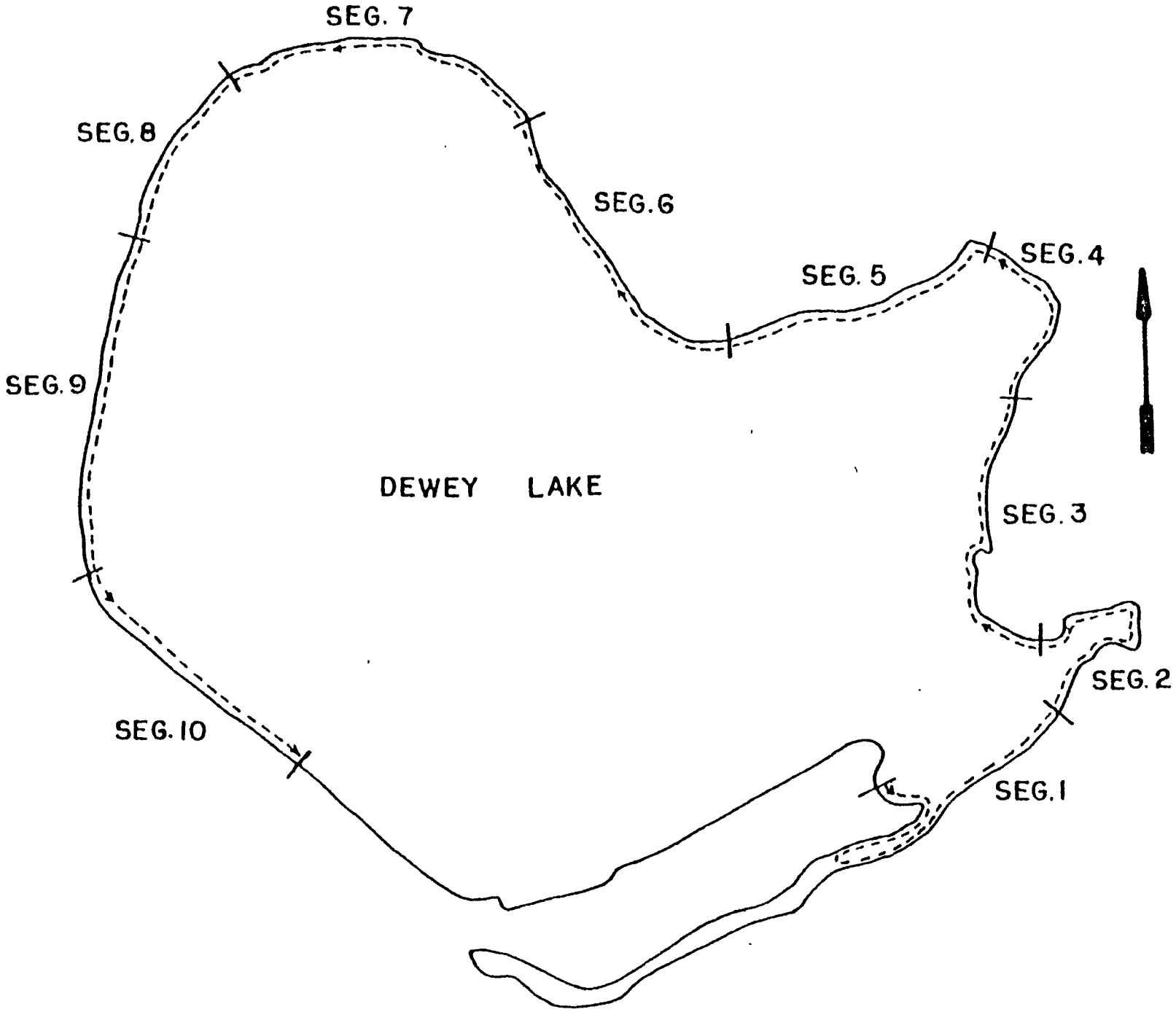
Consistently high ammonia (>1 ppm - reducing conditions) appeared only on Pipestone Lake. Residential areas showing plume problems and beset with high groundwater include the north shores of Magician and Pipestone and more elevated areas of the southwestern corner of Magician Lake and the western shore of Indian Lake.

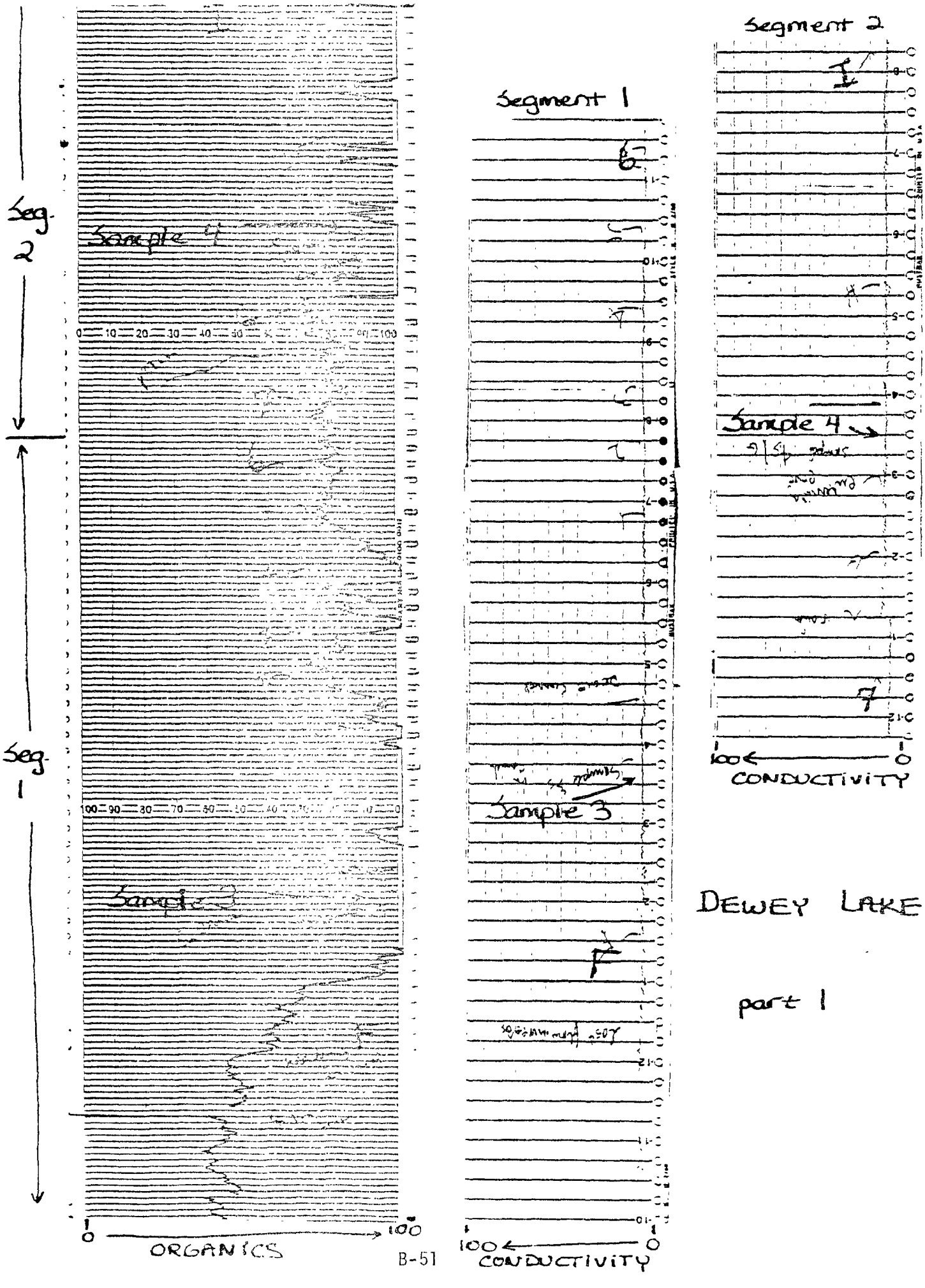
REFERENCES

Larson, G., 1979. Affected environment. Preliminary draft chapter of the Indian Lake - Sister Lakes environmental statement. WAPORA, Inc.

LRPC, 1977. Discussion of nutrient retention coefficients, Draft Report 6F2 from Phase II Nonpoint Source Pollution Control Program, Lakes Region Planning Commission, Meredith, New Hampshire.

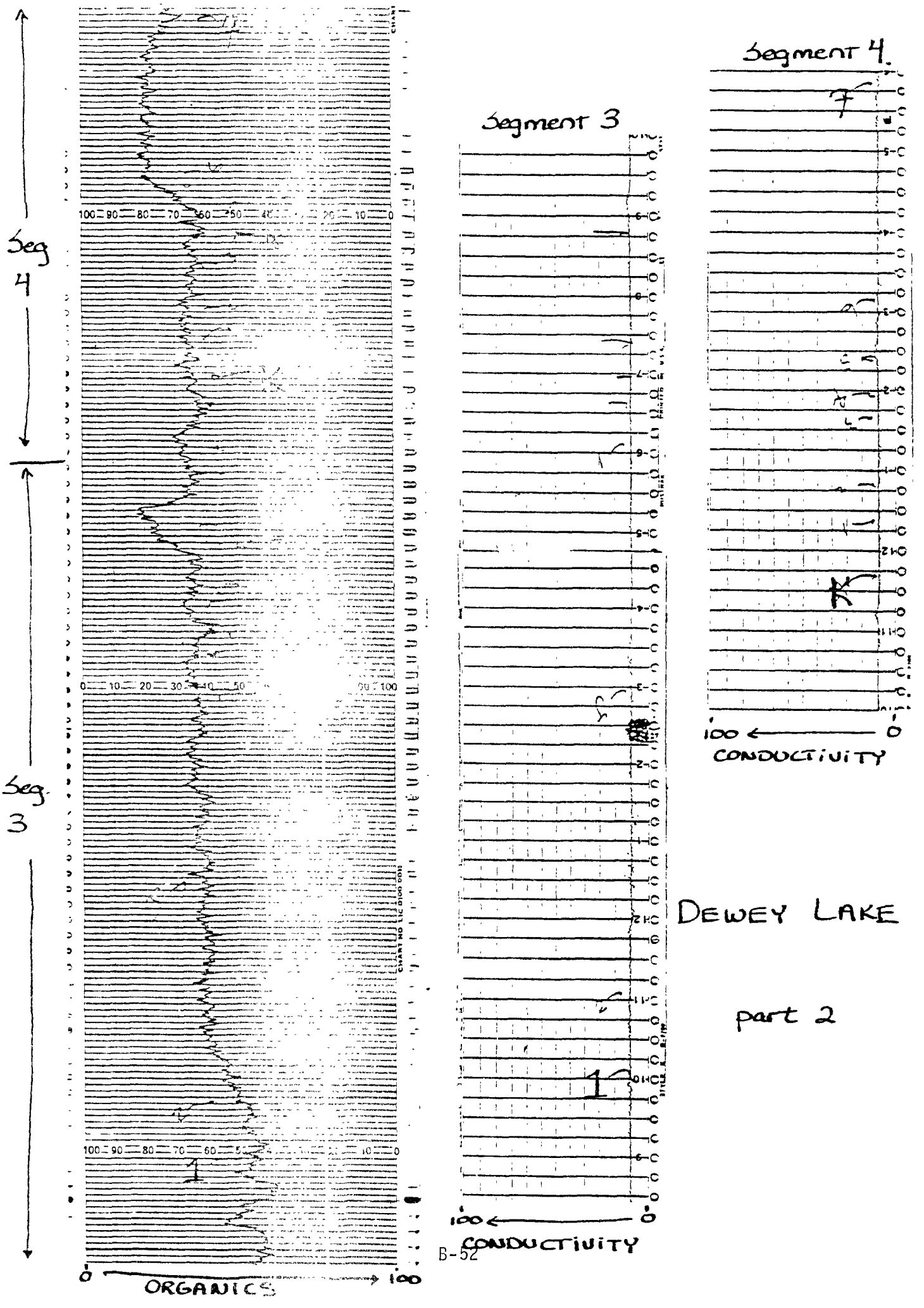
APPENDIX


SEG. 7
SEG. 8
SEG. 6
SEG. 5
SEG. 4
SEG. 9
DEWEY LAKE
SEG. 3
SEG. 2
SEG. 10
SEG. 1



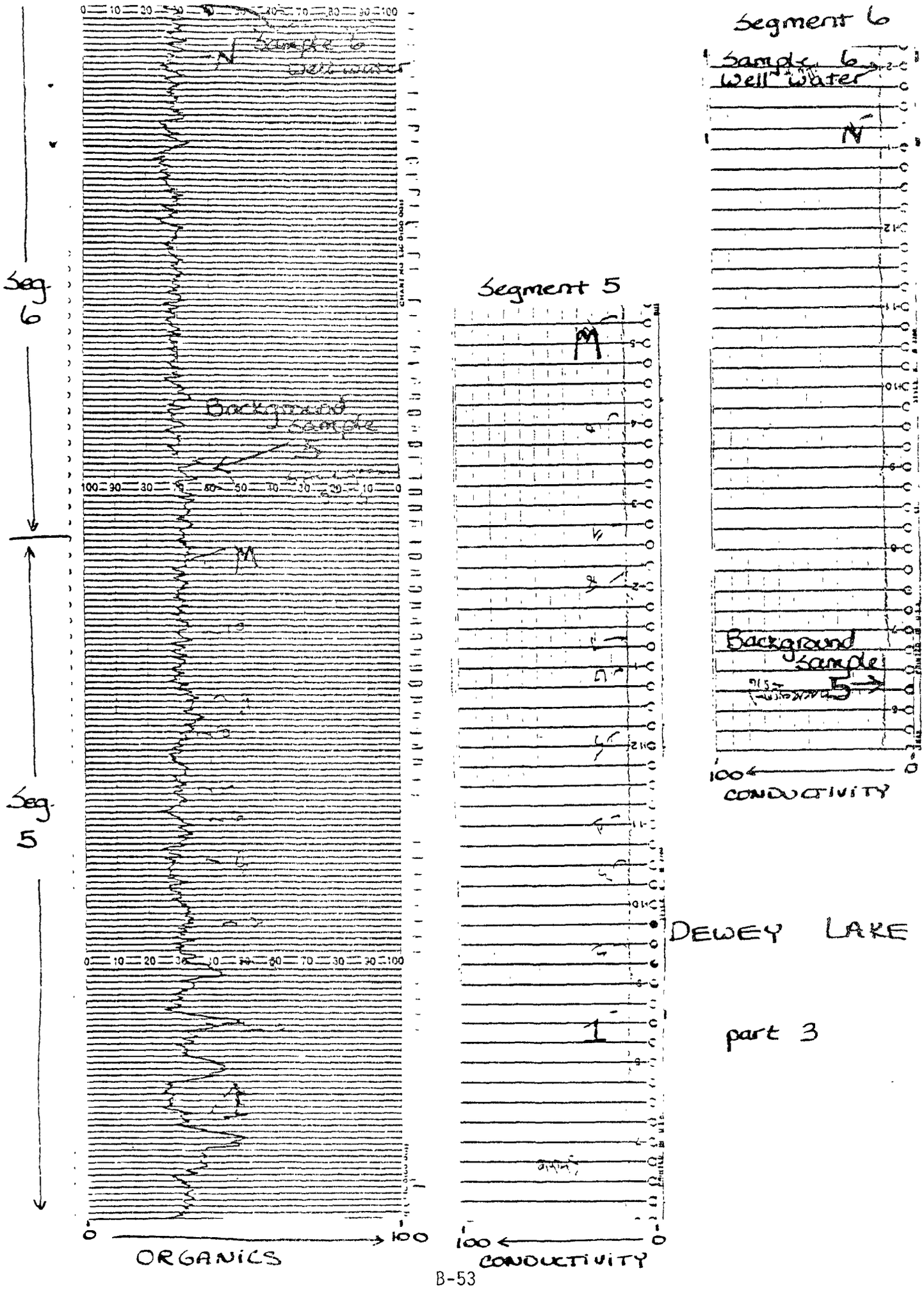
DEWEY LAKE

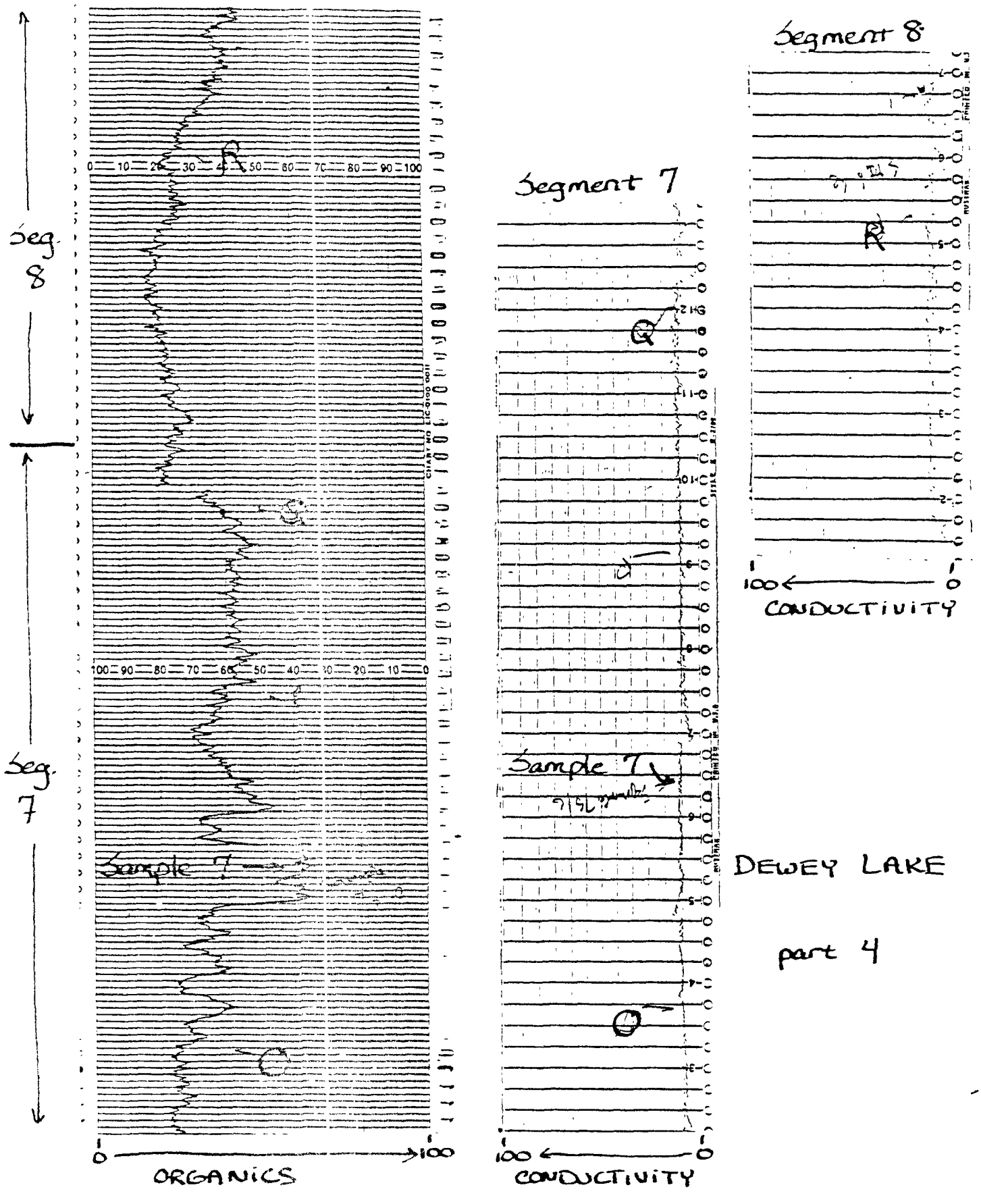
part 1



DEWEY LAKE

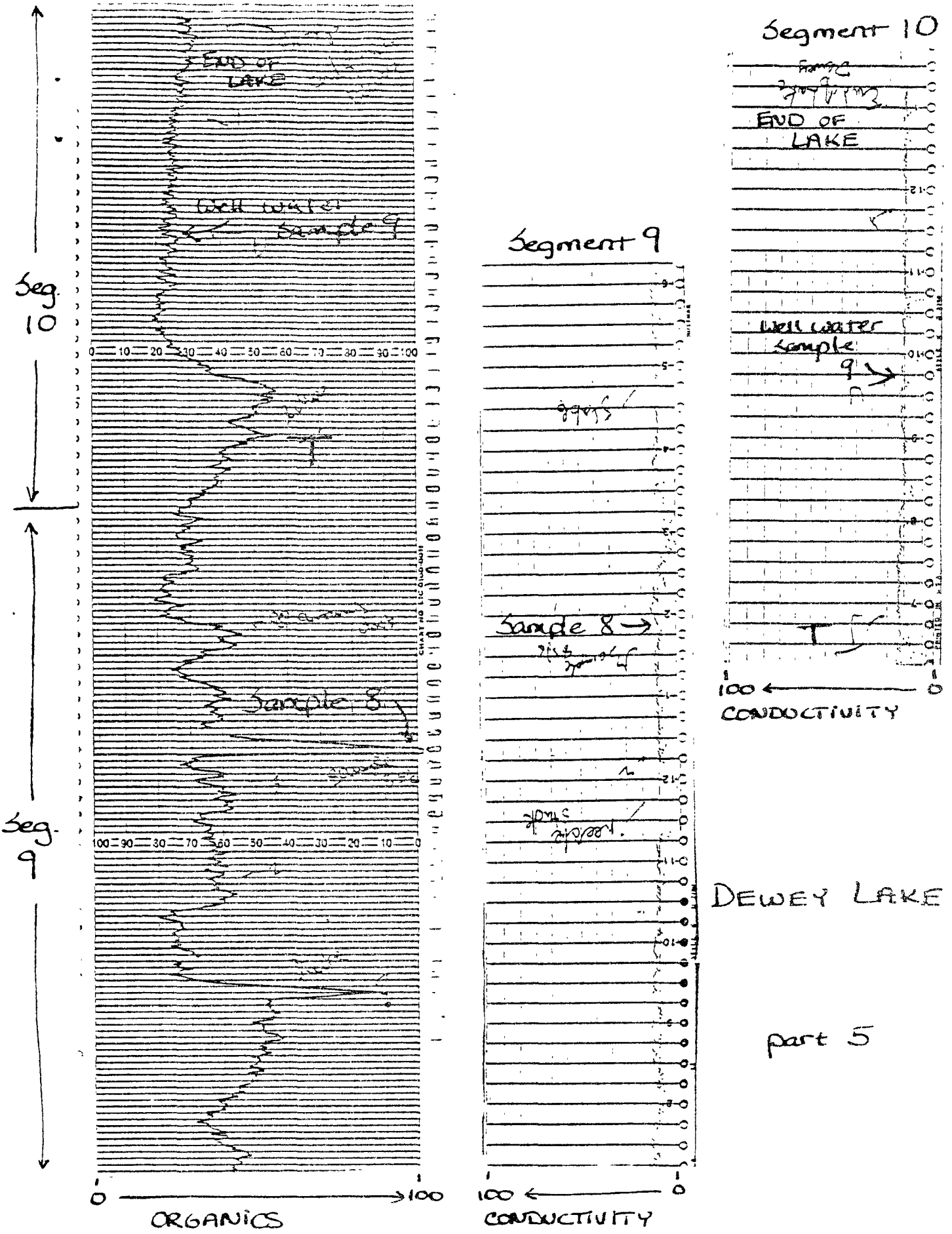
part 2


Seg. 6
Seg. 5
Segment 6
Sample 6
Well water
Background sample
Segment 5
ORGANICS
CONDUCTIVITY
CONDUCTIVITY
DEWEY LAKE
part 3



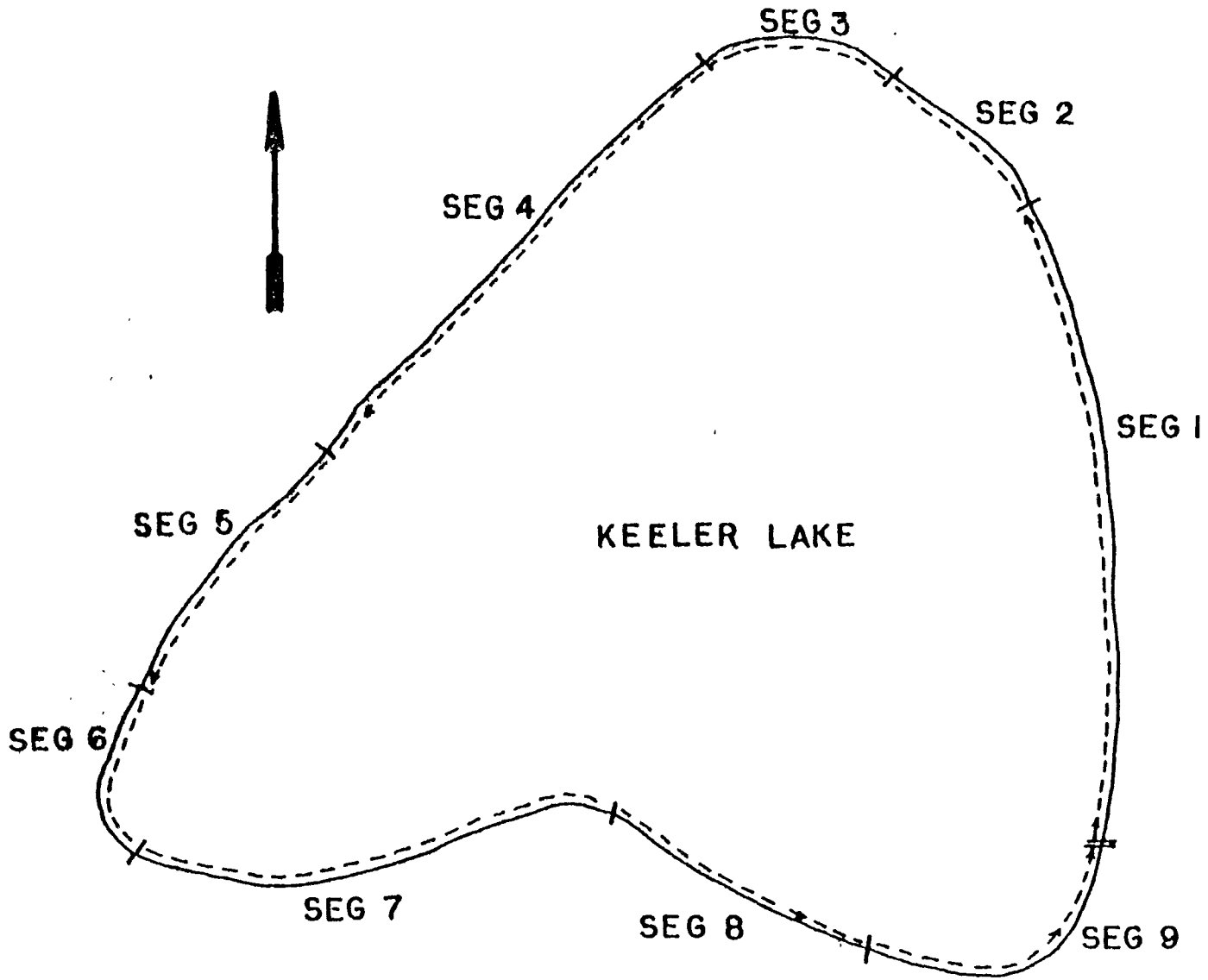
DEWEY LAKE

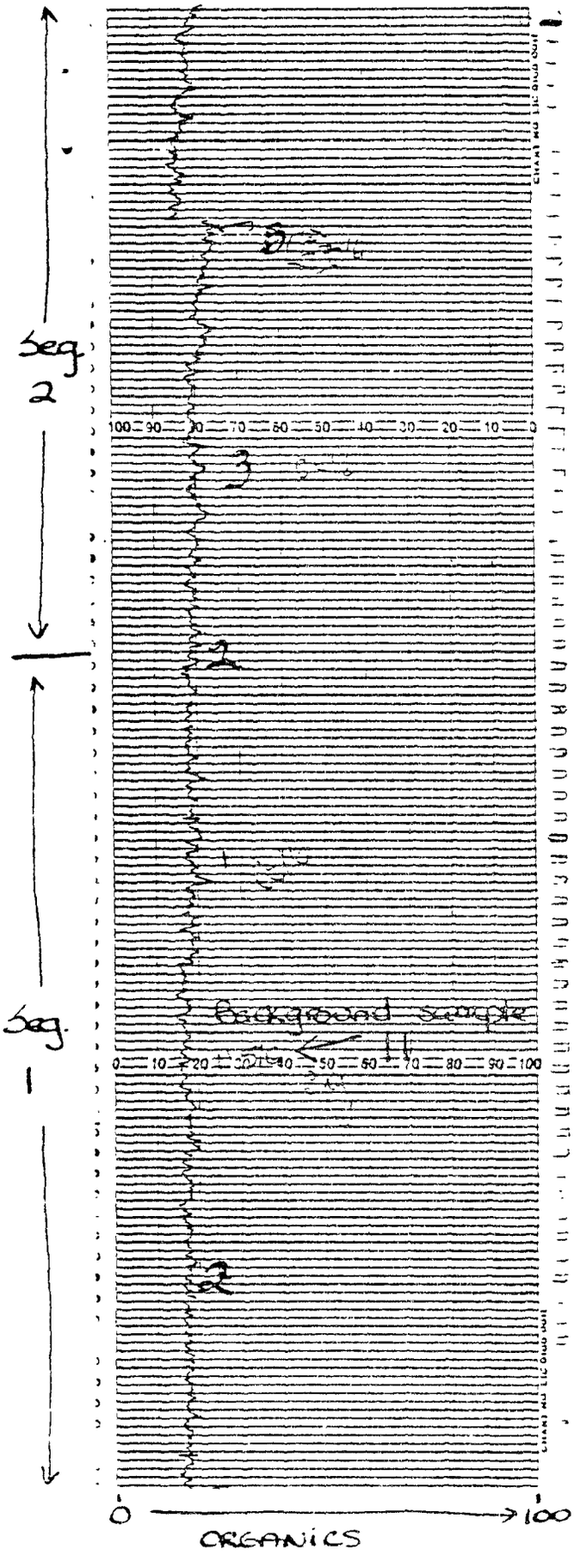
part 4

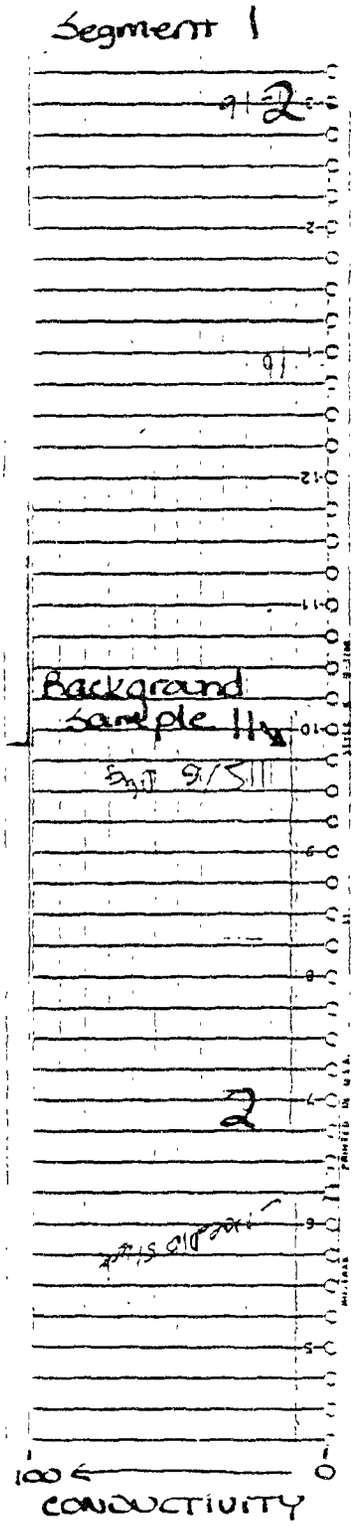


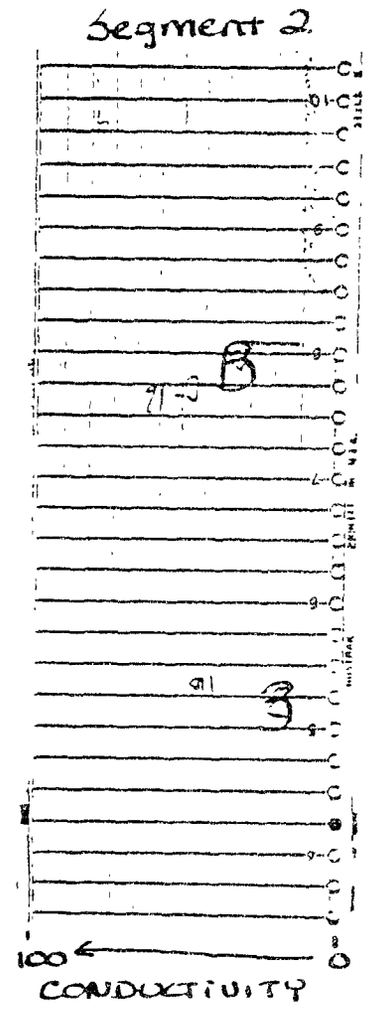
DEWEY LAKE

part 5


SEG 3
SEG 2
SEG 4
SEG 1
SEG 5
KEELER LAKE
SEG 6
SEG 7
SEG 8
SEG 9

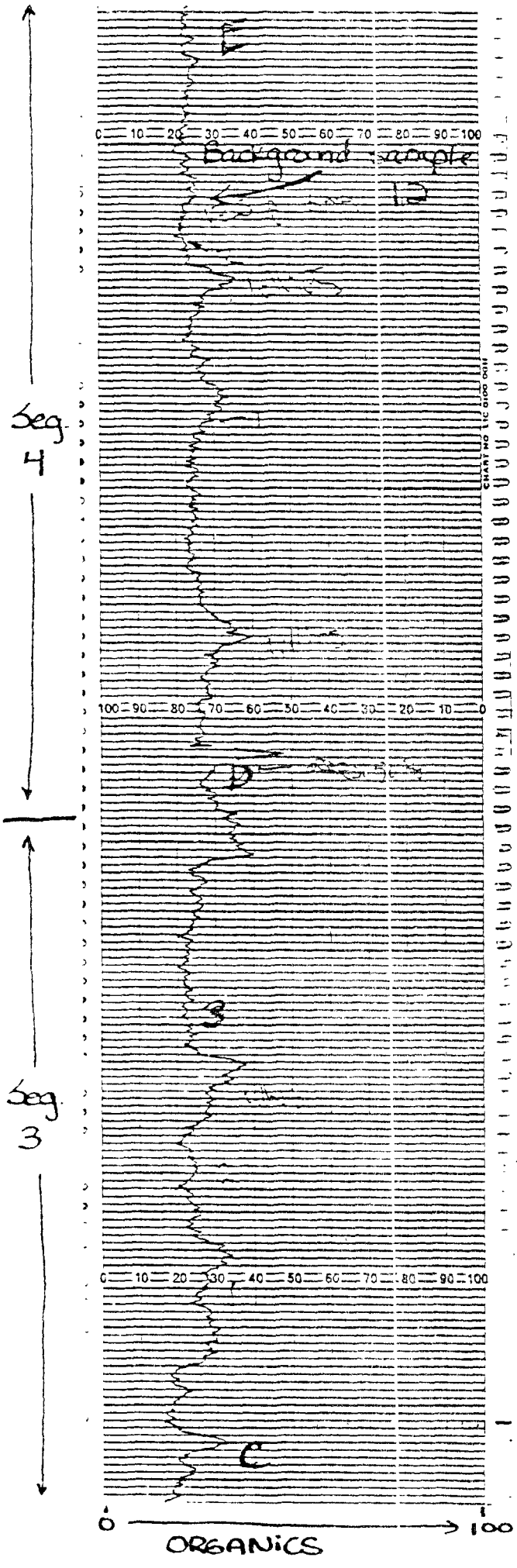


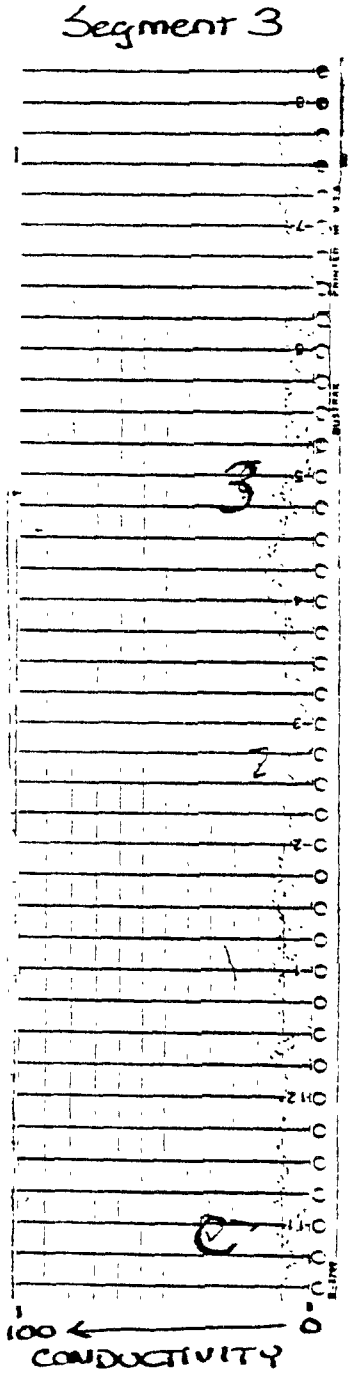


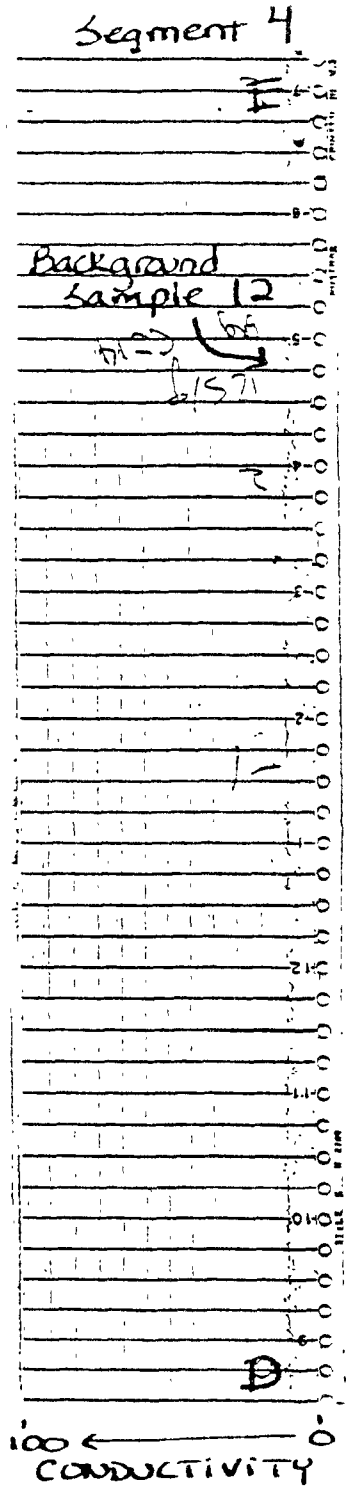


KEELER LAKE

part 1

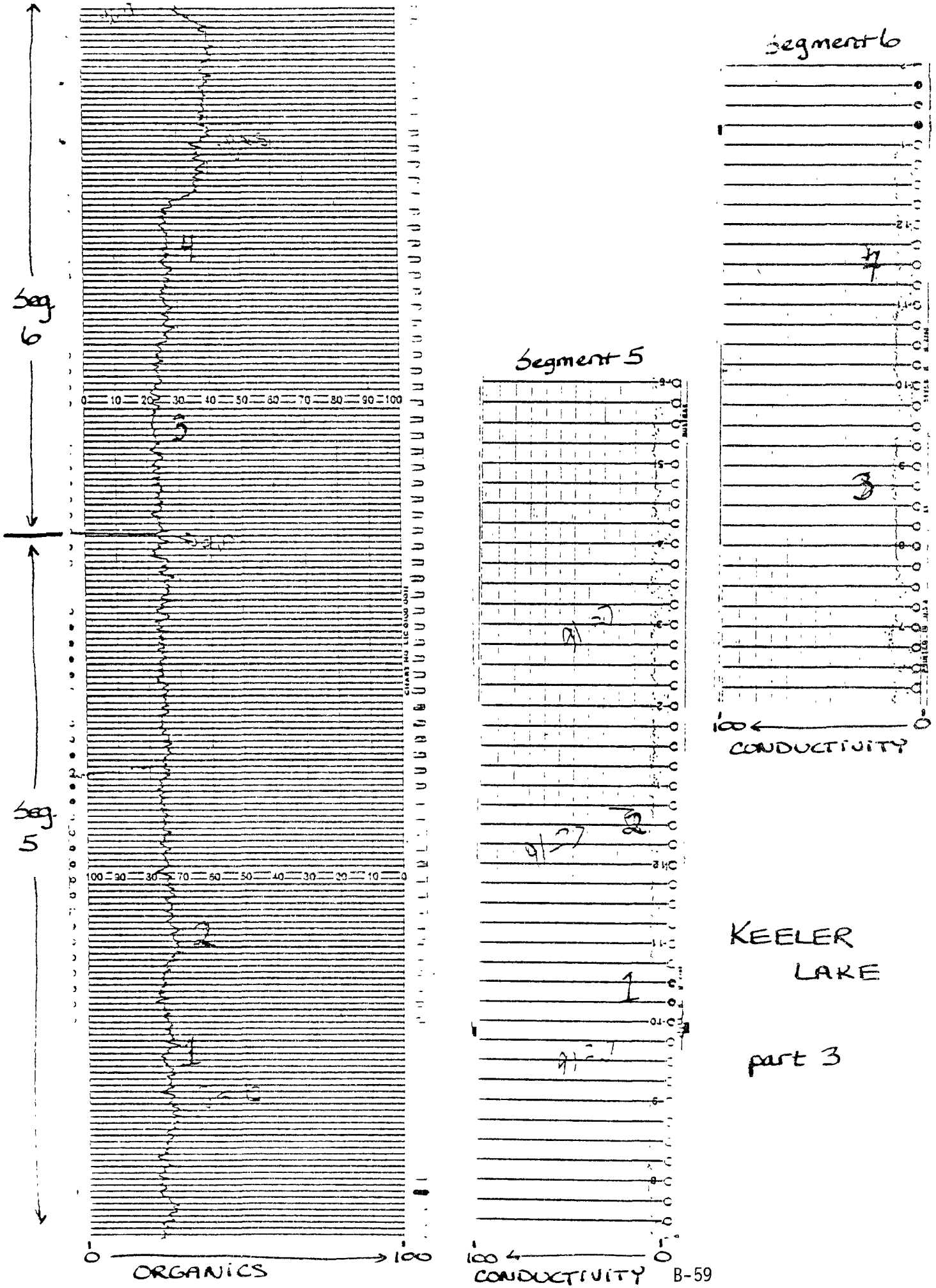






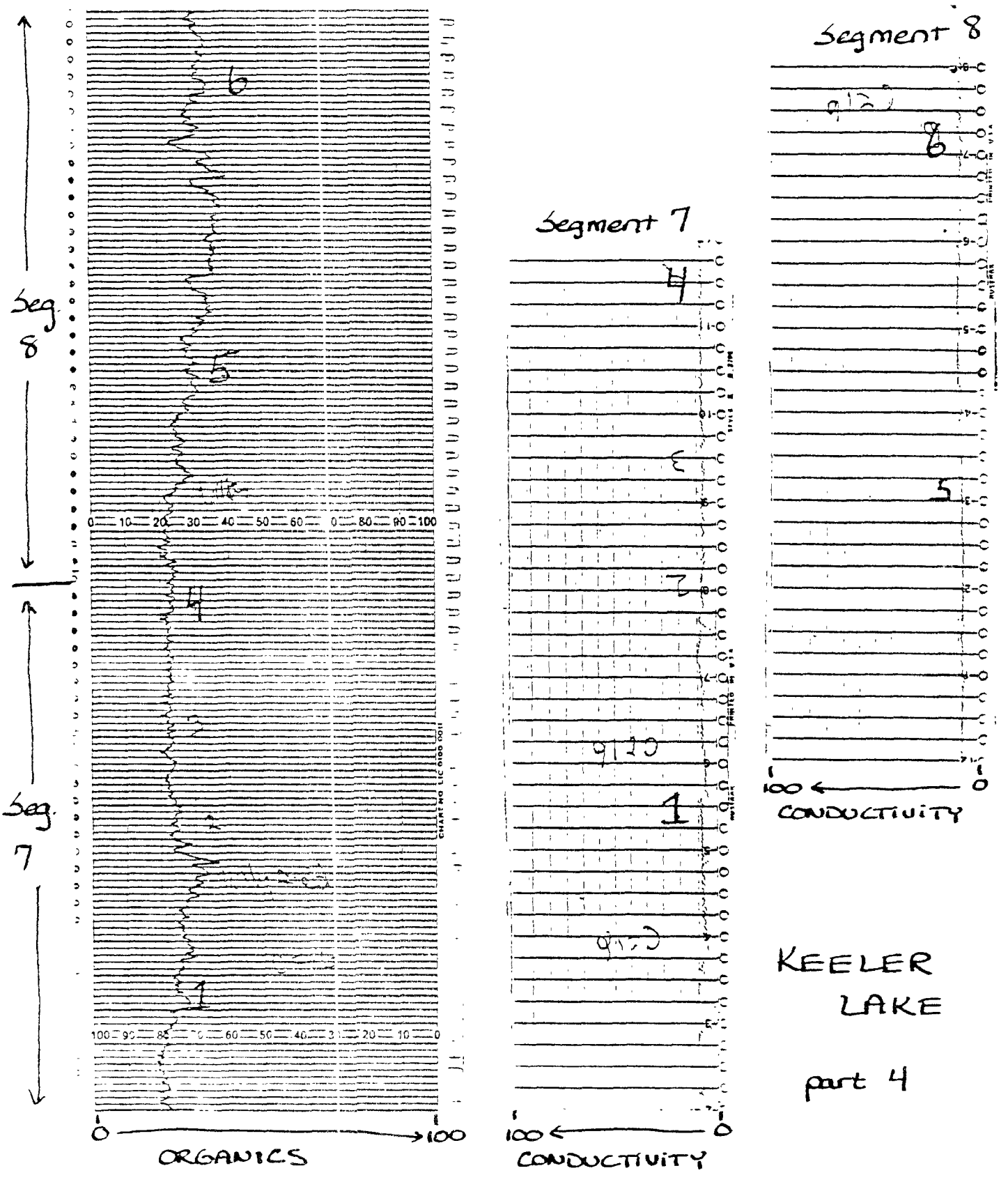
KEELER LAKE

part 2



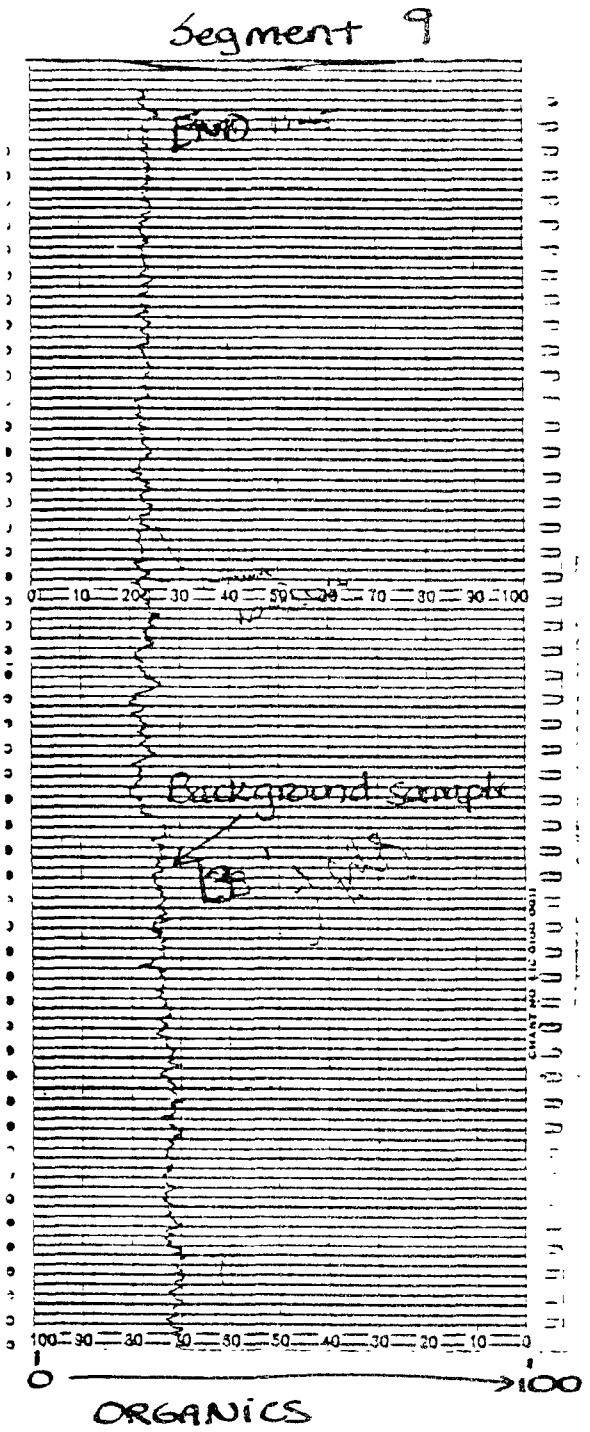
KEELER LAKE

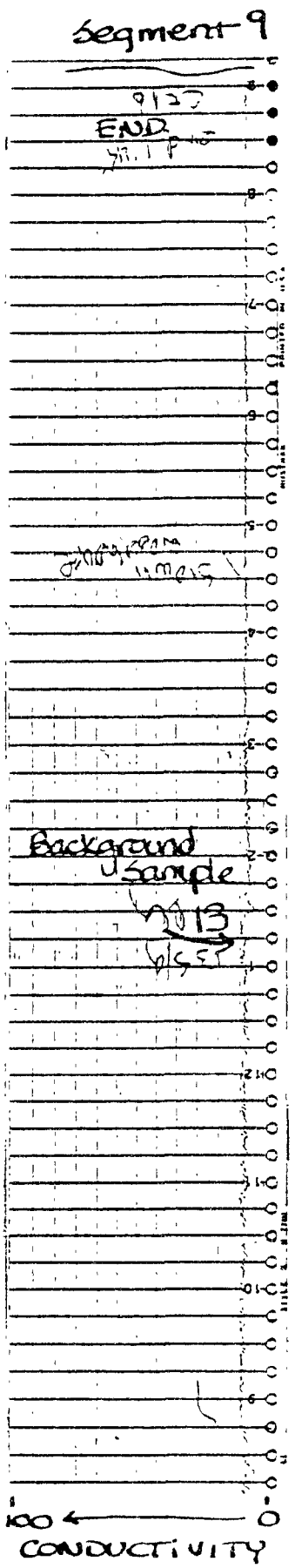
part 3



KEELER LAKE

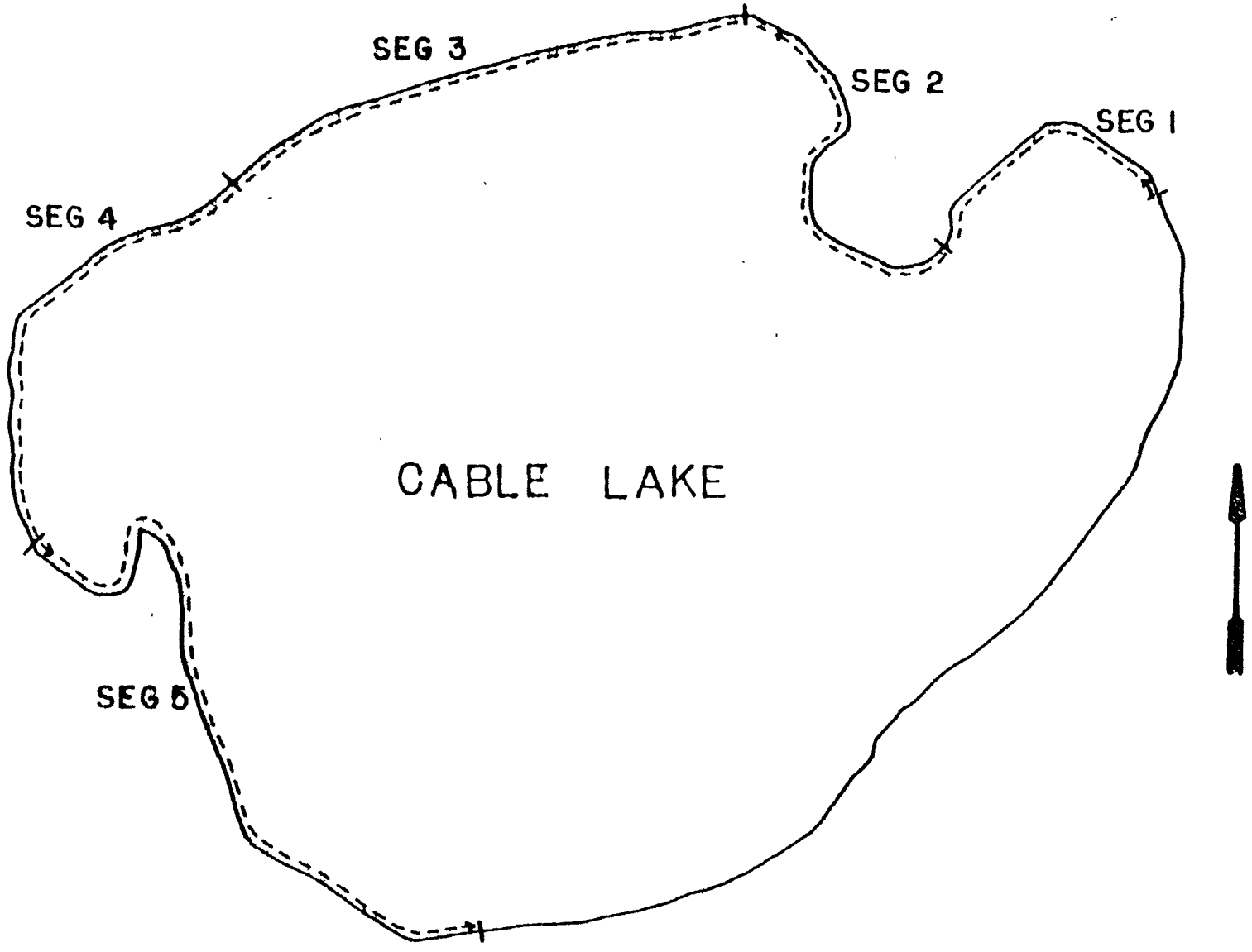
part 4

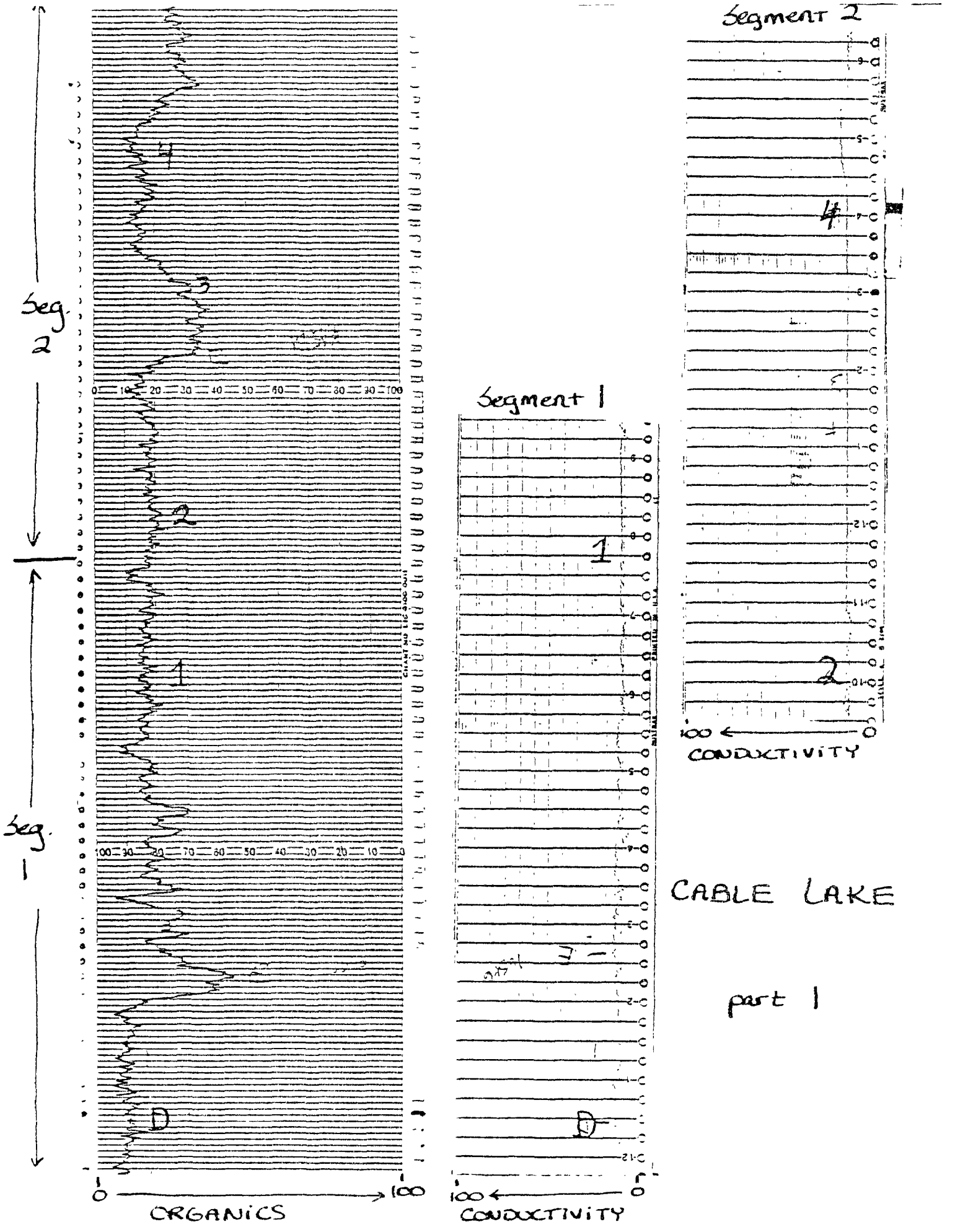




KEELER LAKE

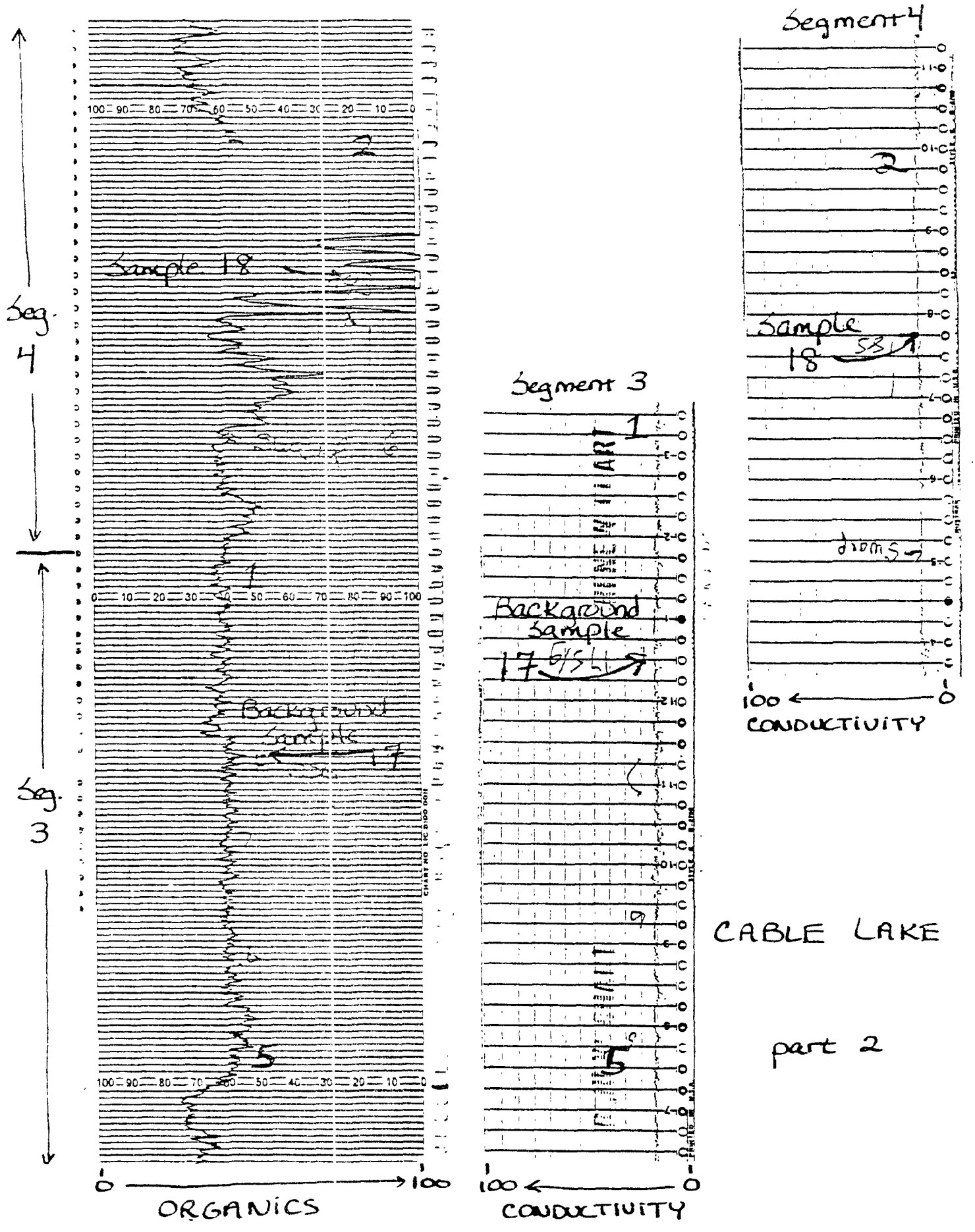
part 5


SEG 3
SEG 2
SEG 1
SEG 4
CABLE LAKE
SEG 5



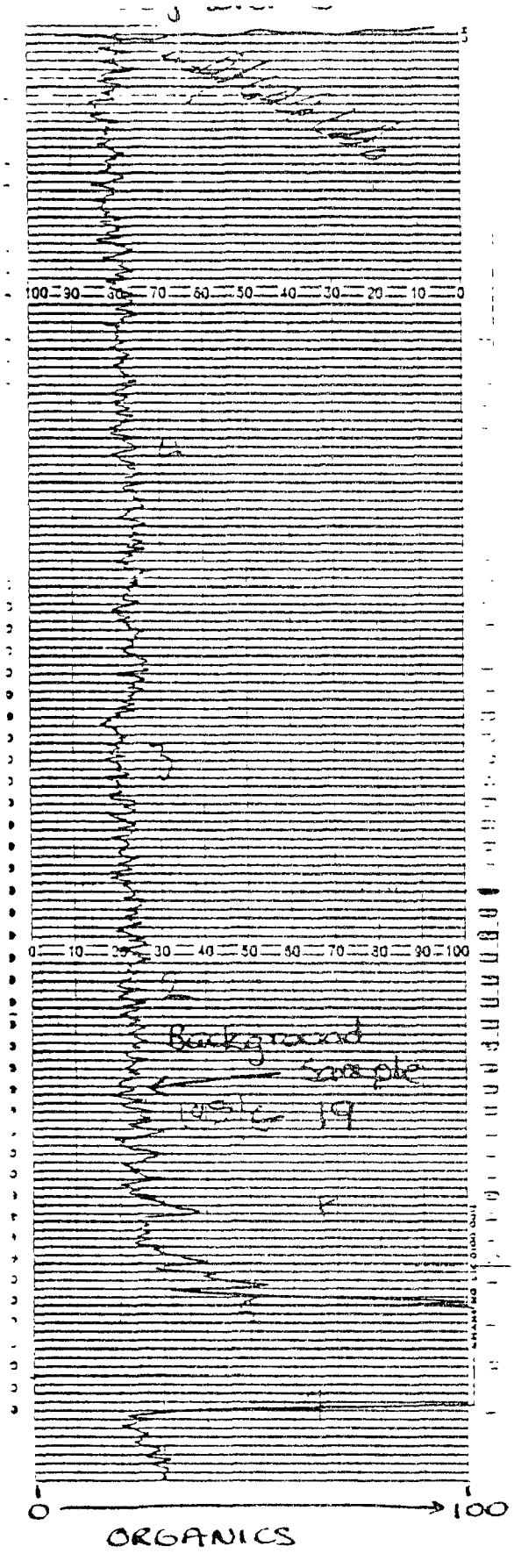
CABLE LAKE

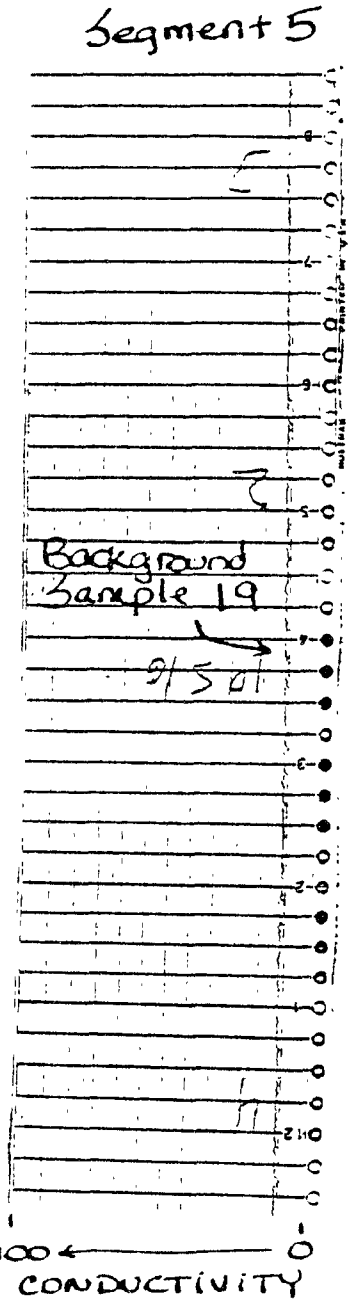
part 1



CABLE LAKE

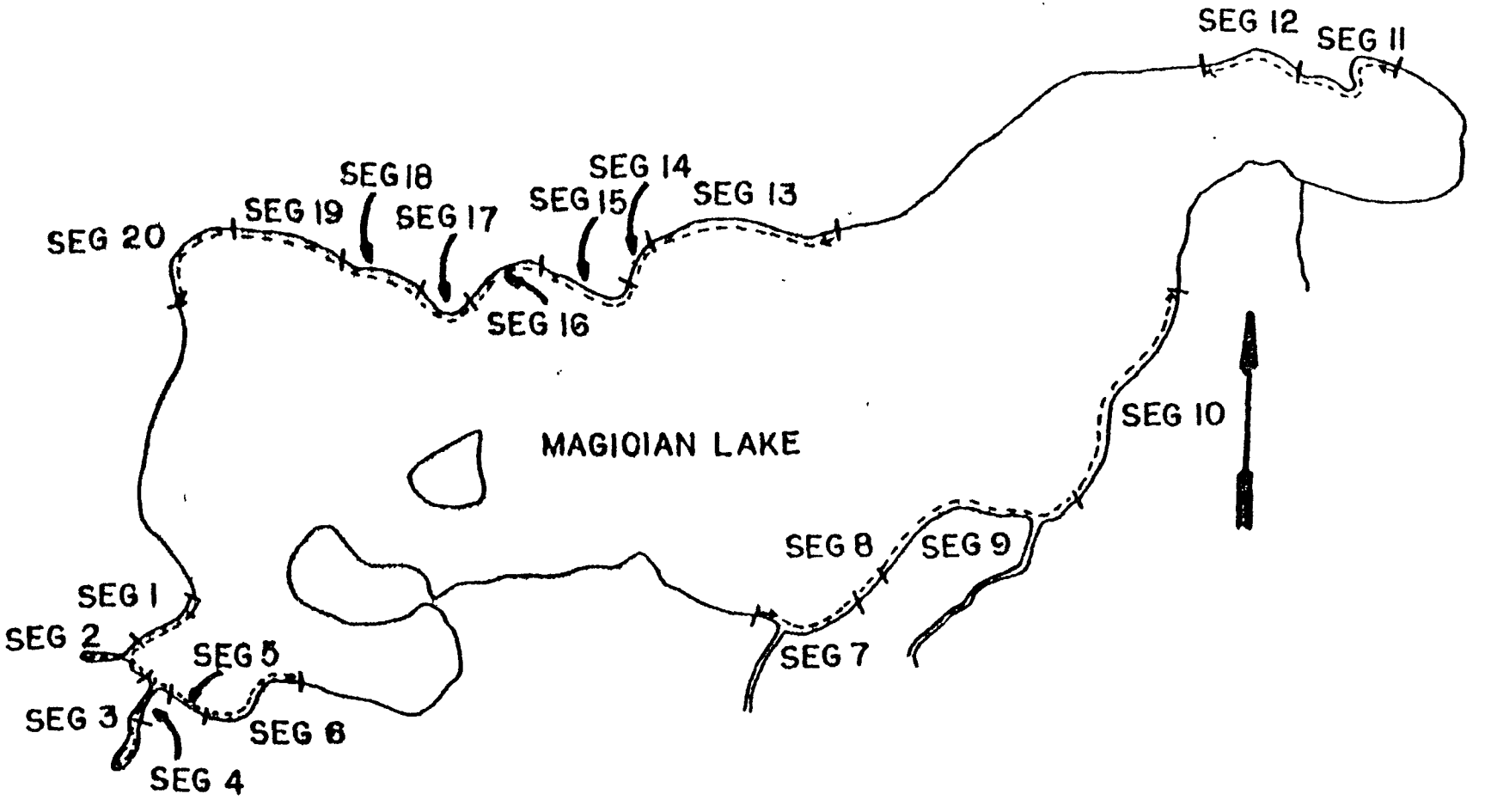
part 2

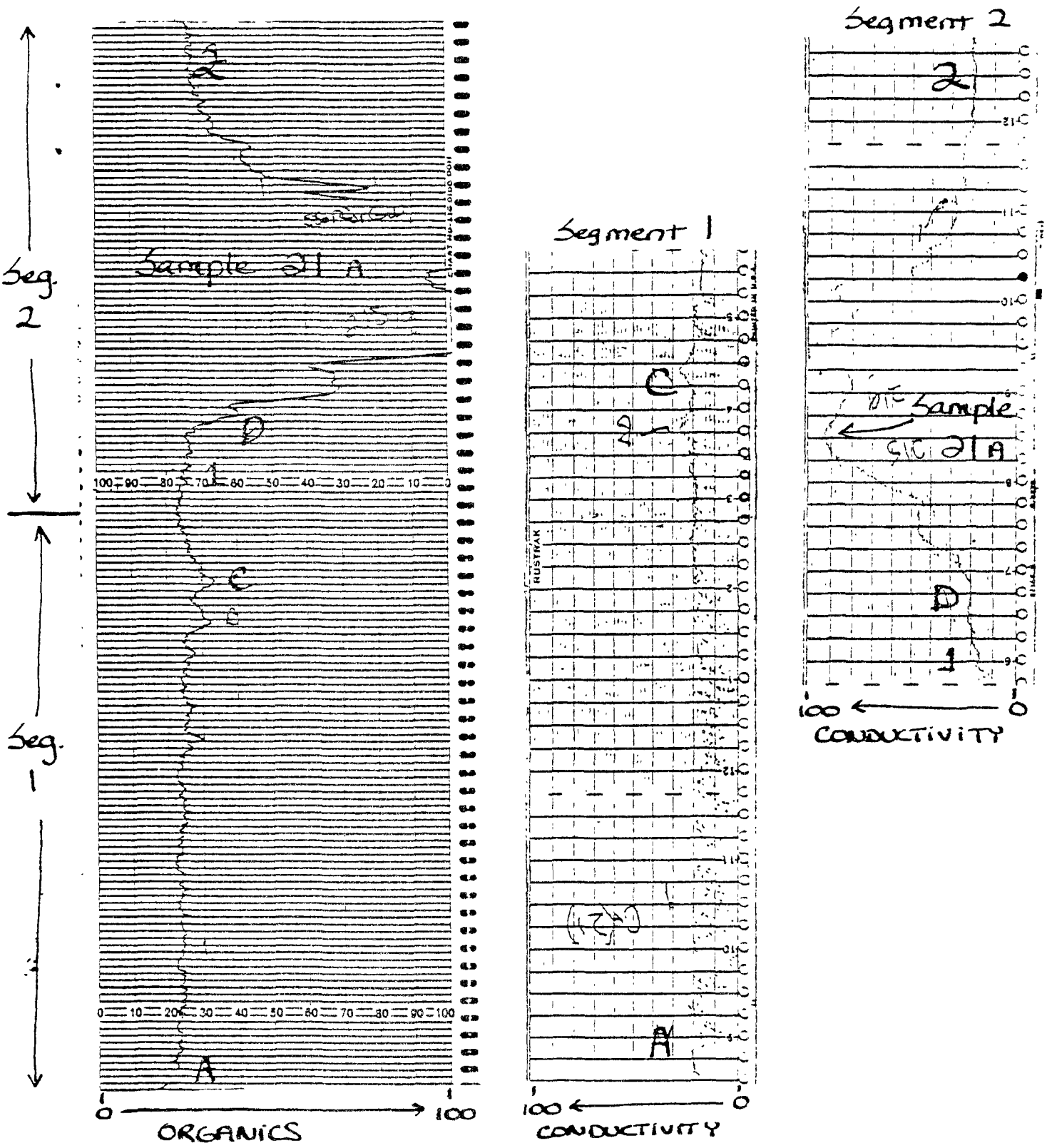




CABLE LAKE

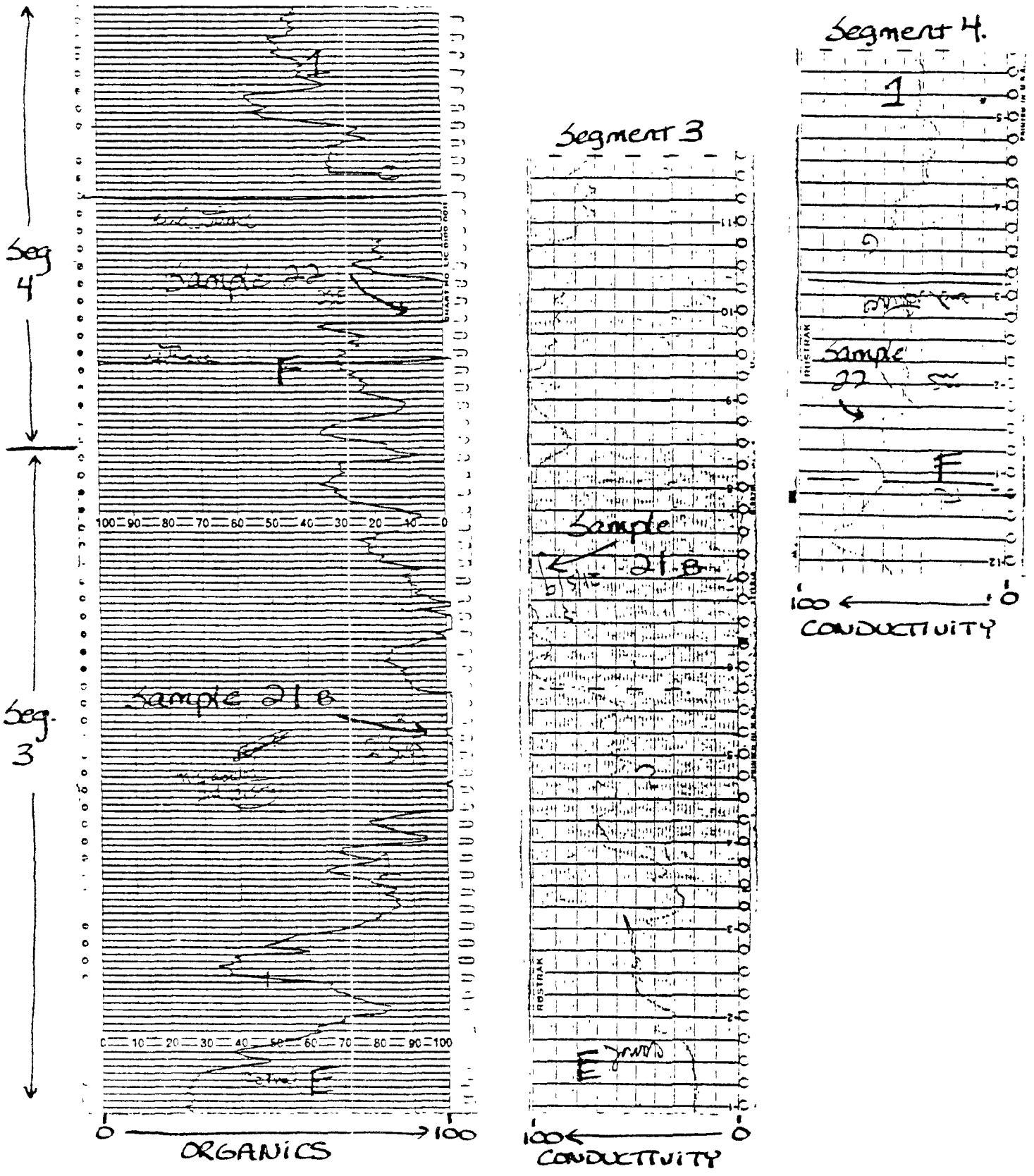
part 3


SEG 12
SEG 11
SEG 18
SEG 14
SEG 19
SEG 17
SEG 15
SEG 13
SEG 20
SEG 16
MAGIOIAN LAKE
SEG 10
SEG 8
SEG 9
SEG 1
SEG 2
SEG 5
SEG 7
SEG 3
SEG 6
SEG 4



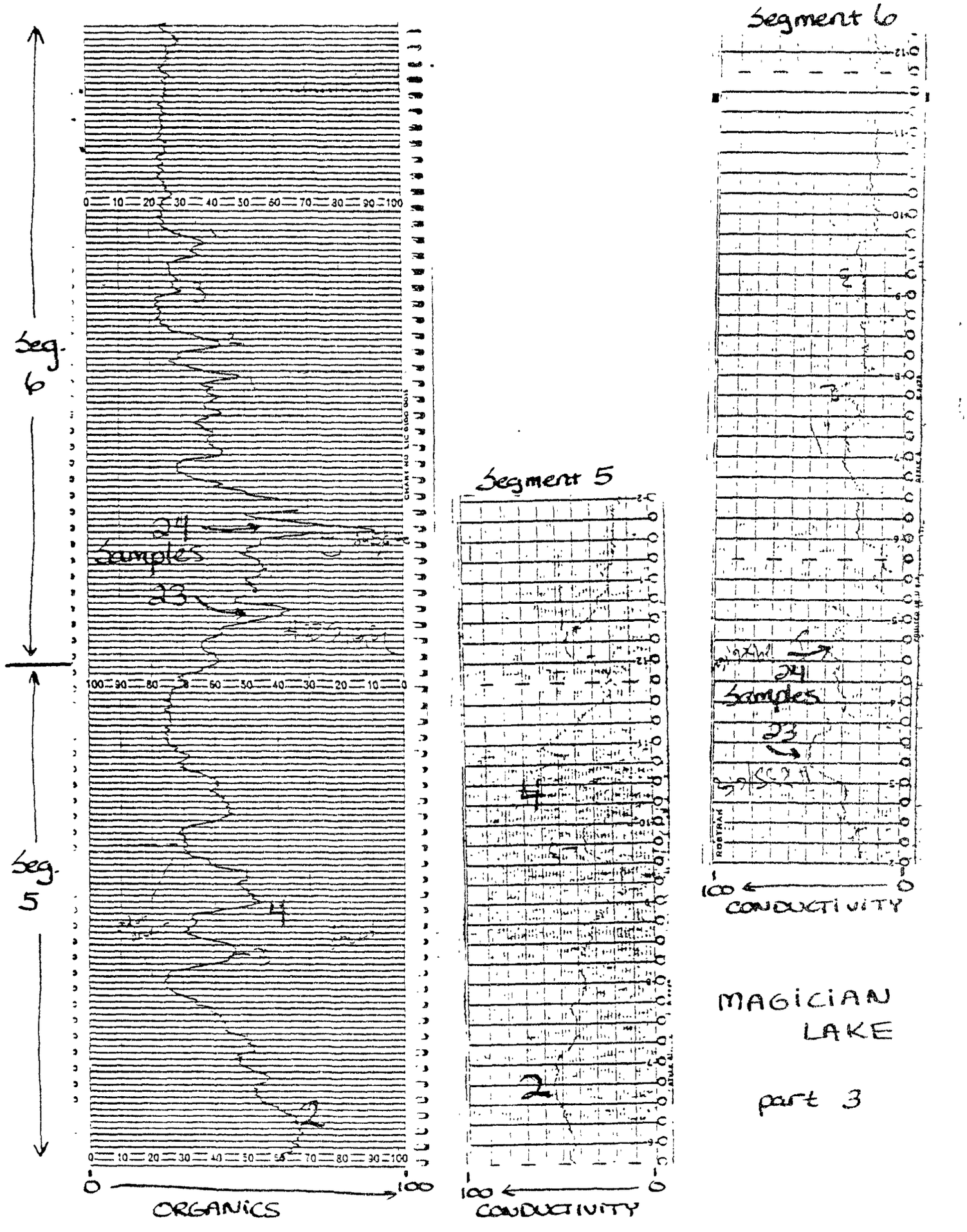
MAGICIAN LAKE

part 1



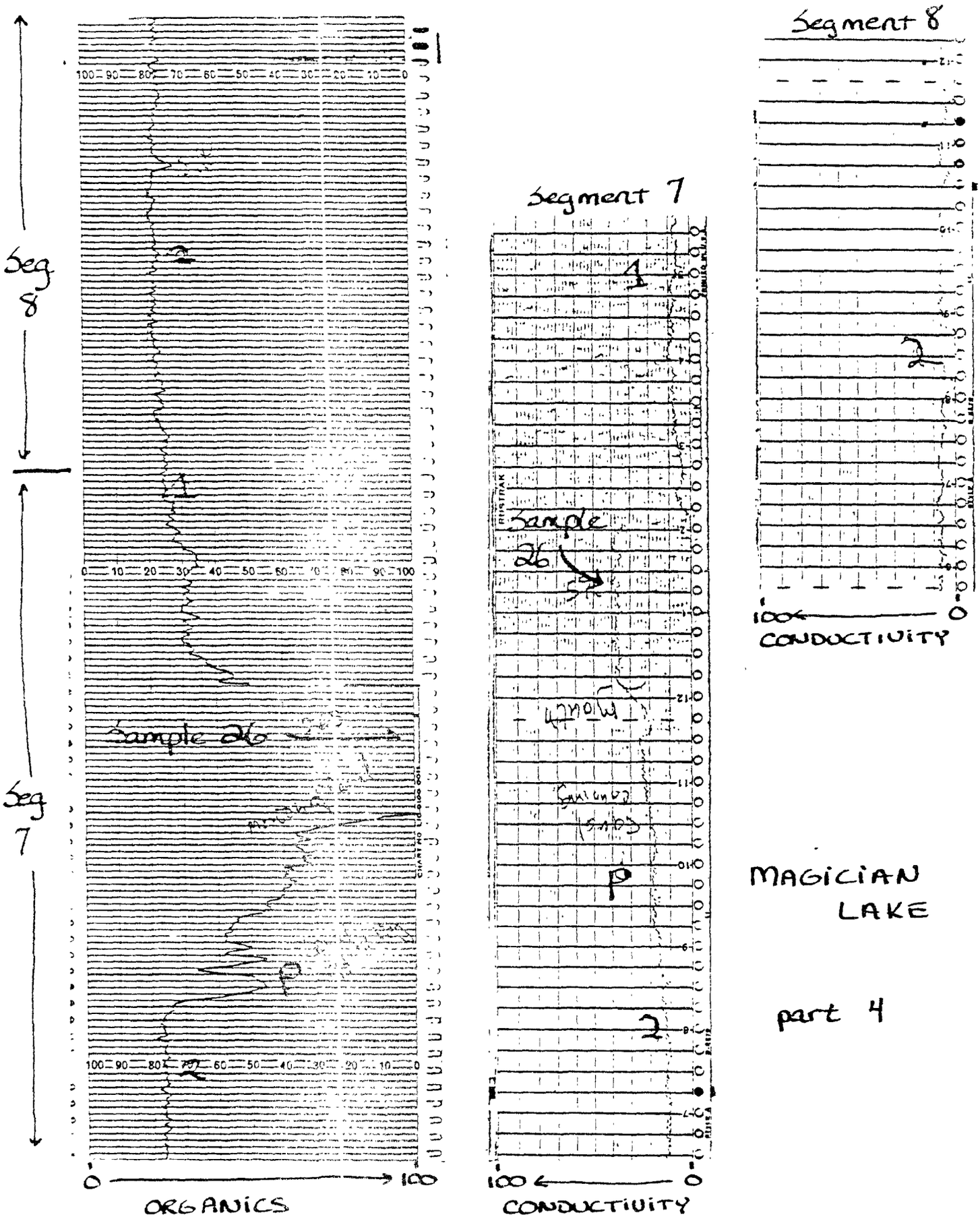
MAGICIAN LAKE

part 2



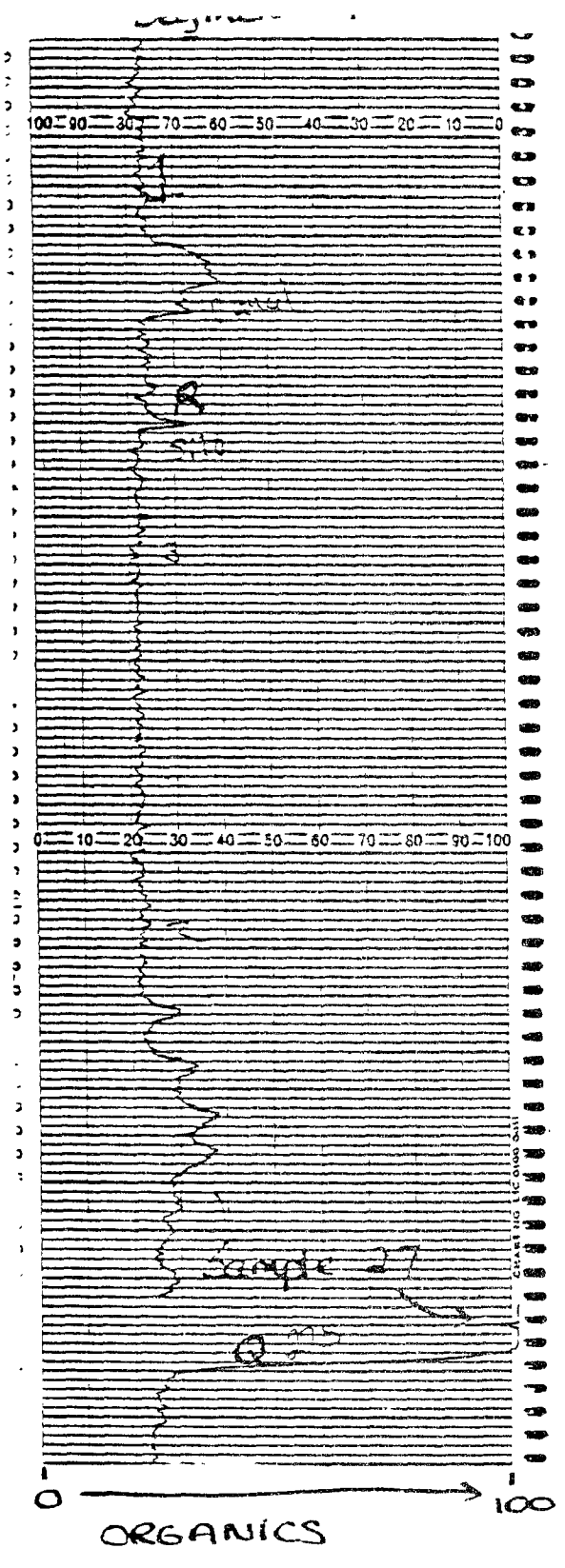
MAGICIAN LAKE

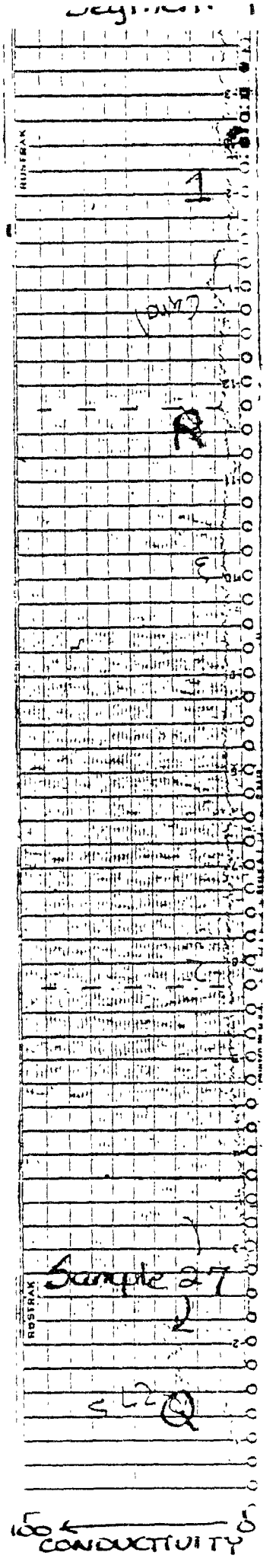
part 3



MAGICIAN LAKE

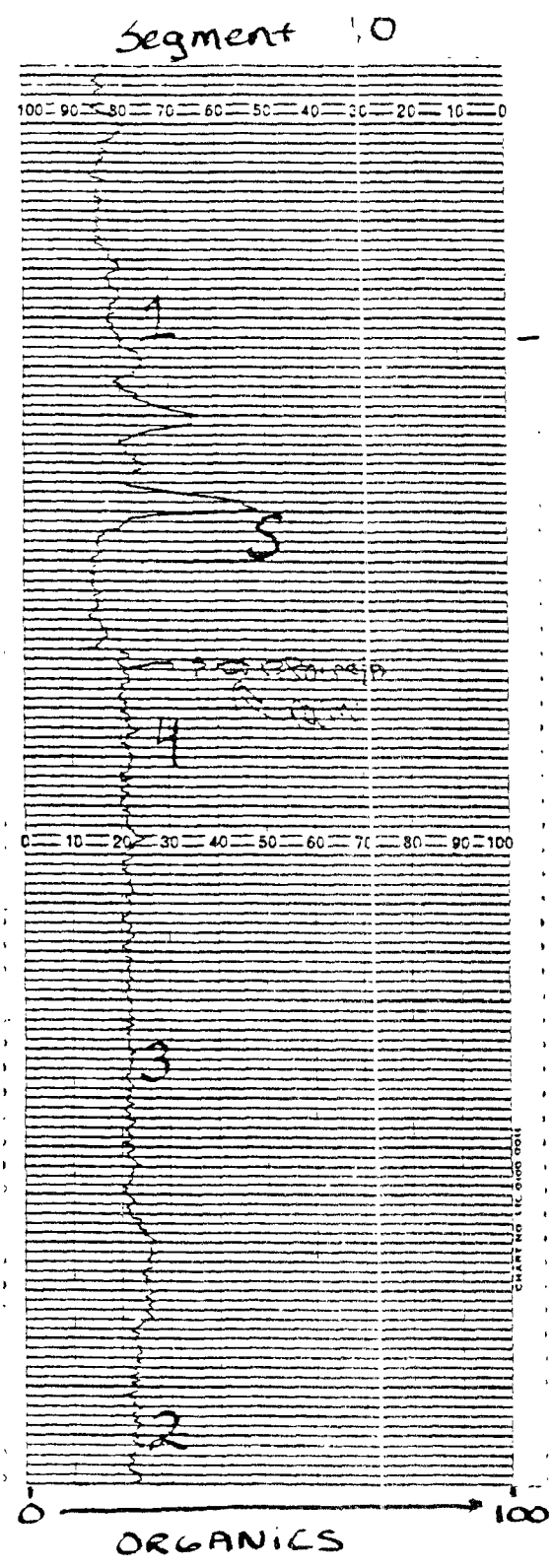
part 4

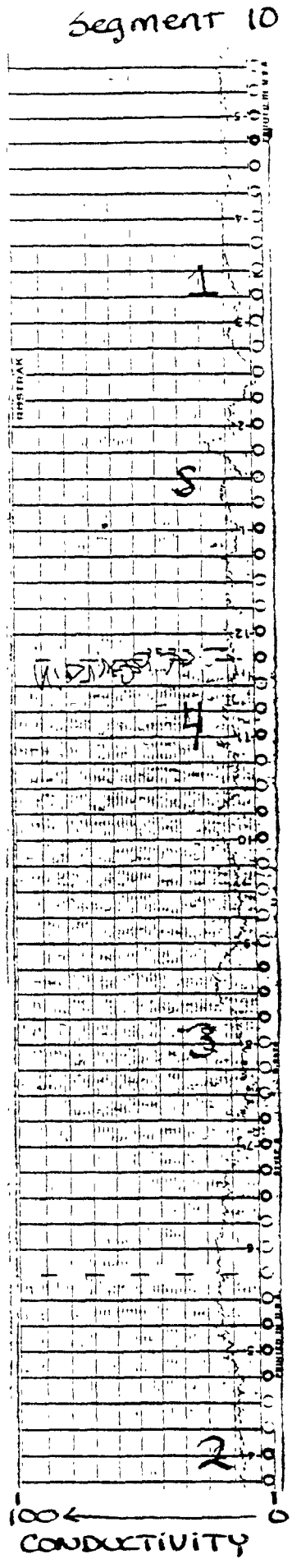




MAGICIAN LAKE

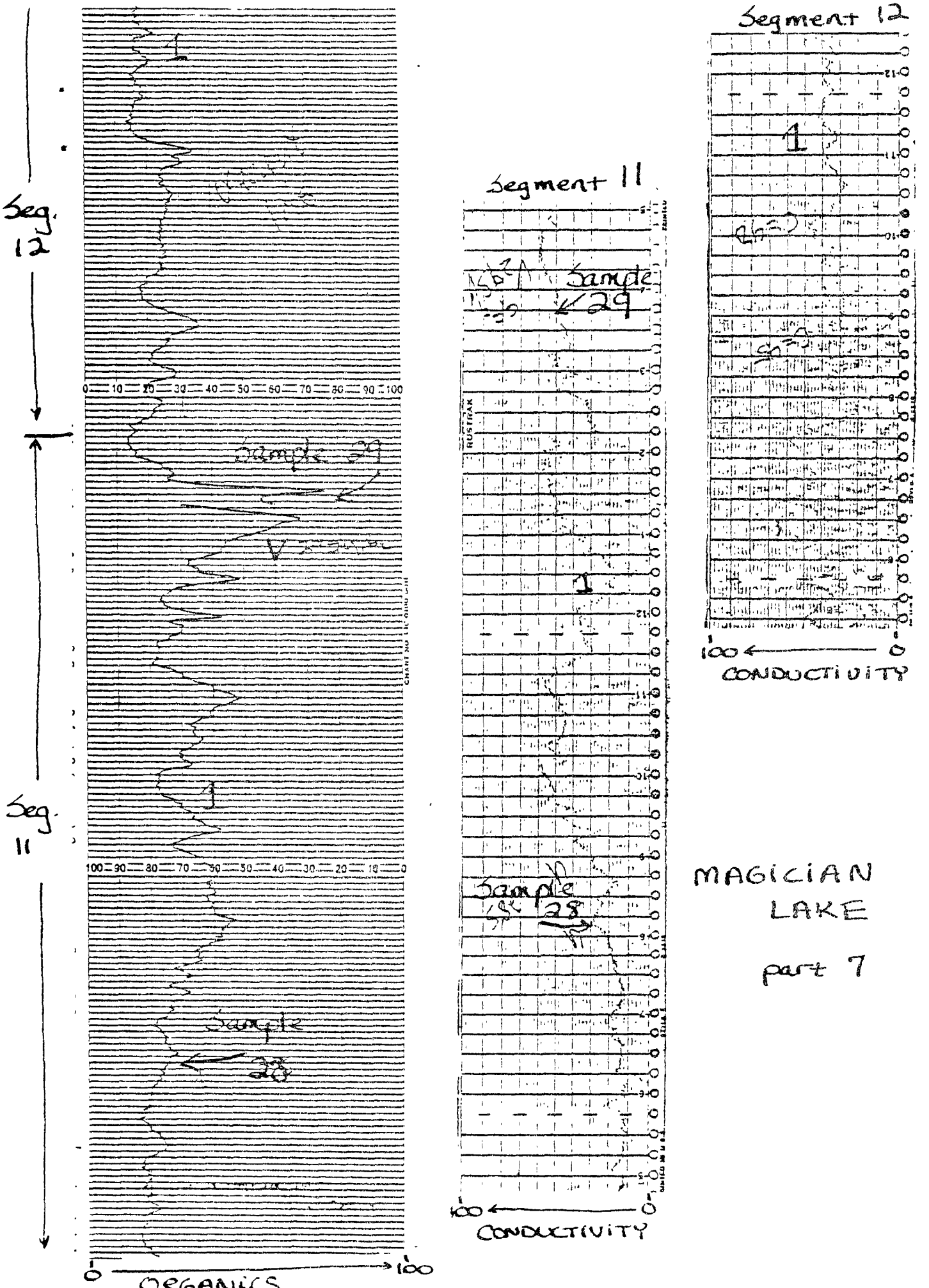
part 5





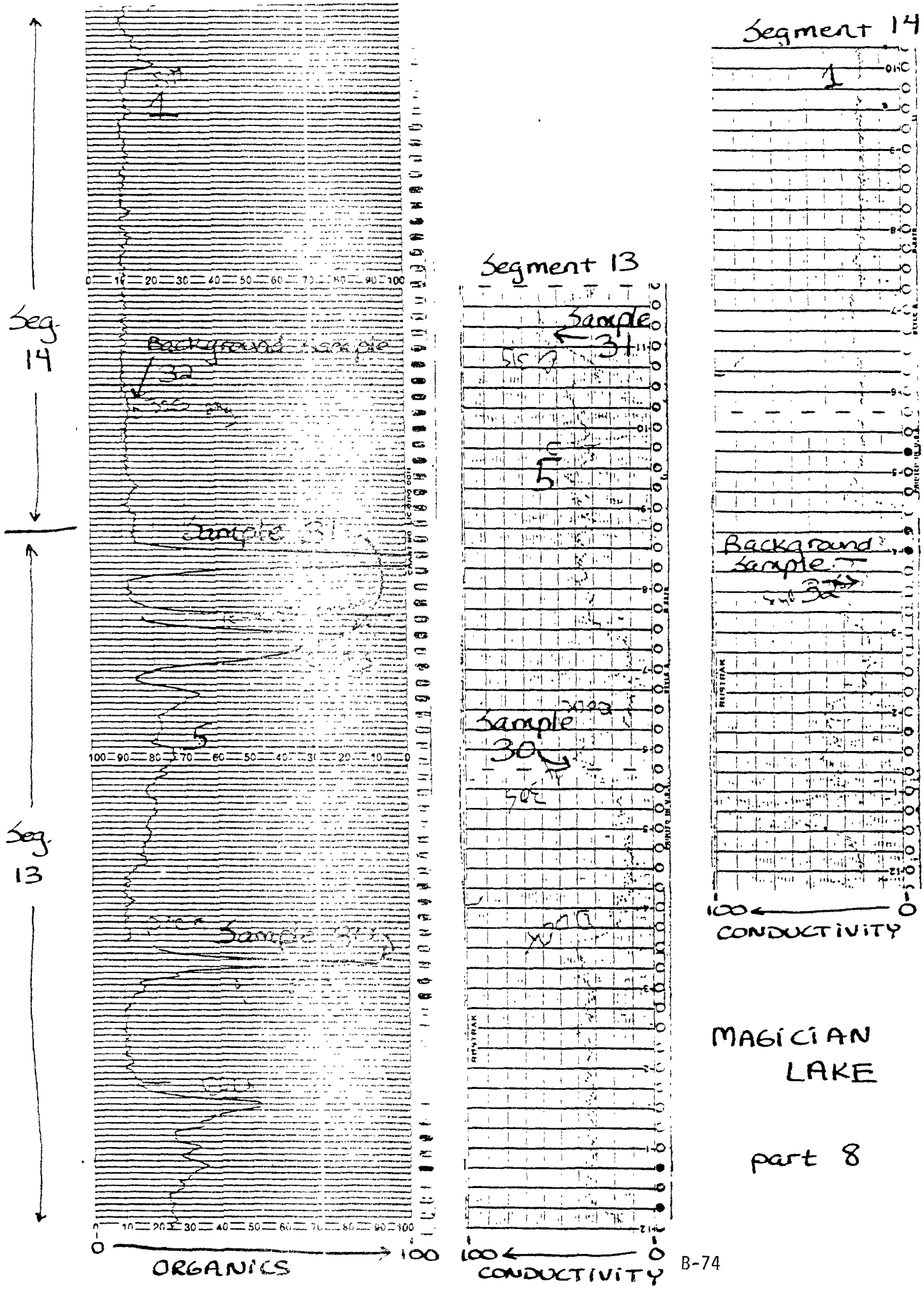
MAGICIAN LAKE

part 6



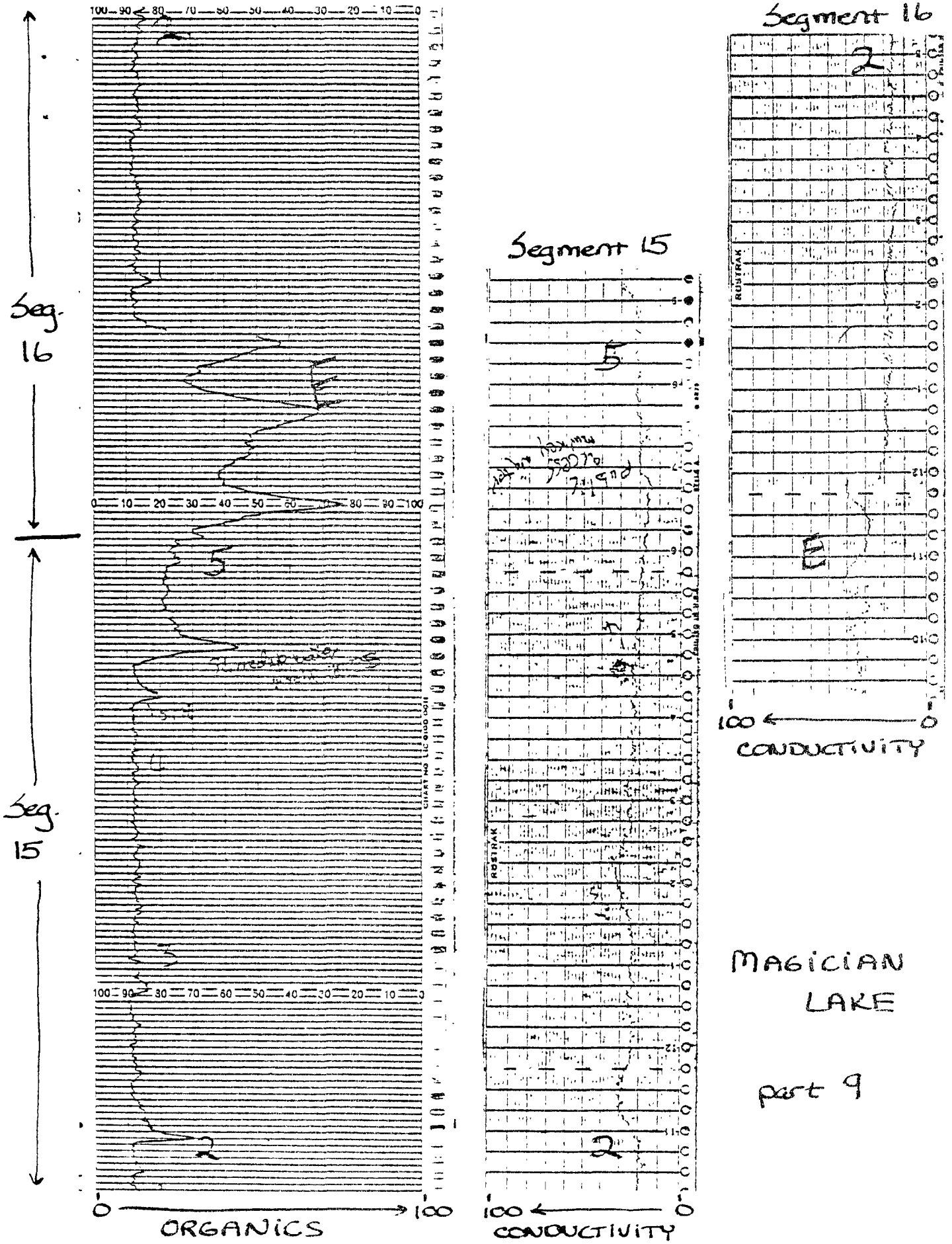
MAGICIAN LAKE

part 7



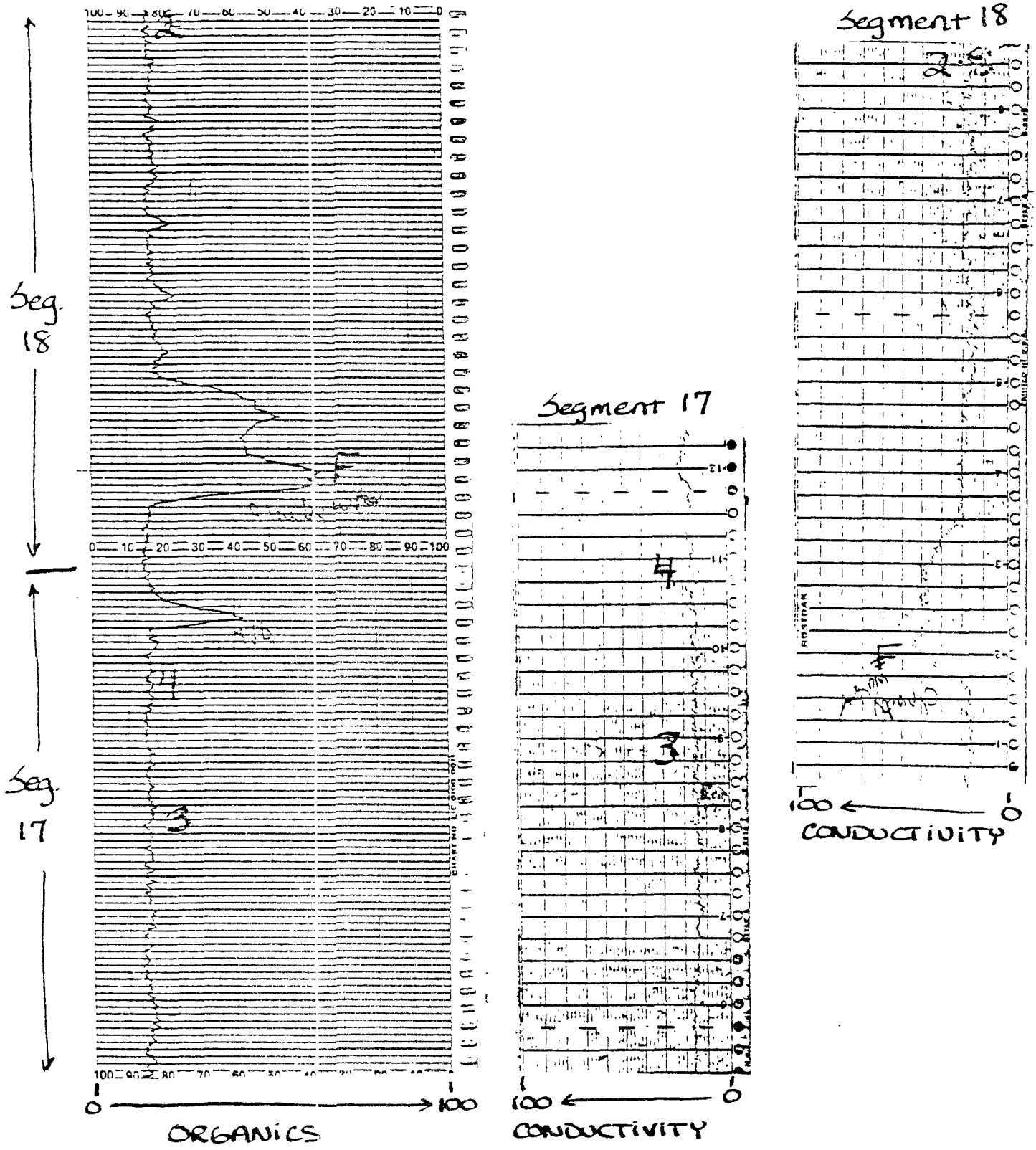
MAGICIAN LAKE

part 8



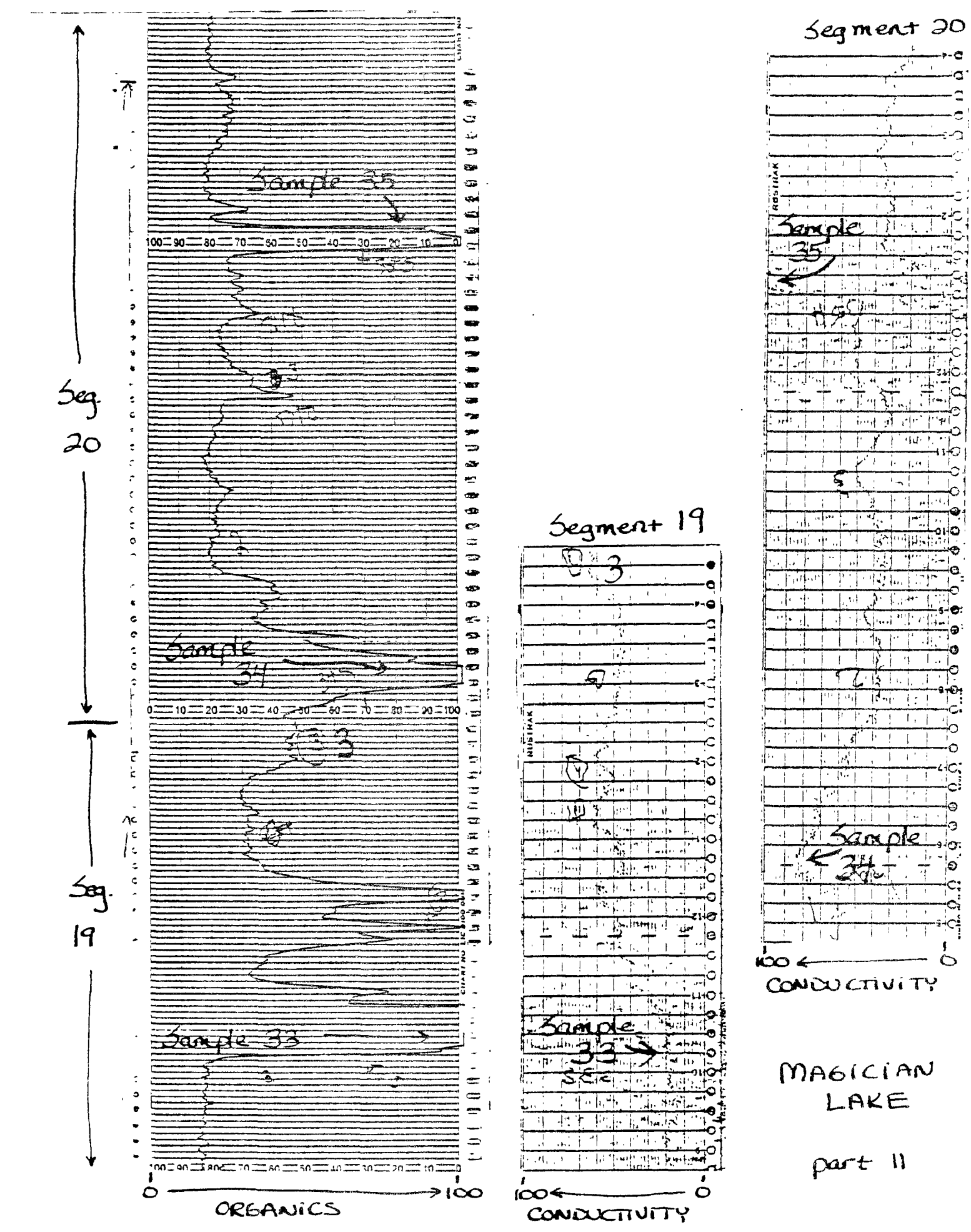
MAGICIAN LAKE

part 9



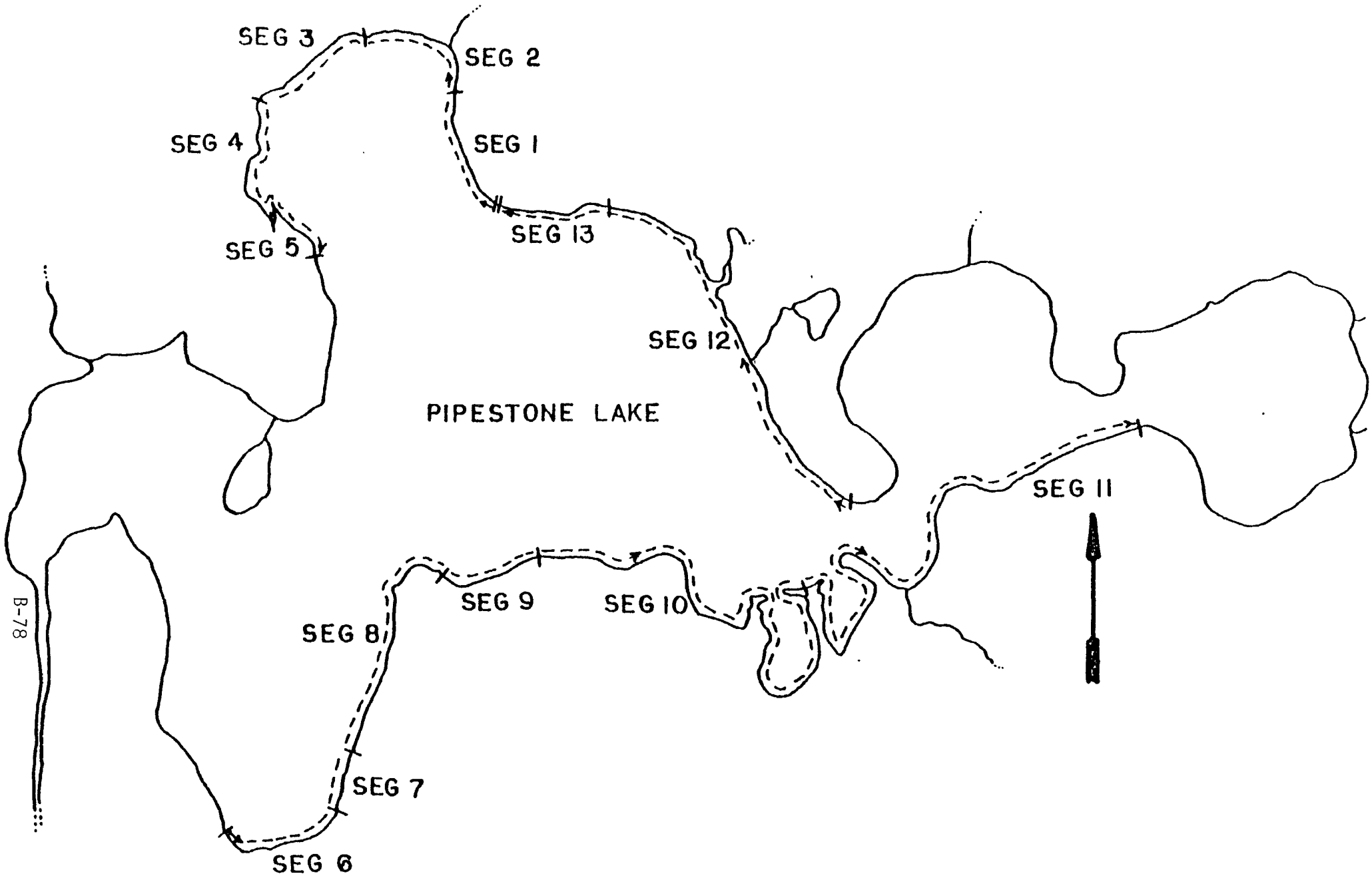
MAGICIAN LAKE

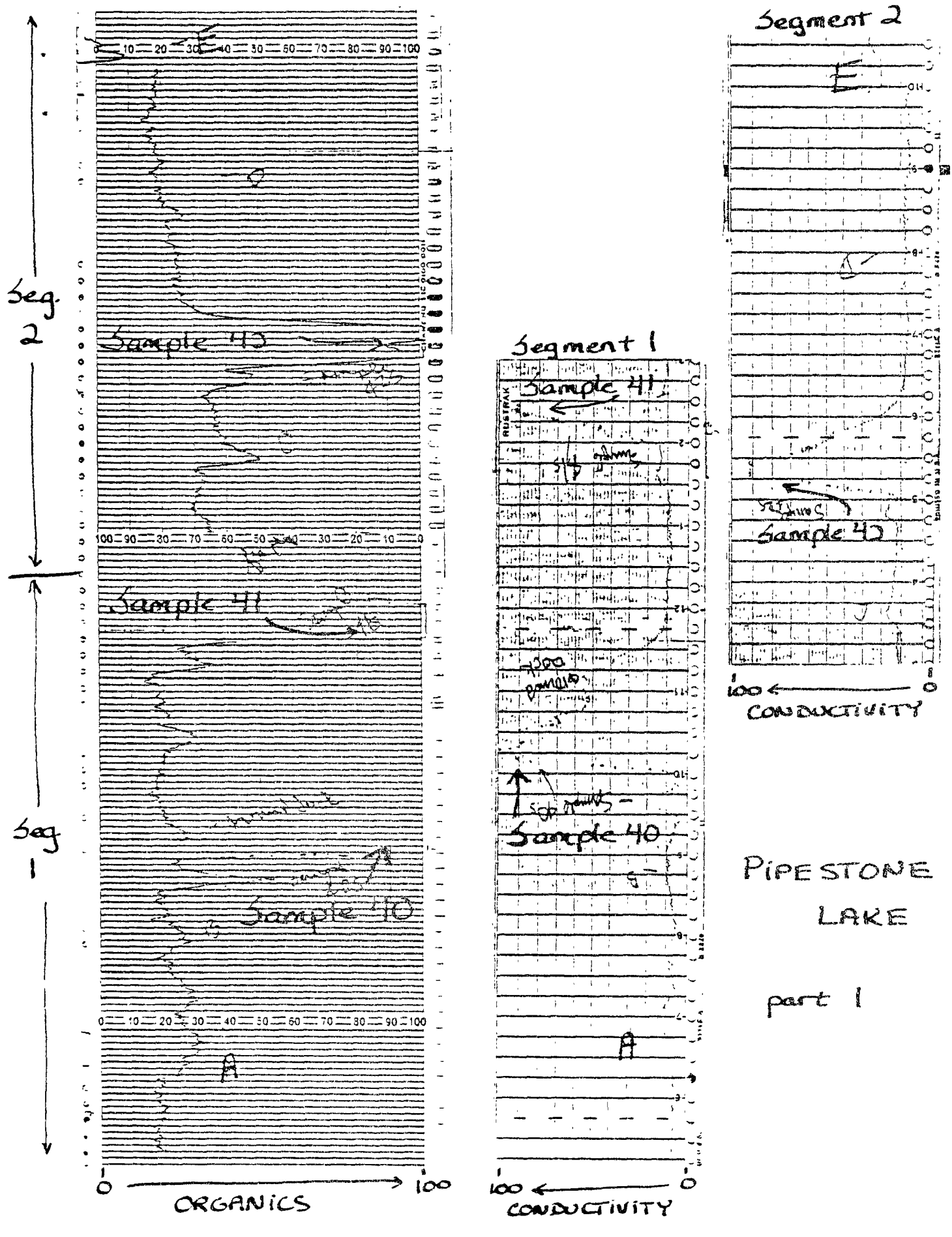
part 10



MAGICIAN LAKE

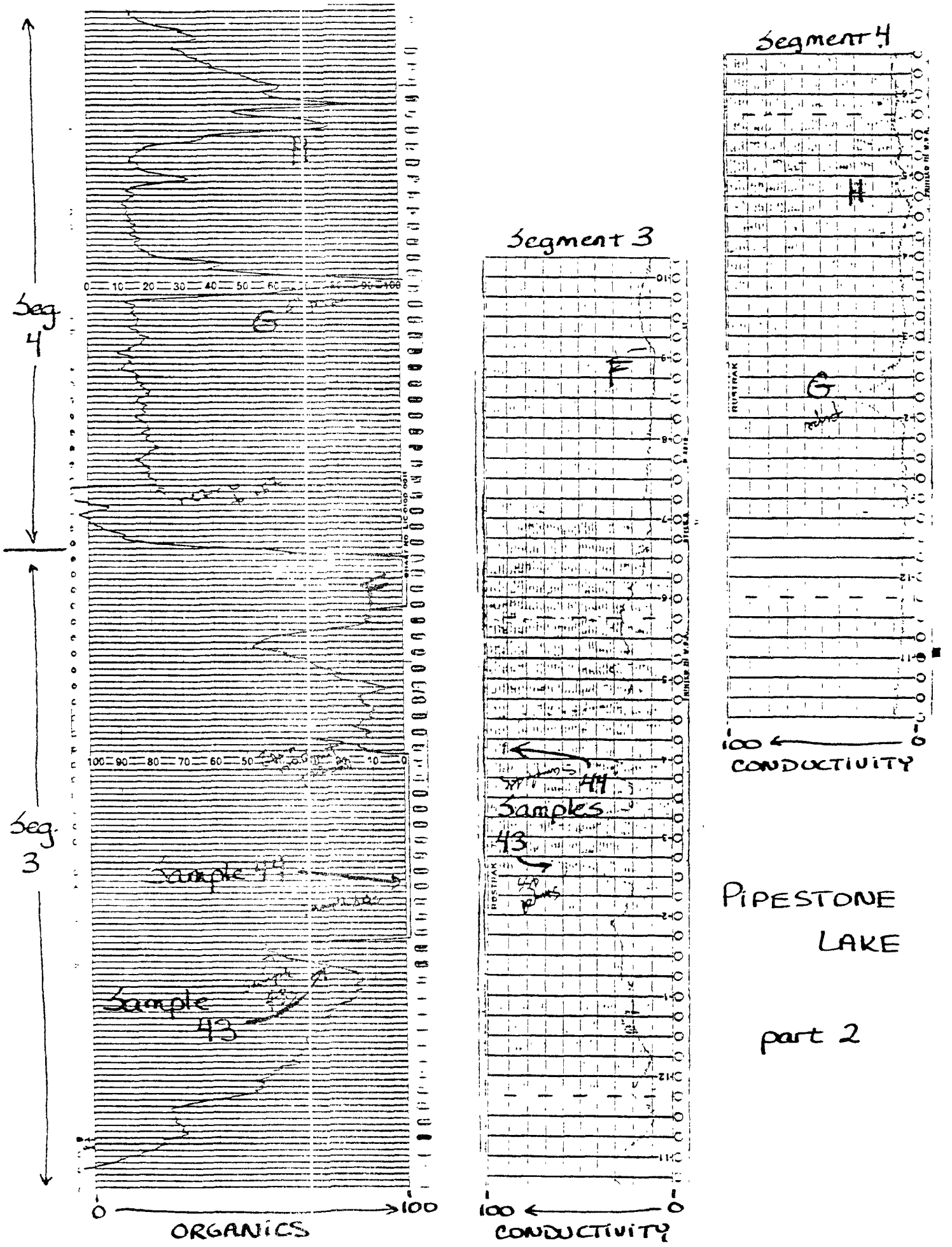
part II


SEG 3
SEG 2
SEG 4
SEG 1
SEG 5
SEG 13
SEG 12
PIPESTONE LAKE
SEG 11
SEG 9
SEG 10
SEG 8
SEG 7
SEG 6
B-78

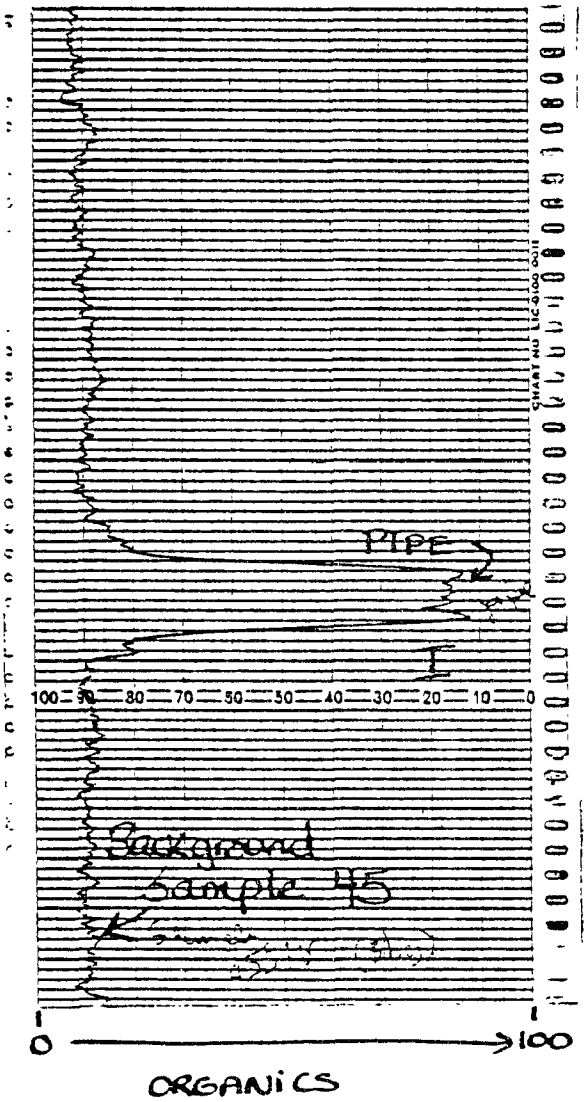


PIPESTONE LAKE

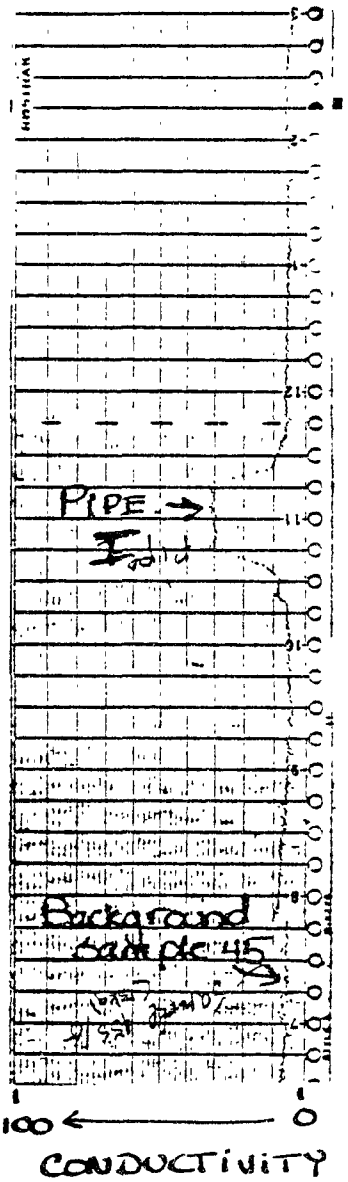
part 1


Seg 4
Seg 3
Segment 3
Segment 4
Sample 44
Sample 43
Samples 44 43
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0
0 → 100
ORGANICS
100 ← 0
CONDUCTIVITY
100 ← 0
CONDUCTIVITY
PIPESTONE LAKE
part 2

Segment 5

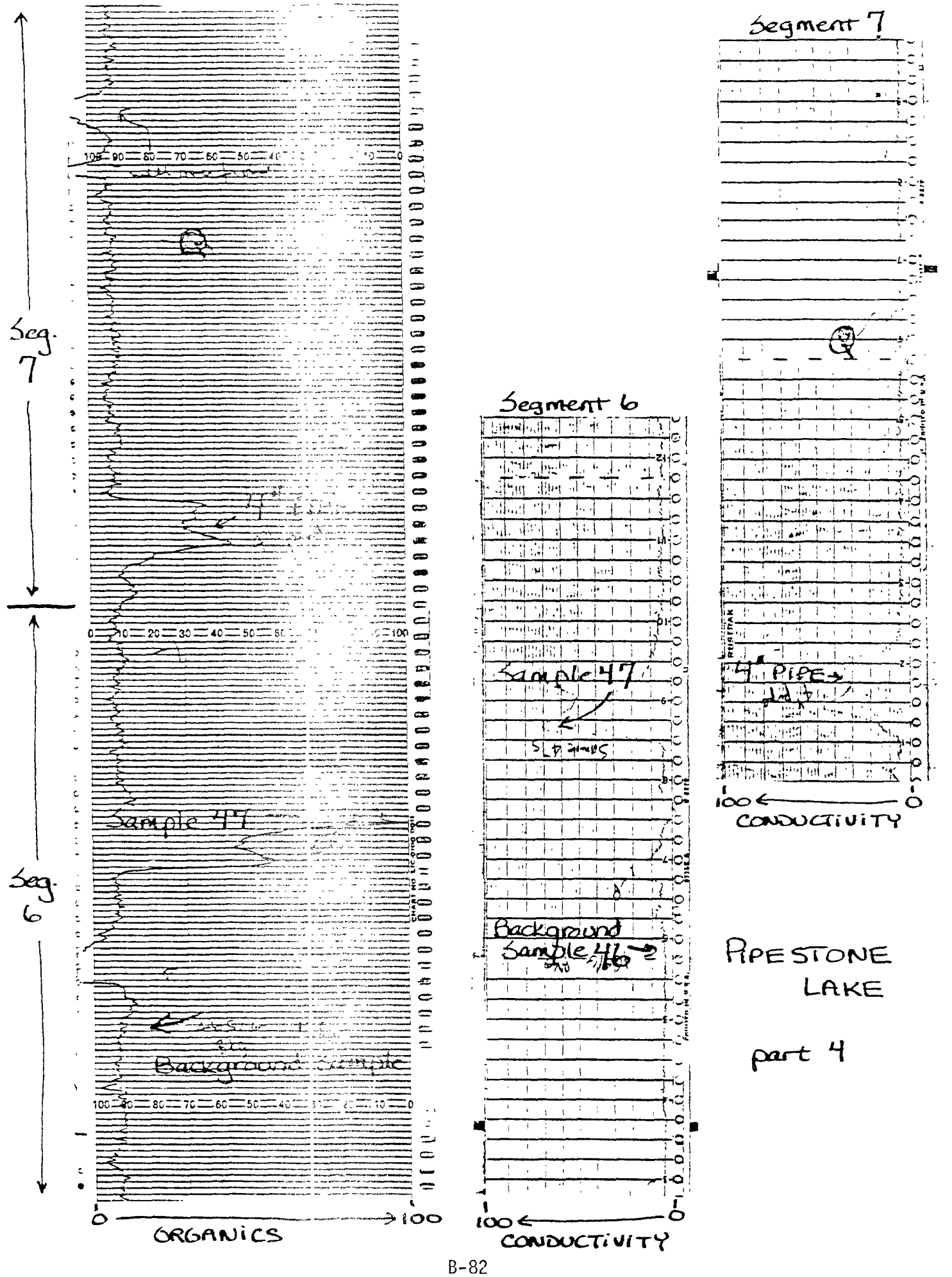


Segment 5



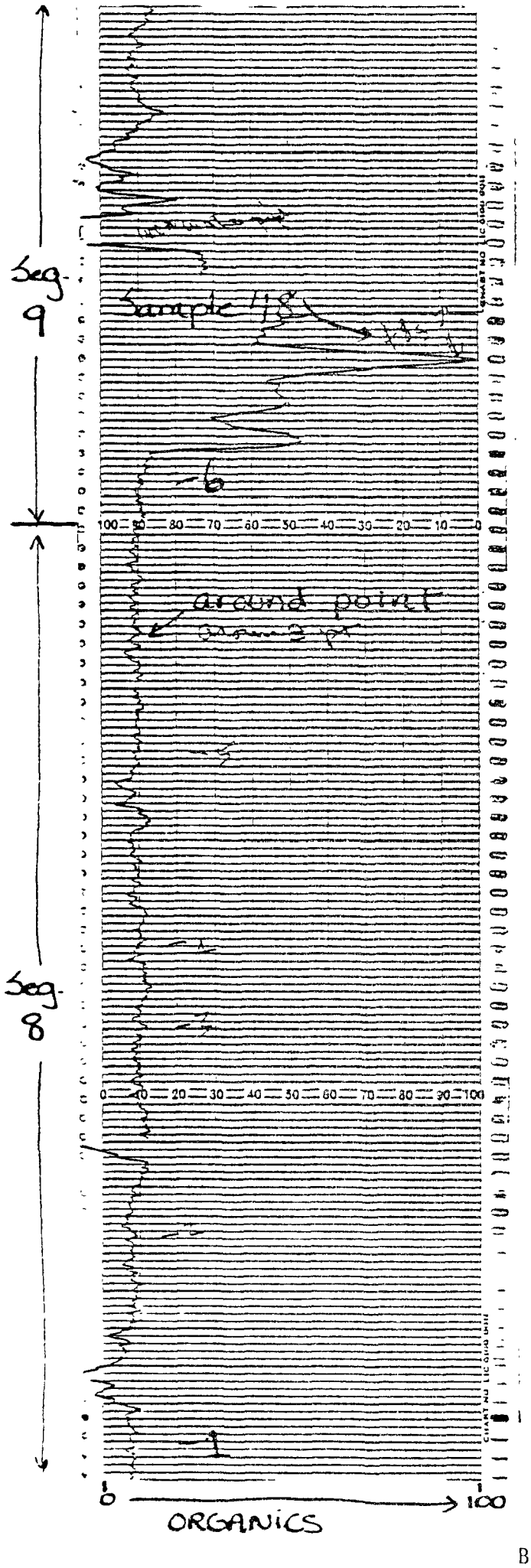
PIPESTONE LAKE

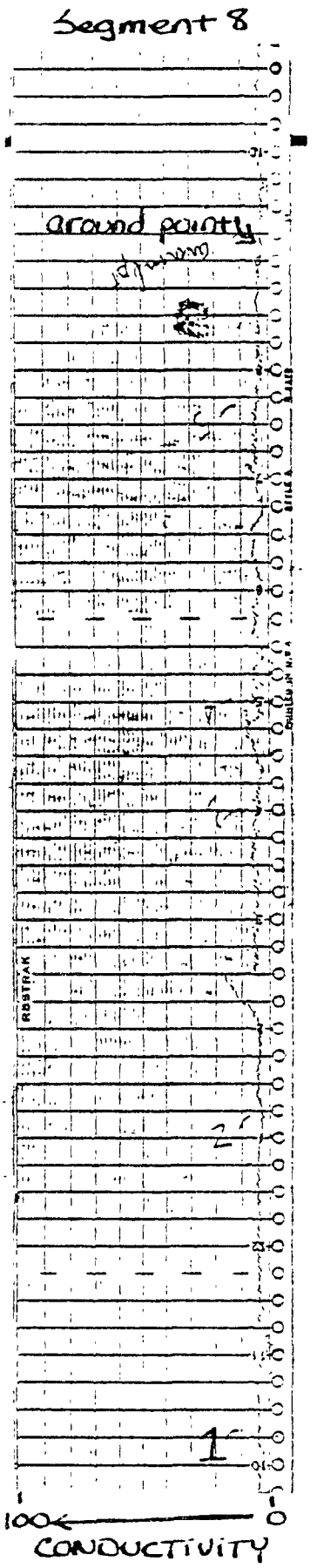
part 3

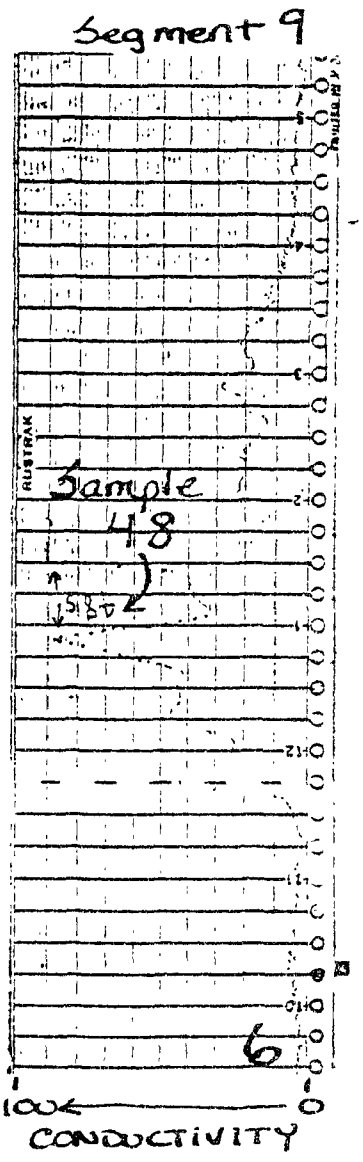


PIPESTONE LAKE

part 4

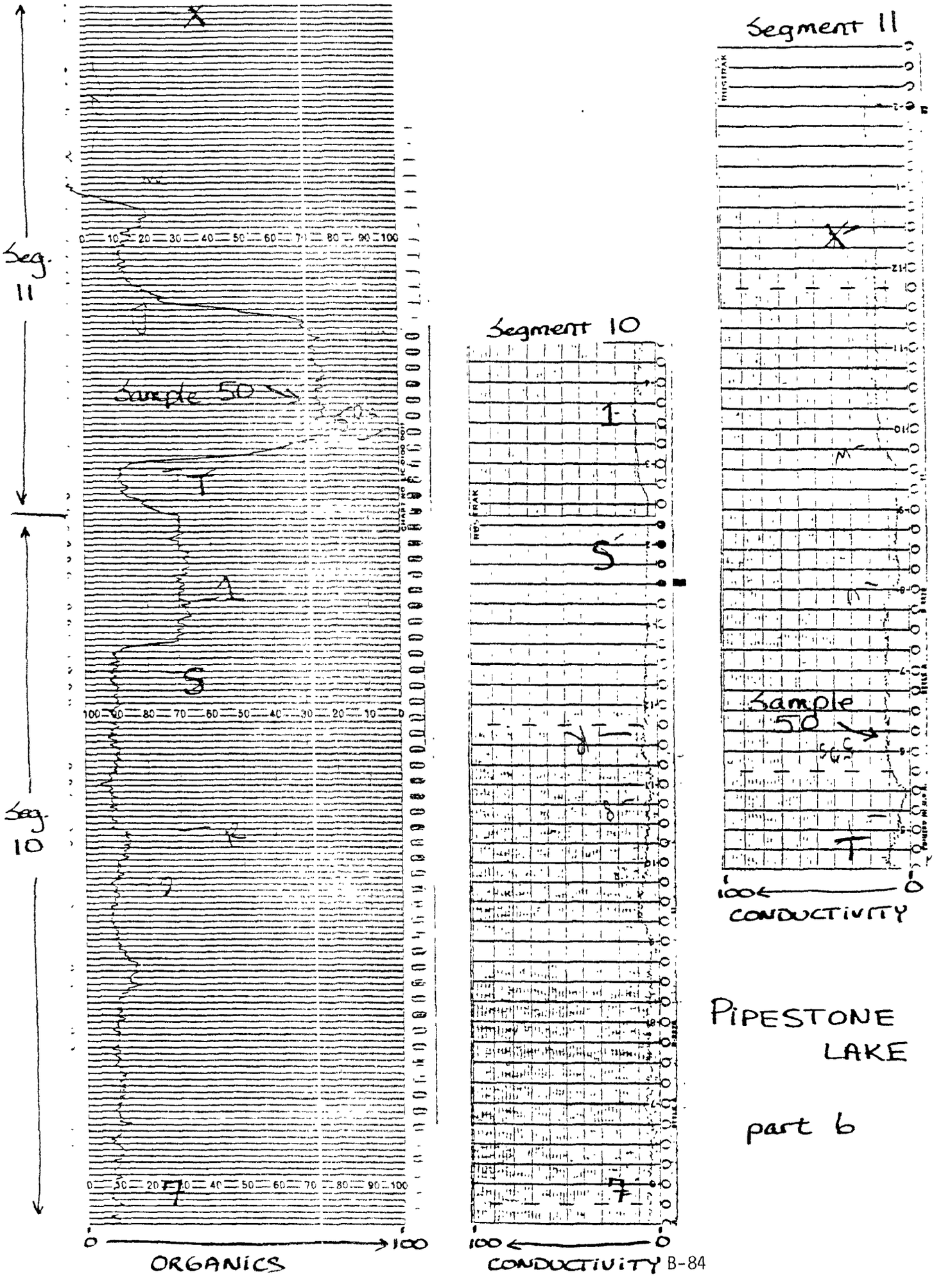






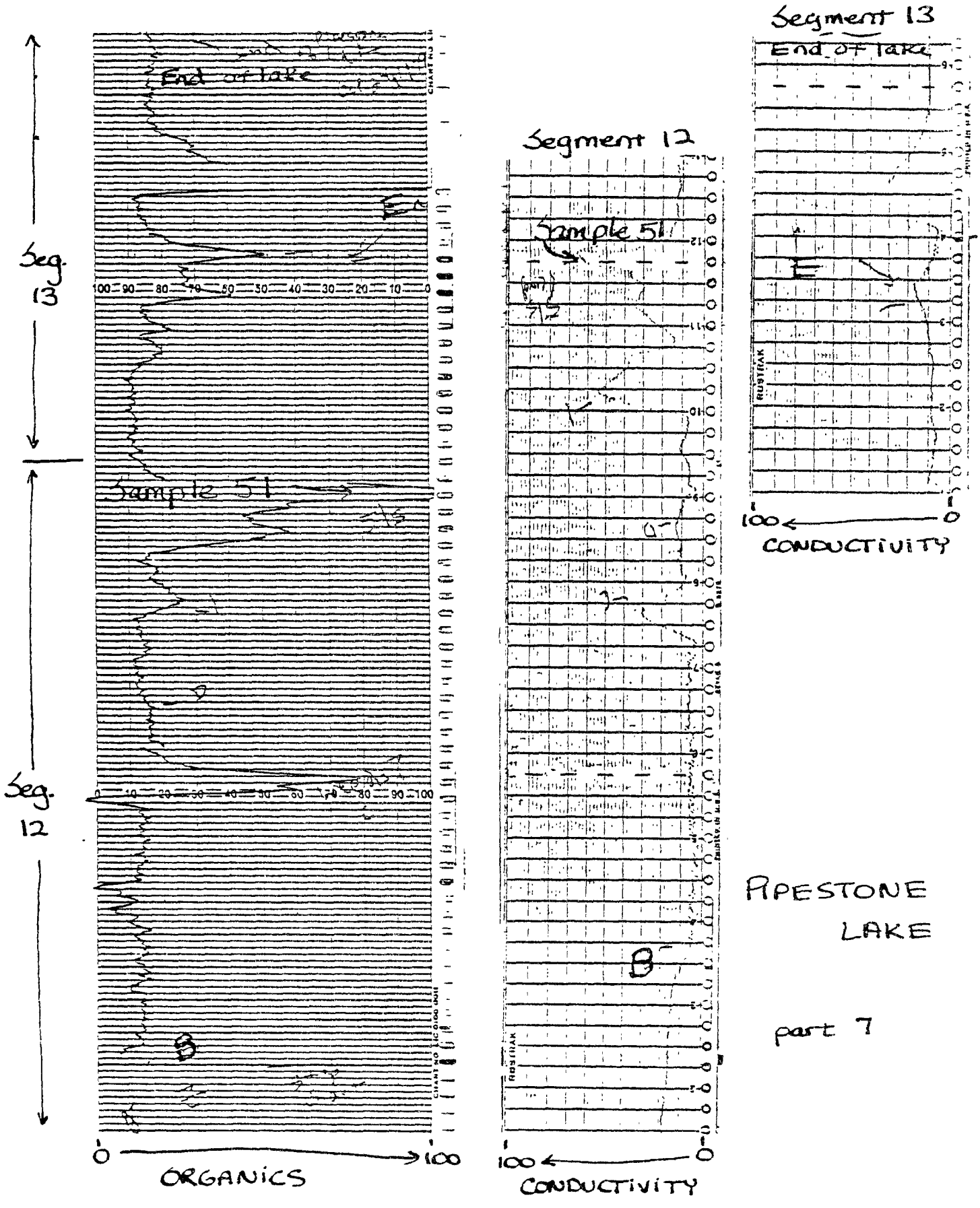
PIPESTONE LAKE

part 5



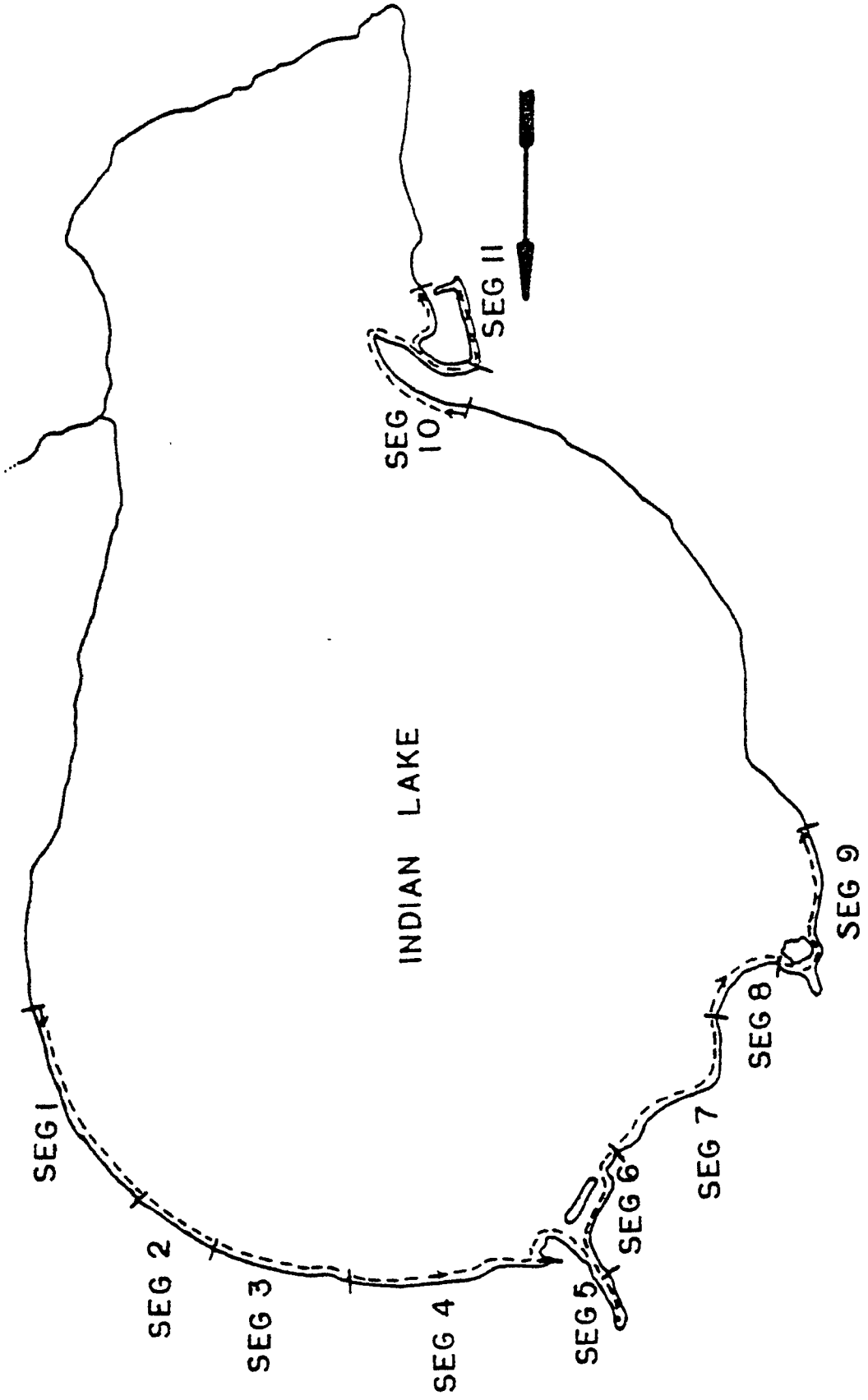
PIPESTONE LAKE

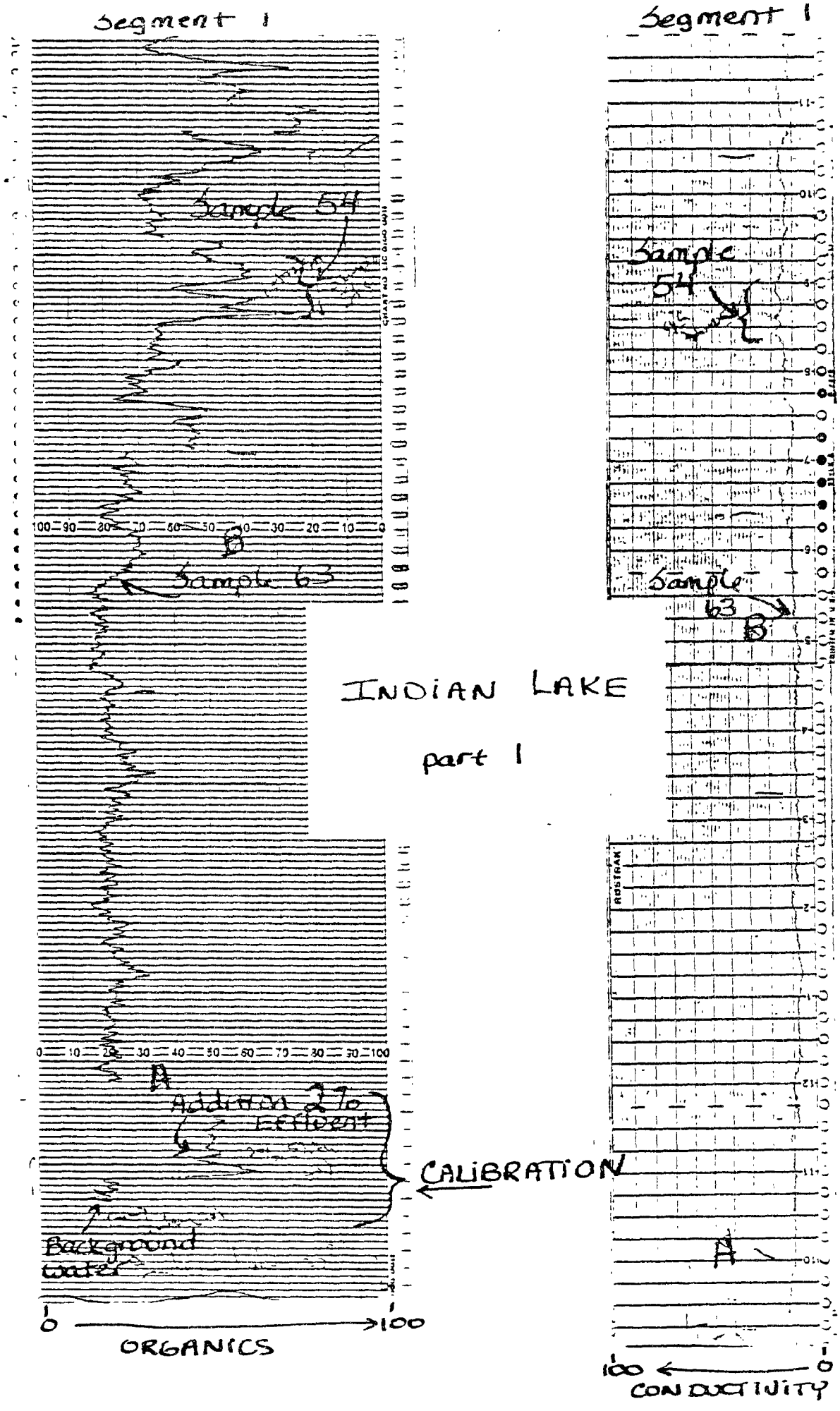
part 6



APESTONE LAKE

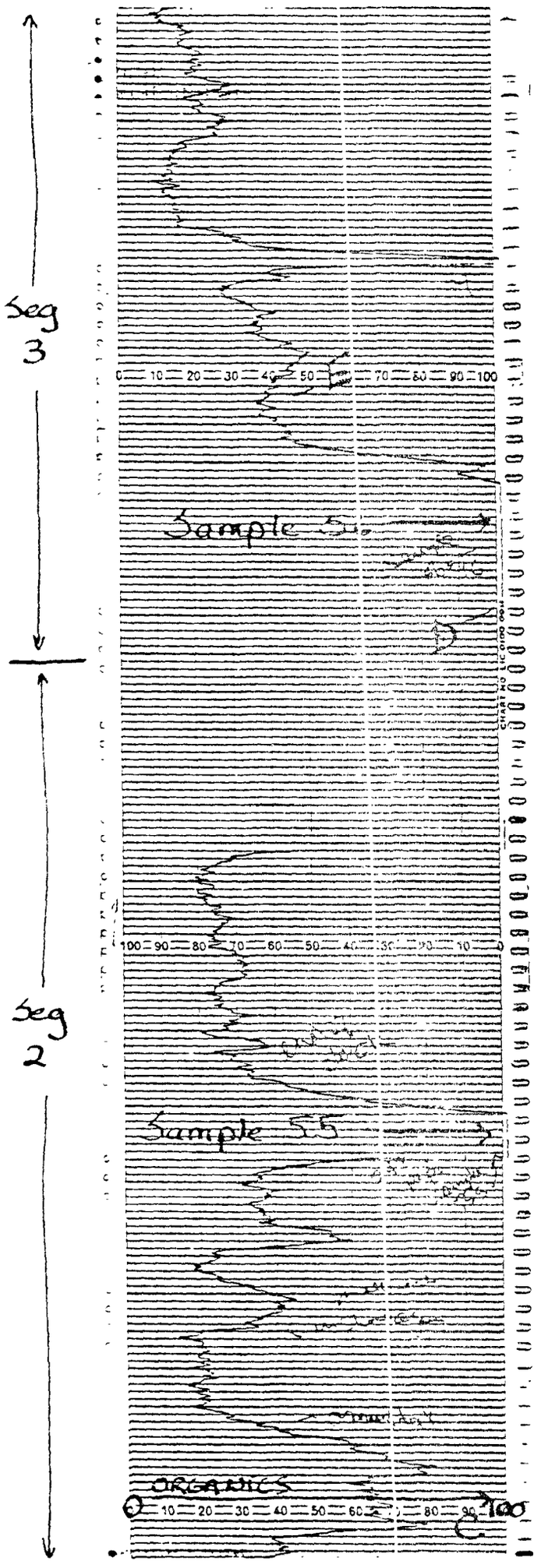
part 7

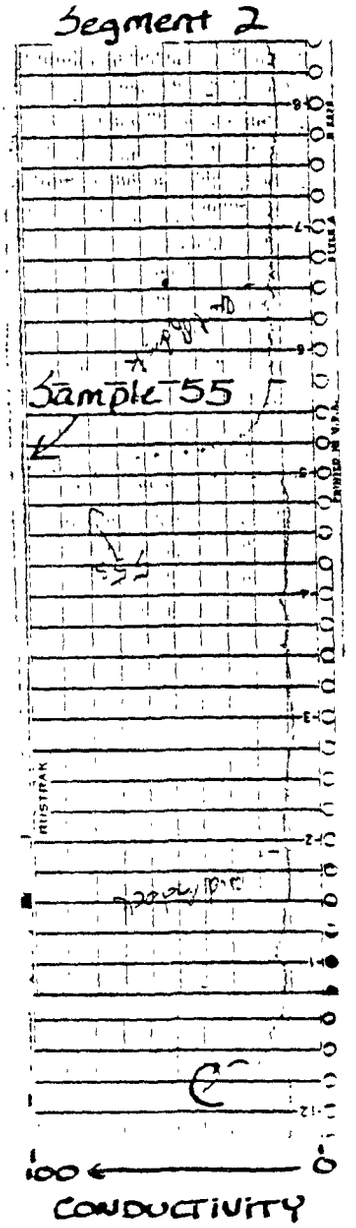

INDIAN LAKE
SEG 1
SEG 2
SEG 3
SEG 4
SEG 5
SEG 6
SEG 7
SEG 8
SEG 9
SEG 10
SEG 11

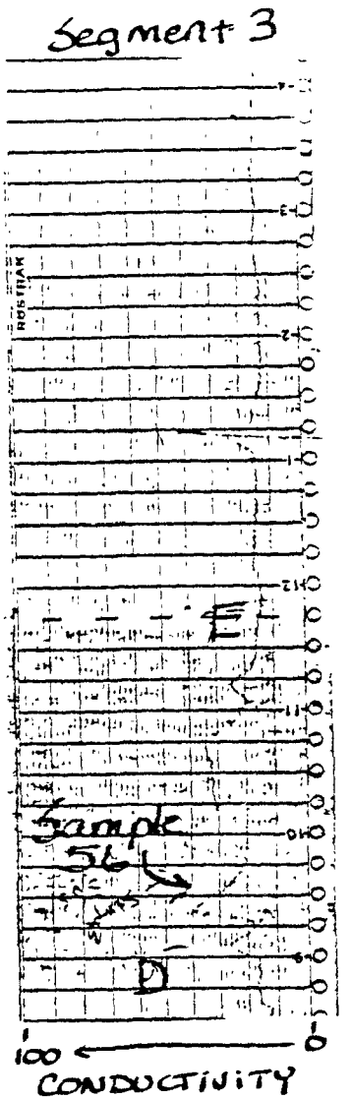


INDIAN LAKE

part 1

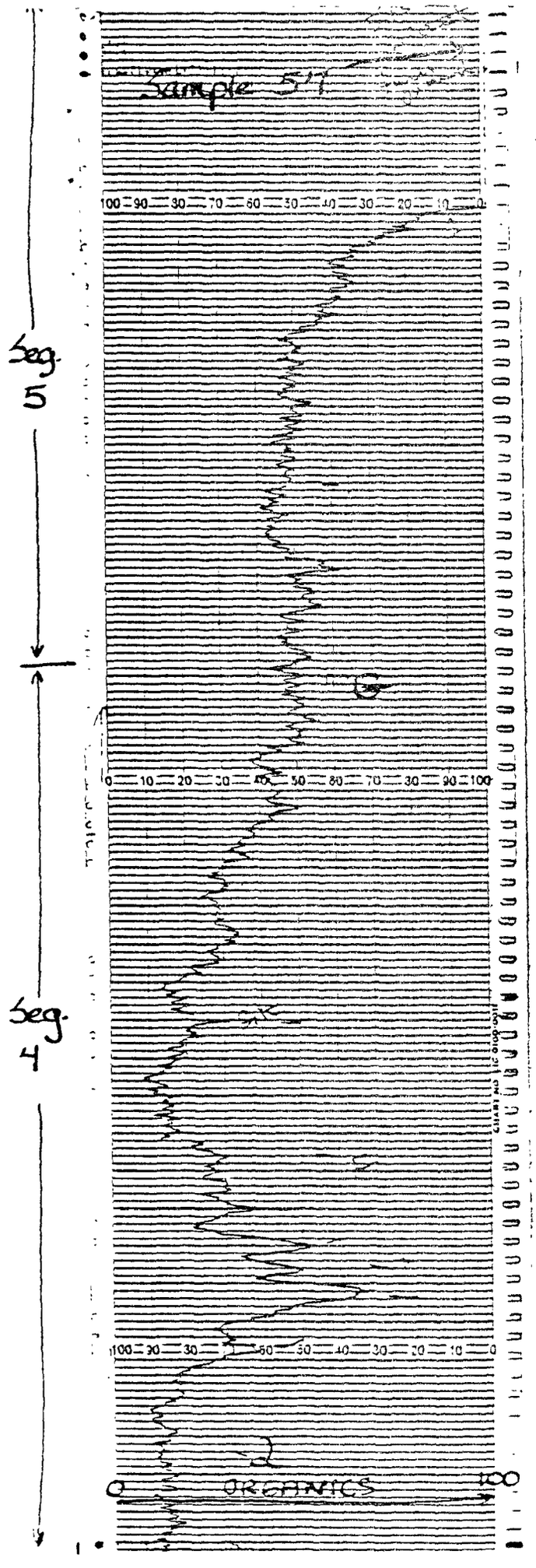


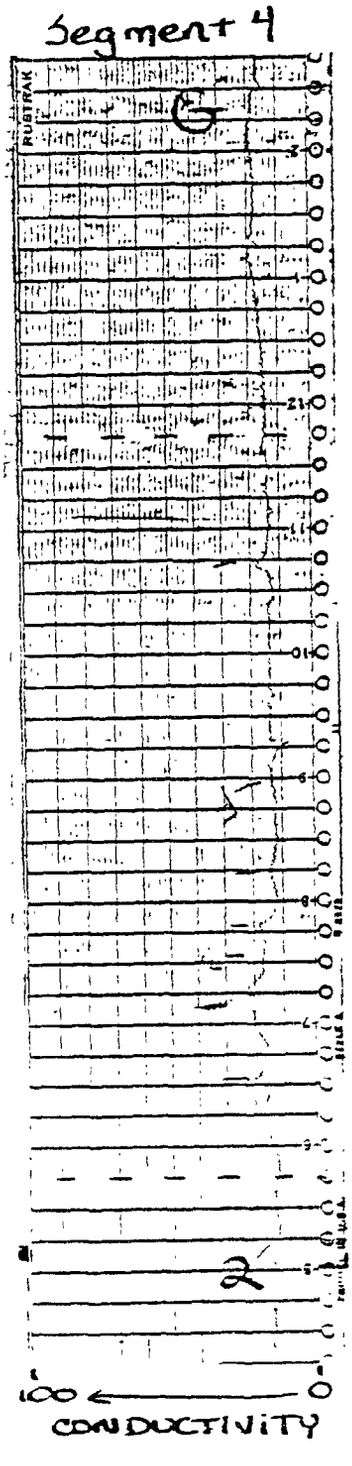


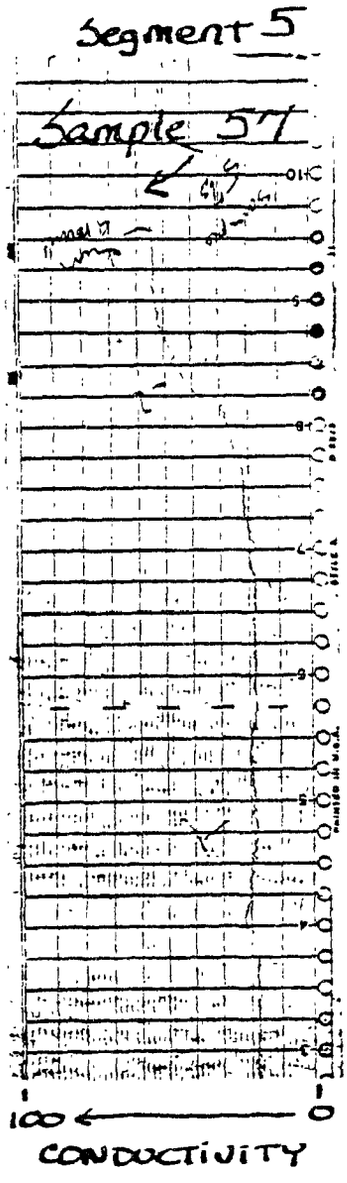


INDIAN LAKE

part 2

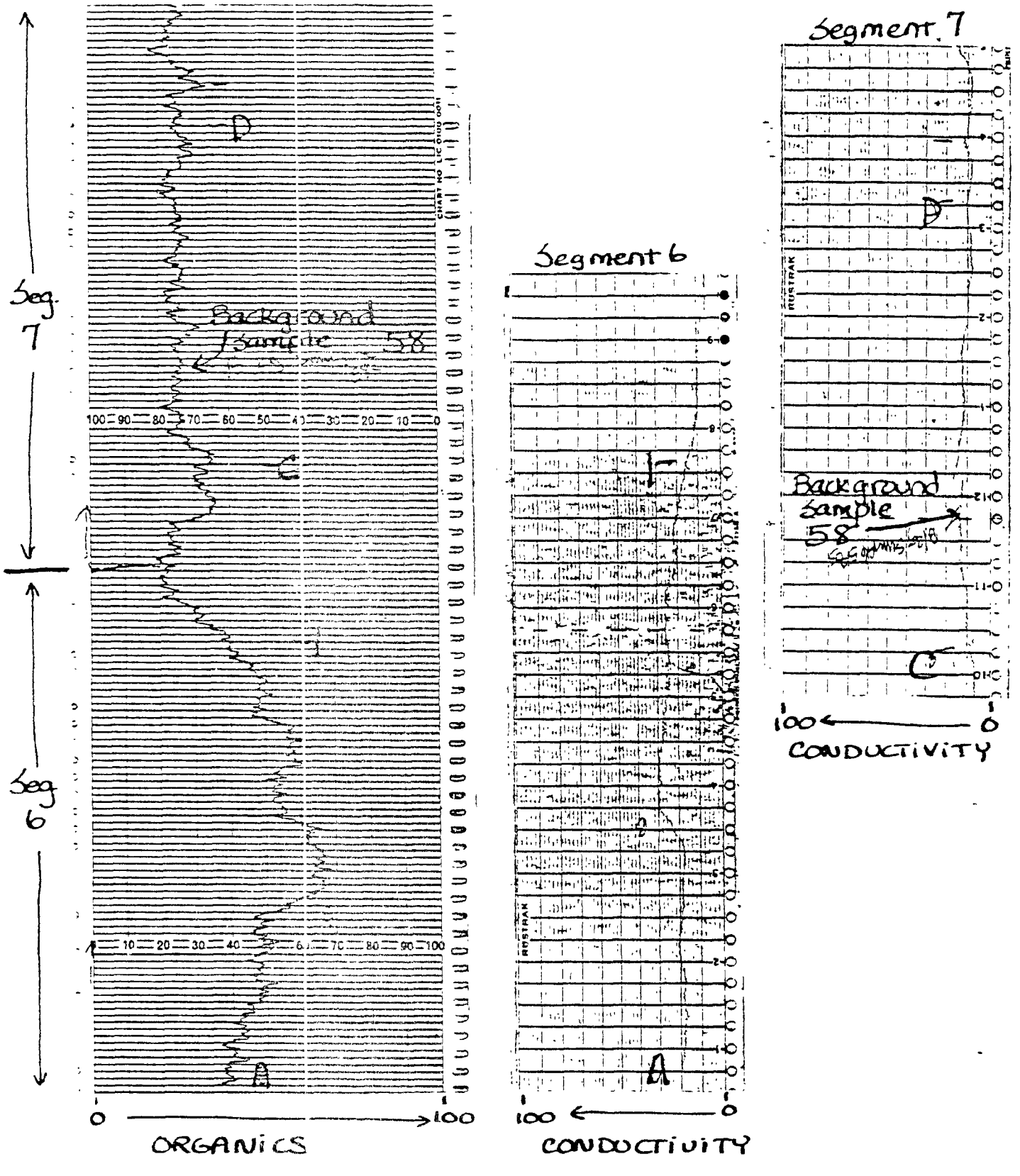






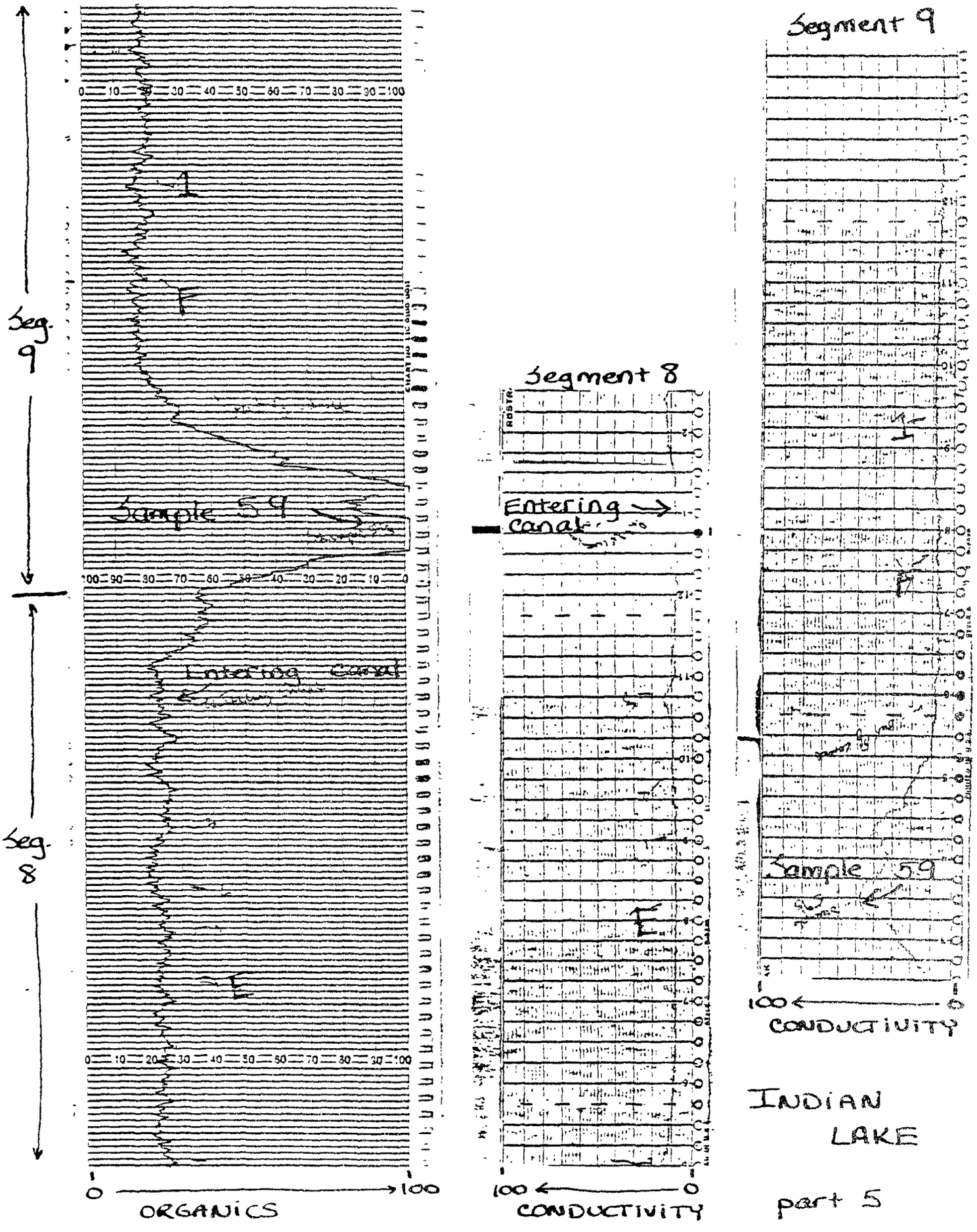
INDIAN LAKE

part 3



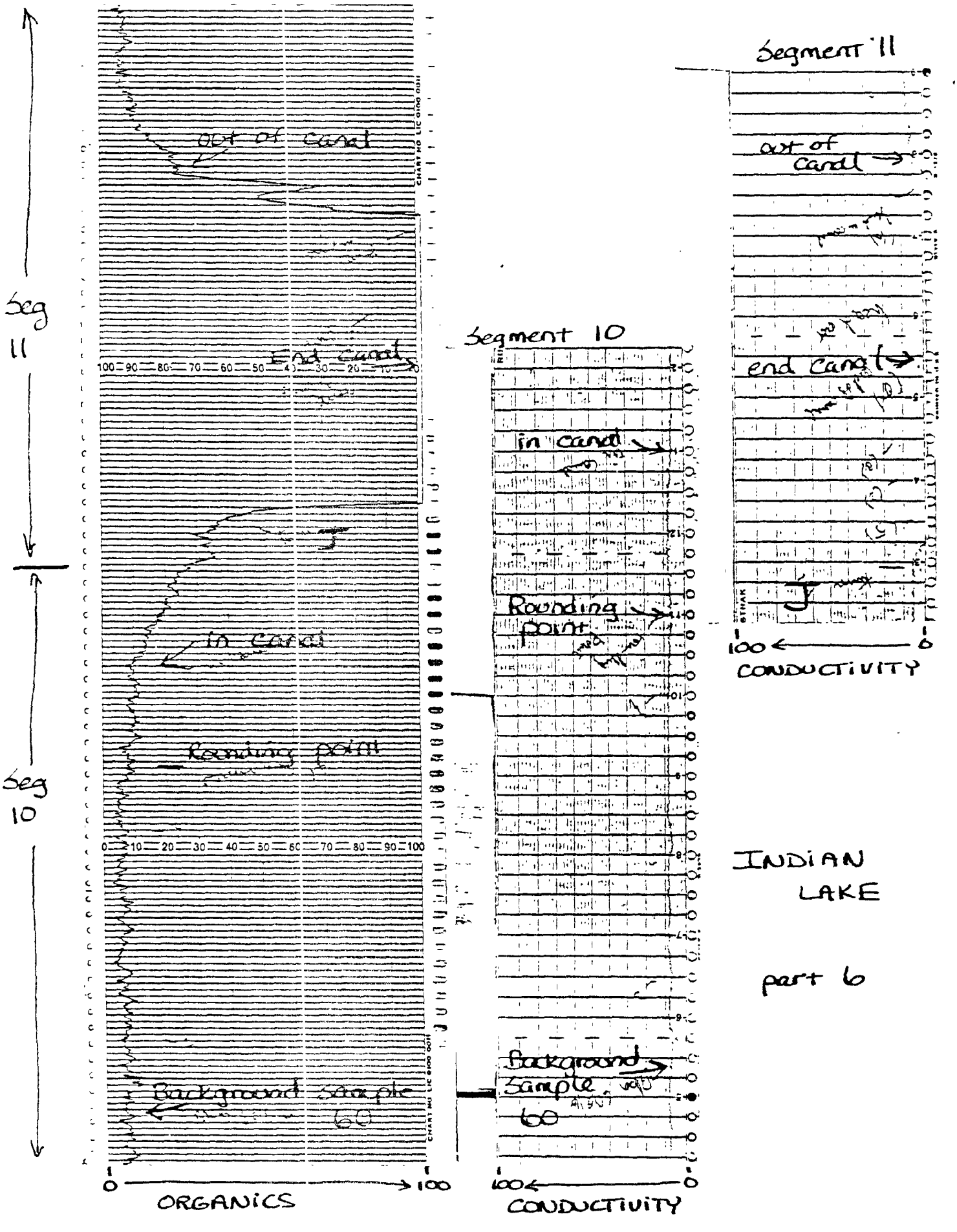
INDIAN LAKE

part 4



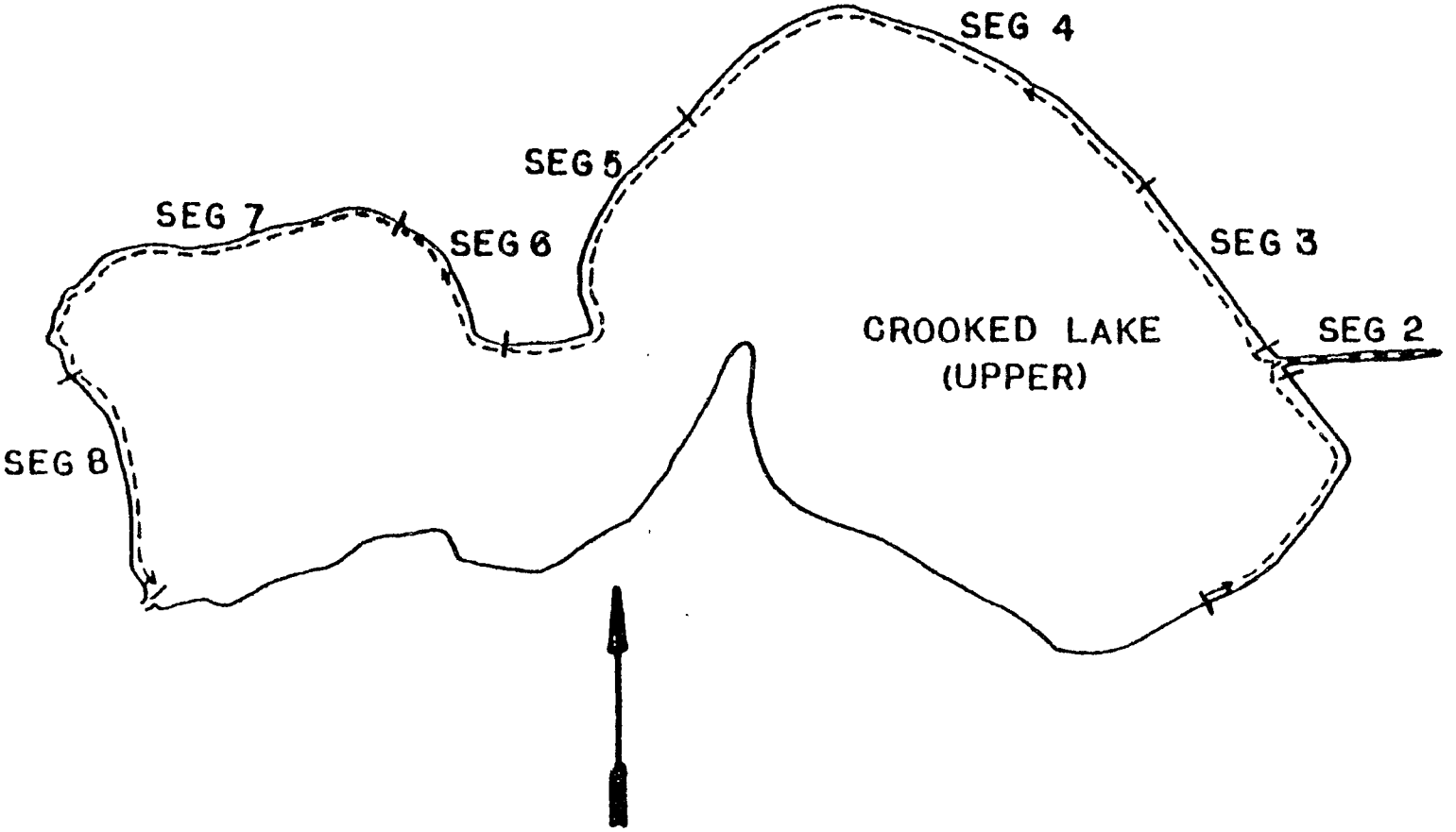
INDIAN LAKE

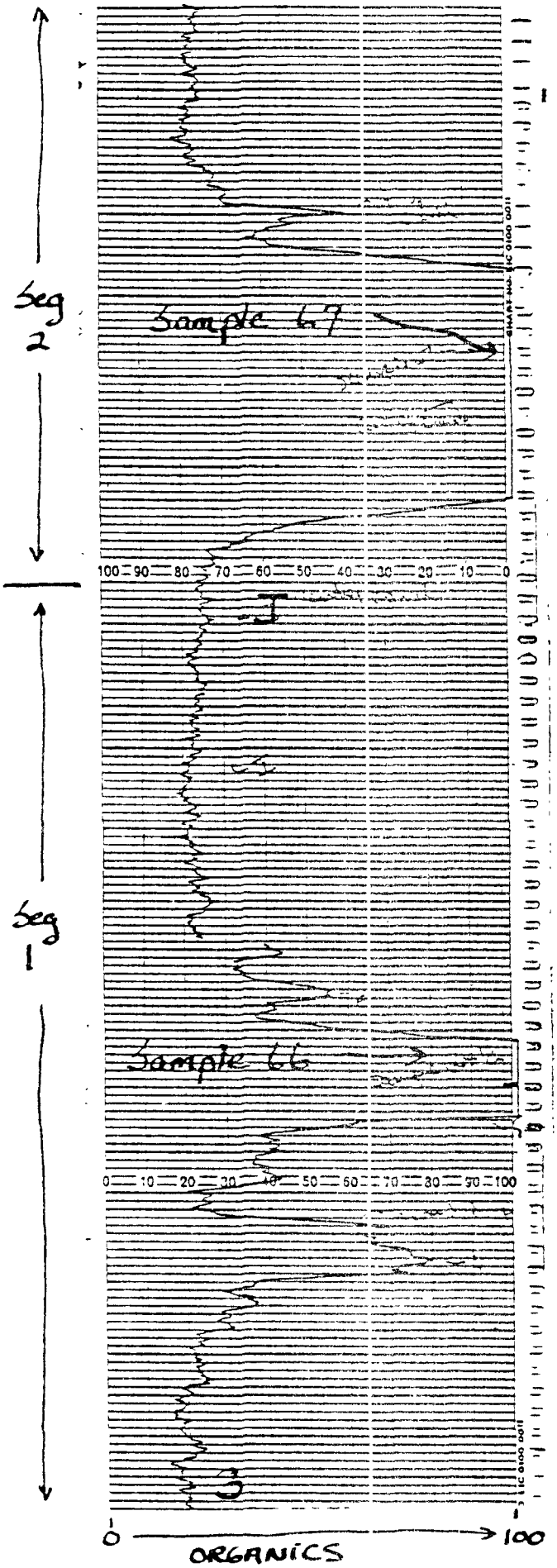
part 5

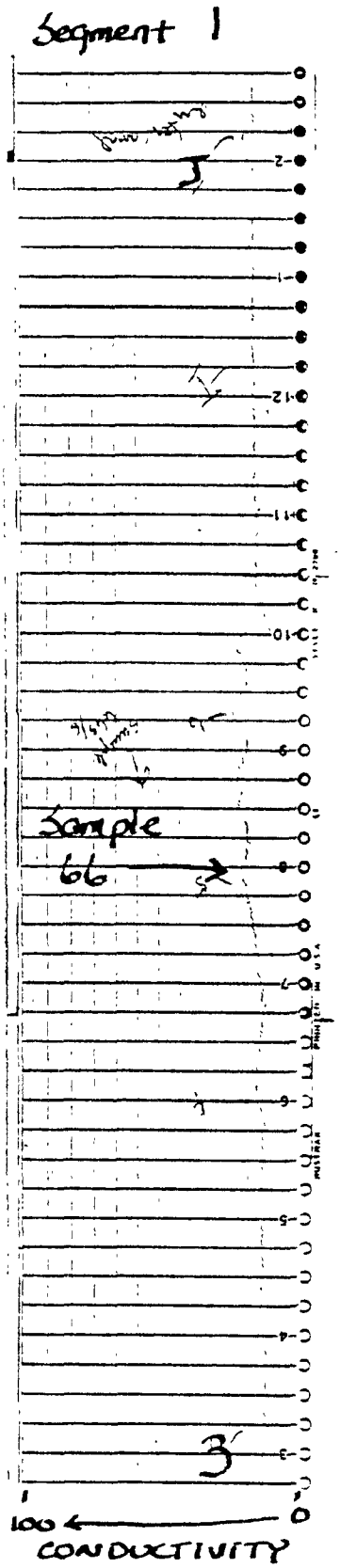


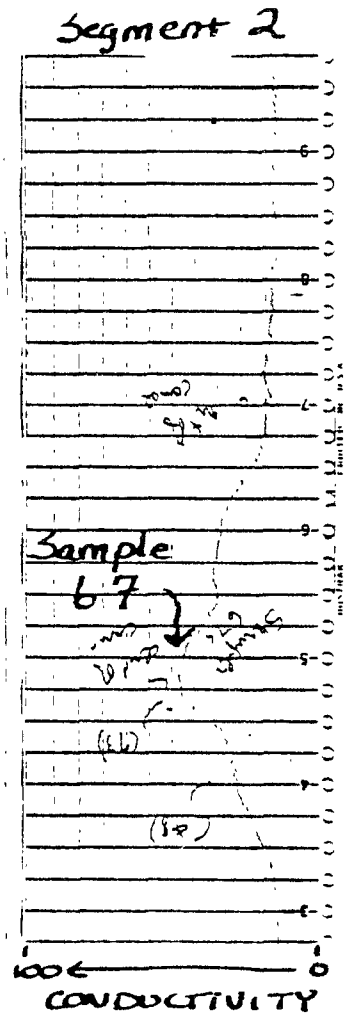
INDIAN LAKE

part 6


SEG 4
SEG 5
SEG 7
SEG 6
SEG 3
CROOKED LAKE
(UPPER)
SEG 2
SEG 8



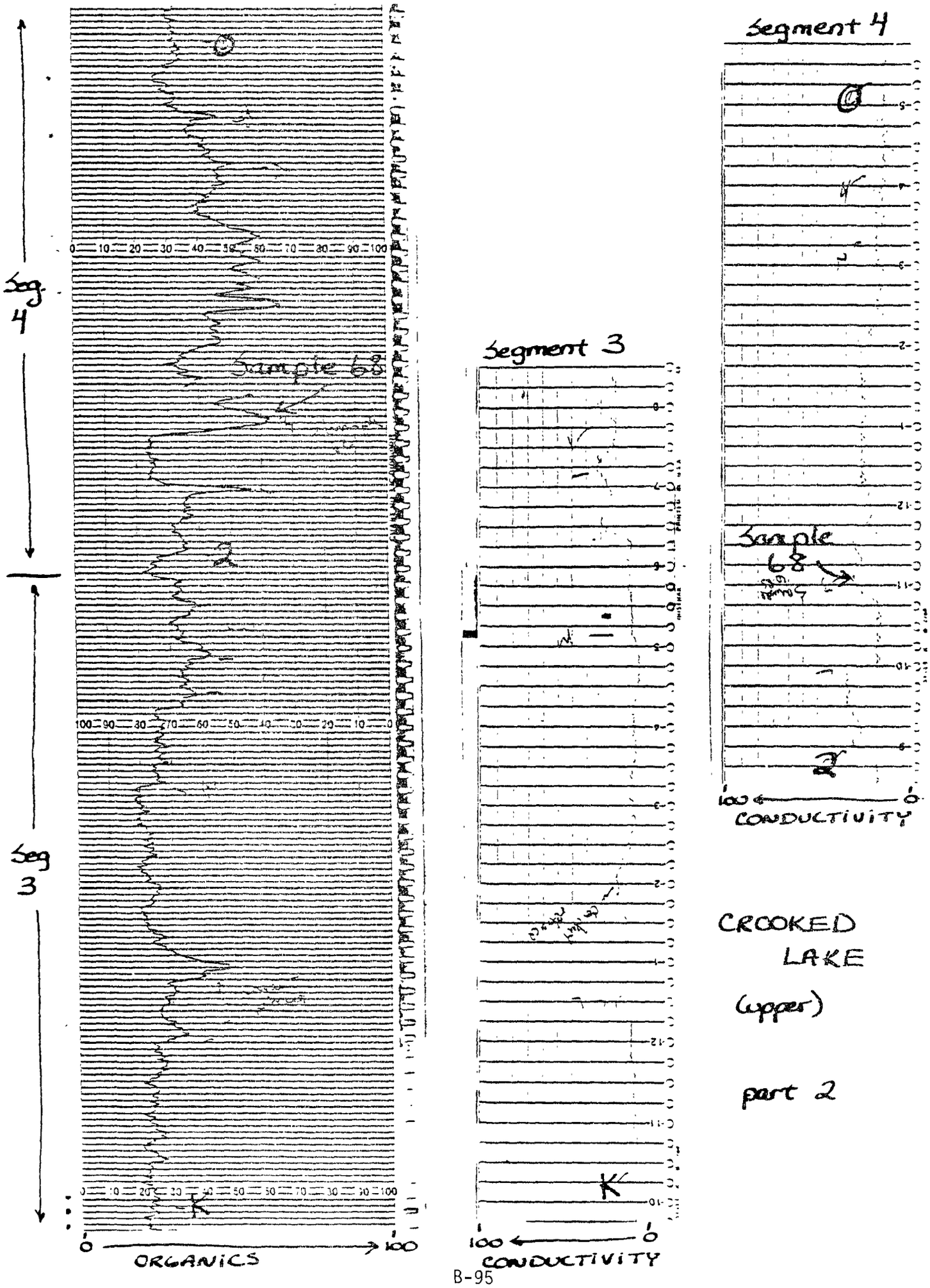




CROOKED LAKE

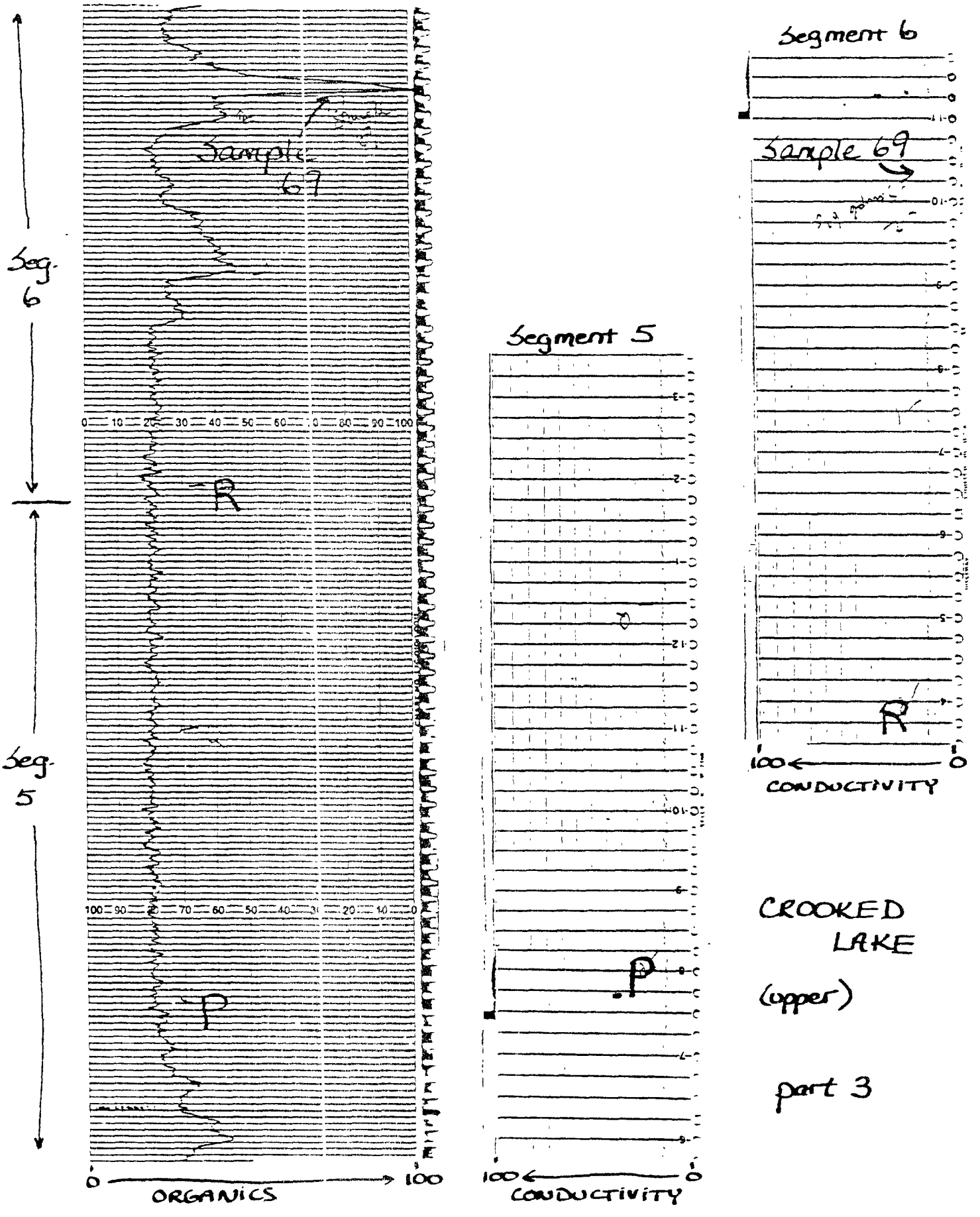
(upper)

part 1



CROOKED LAKE (upper)

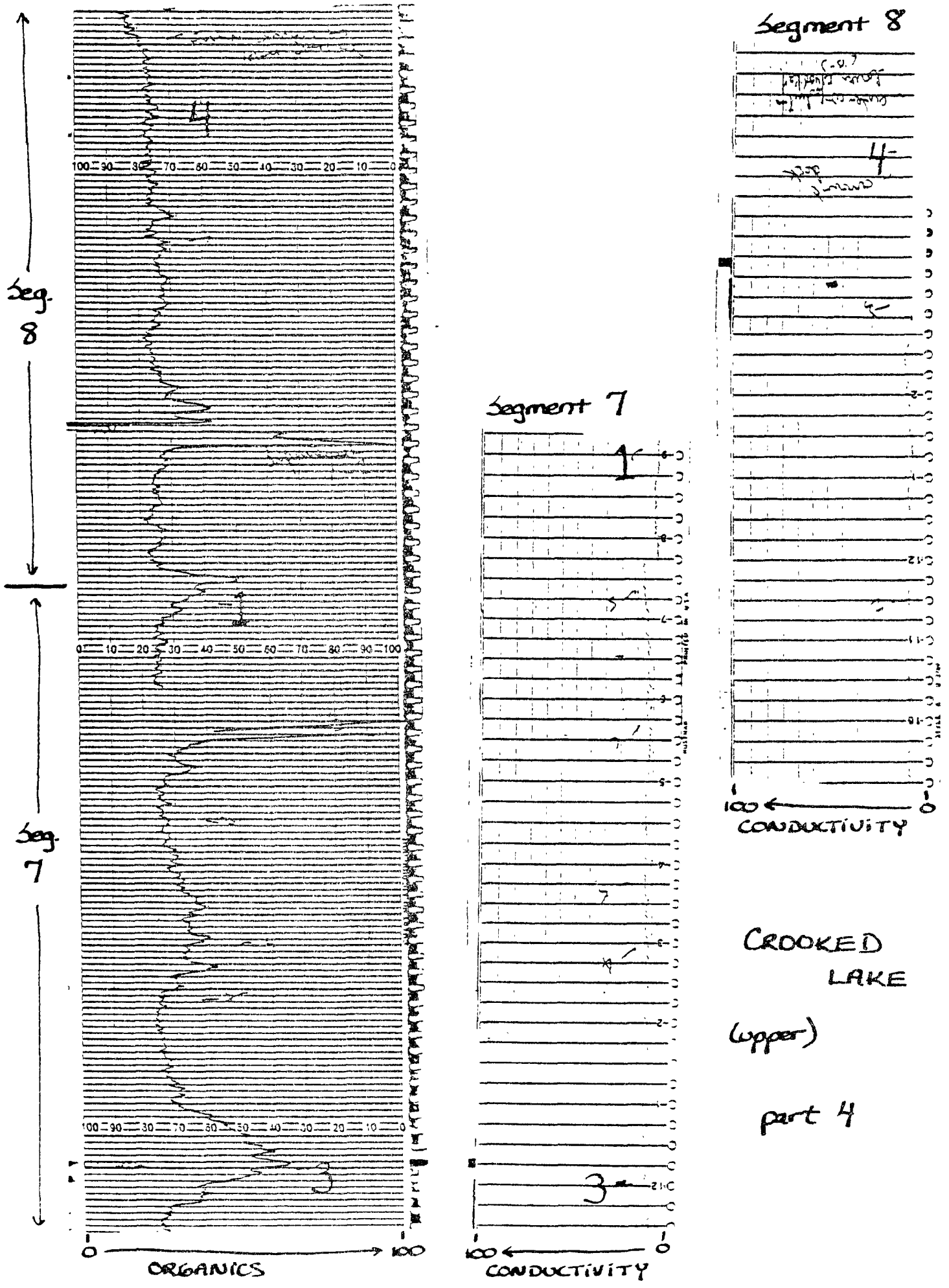
part 2



CROOKED LAKE

(upper)

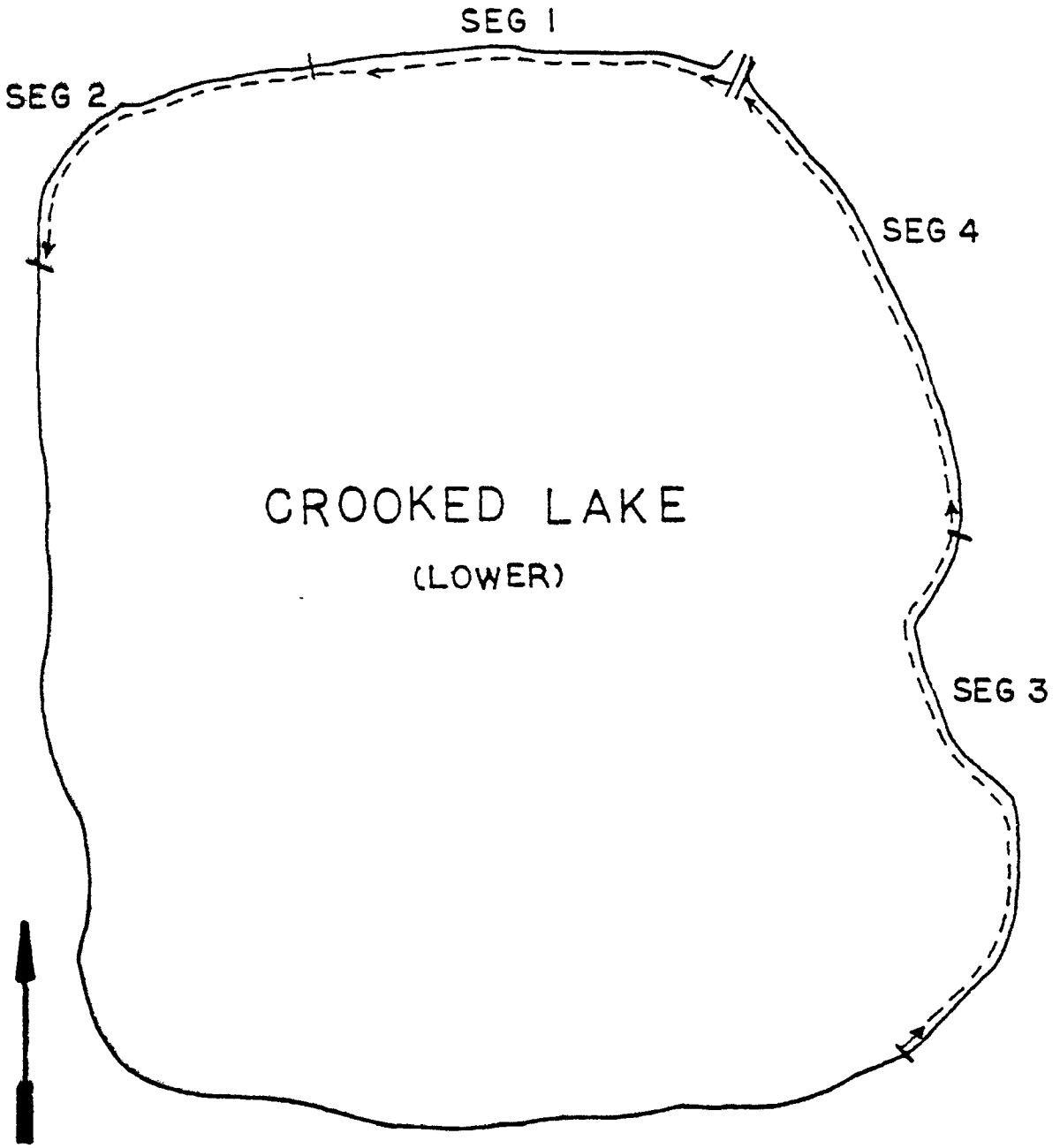
part 3

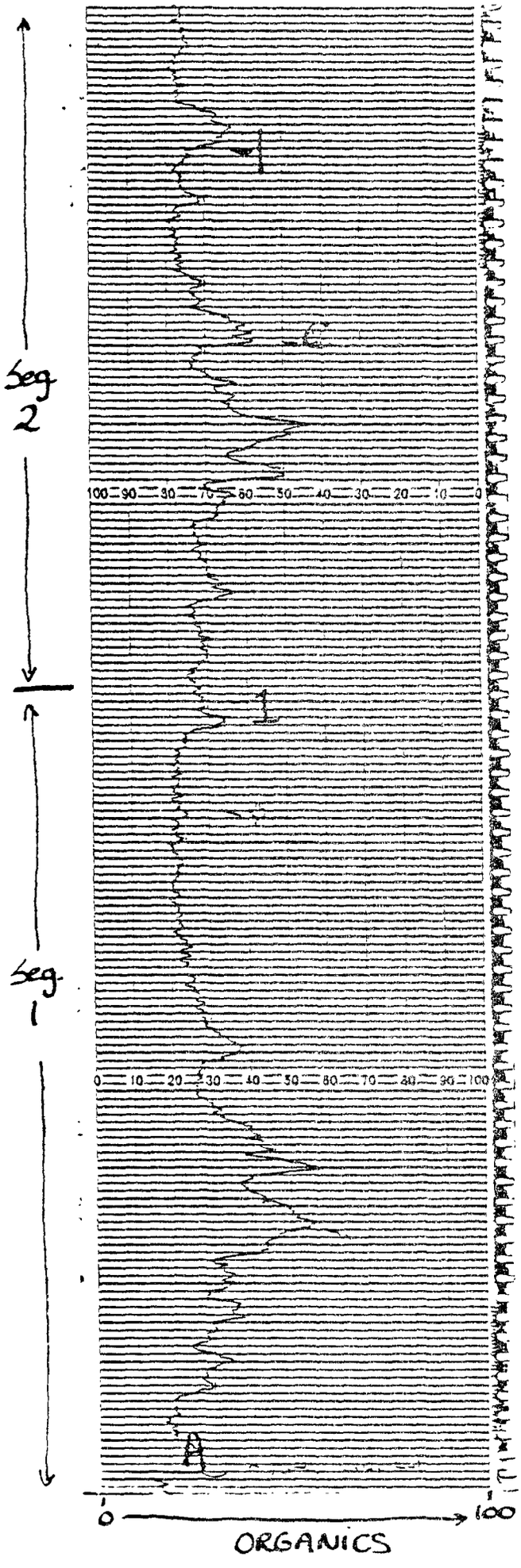


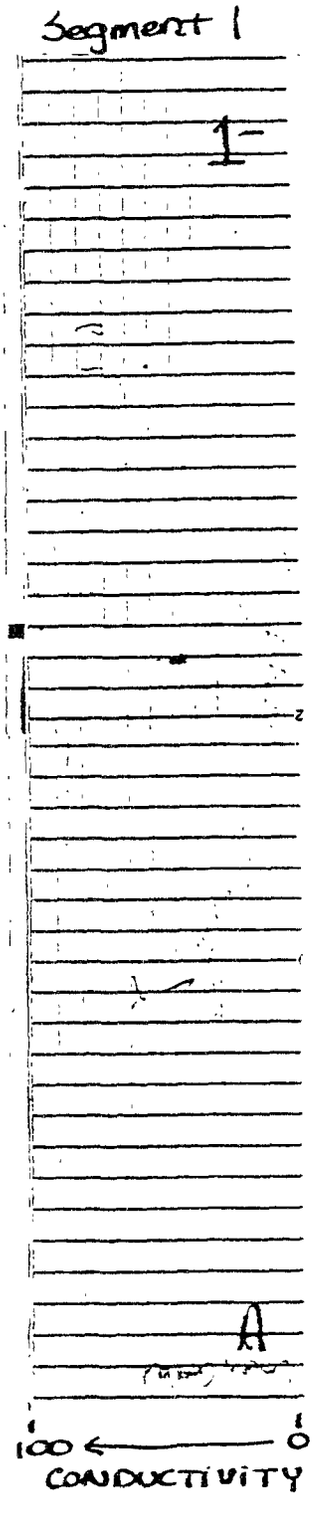
CROOKED LAKE

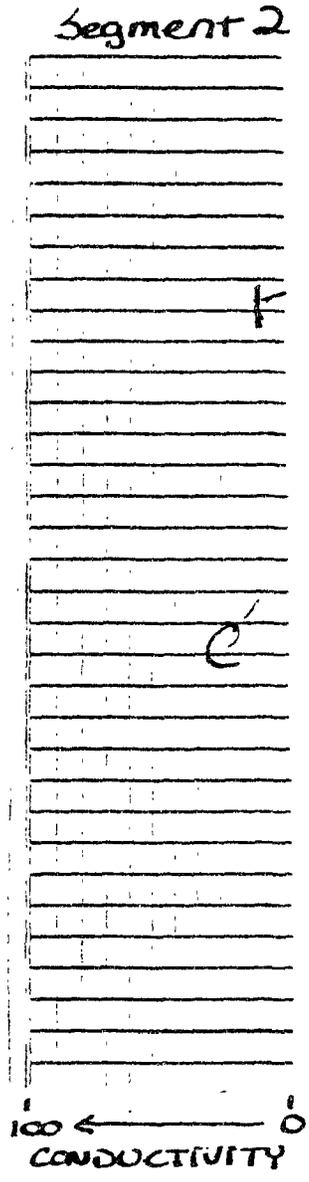
(upper)

part 4


SEG 1
SEG 2
SEG 4
CROOKED LAKE
(LOWER)
SEG 3



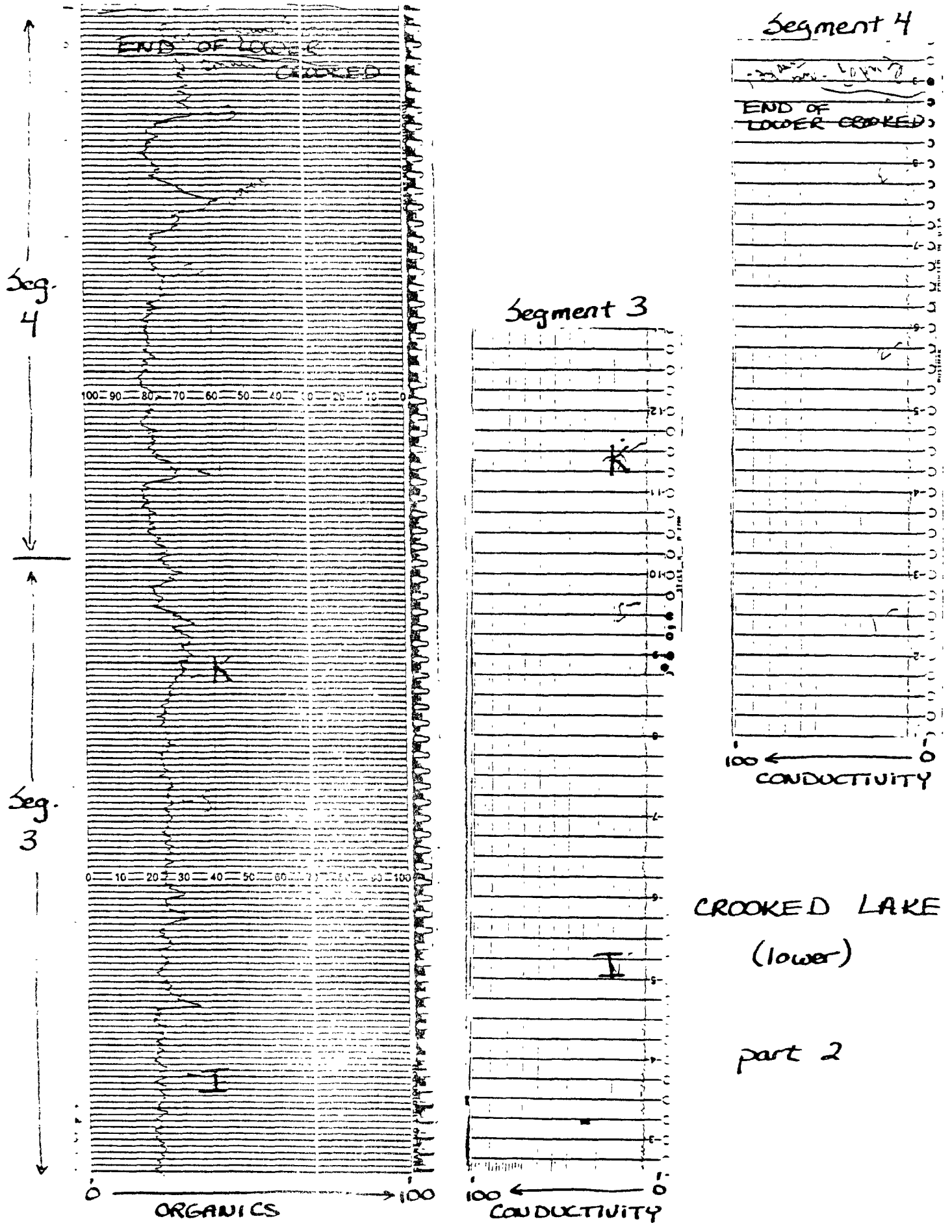




CROOKED LAKE

(lower)

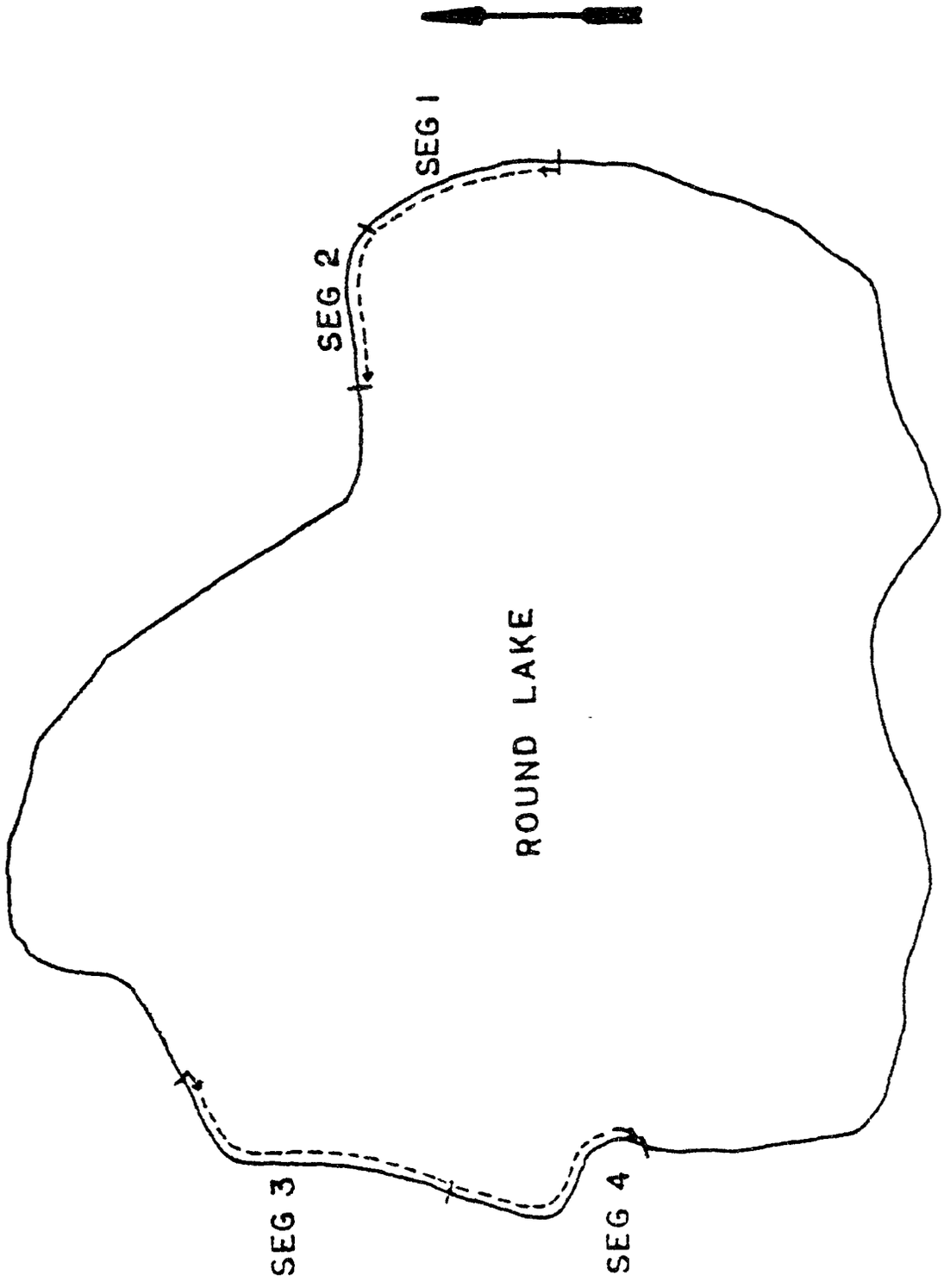
part 1

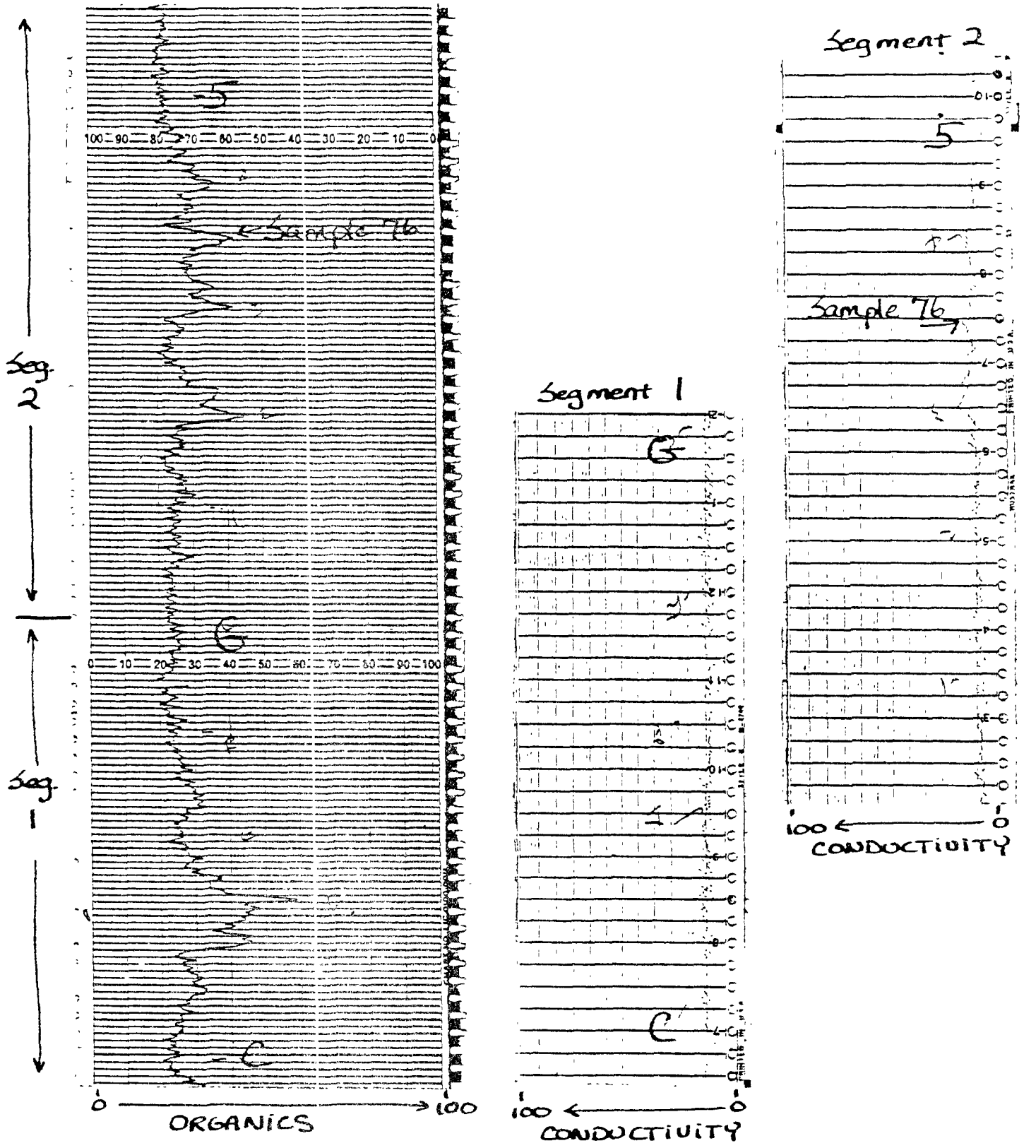


CROOKED LAKE

(lower)

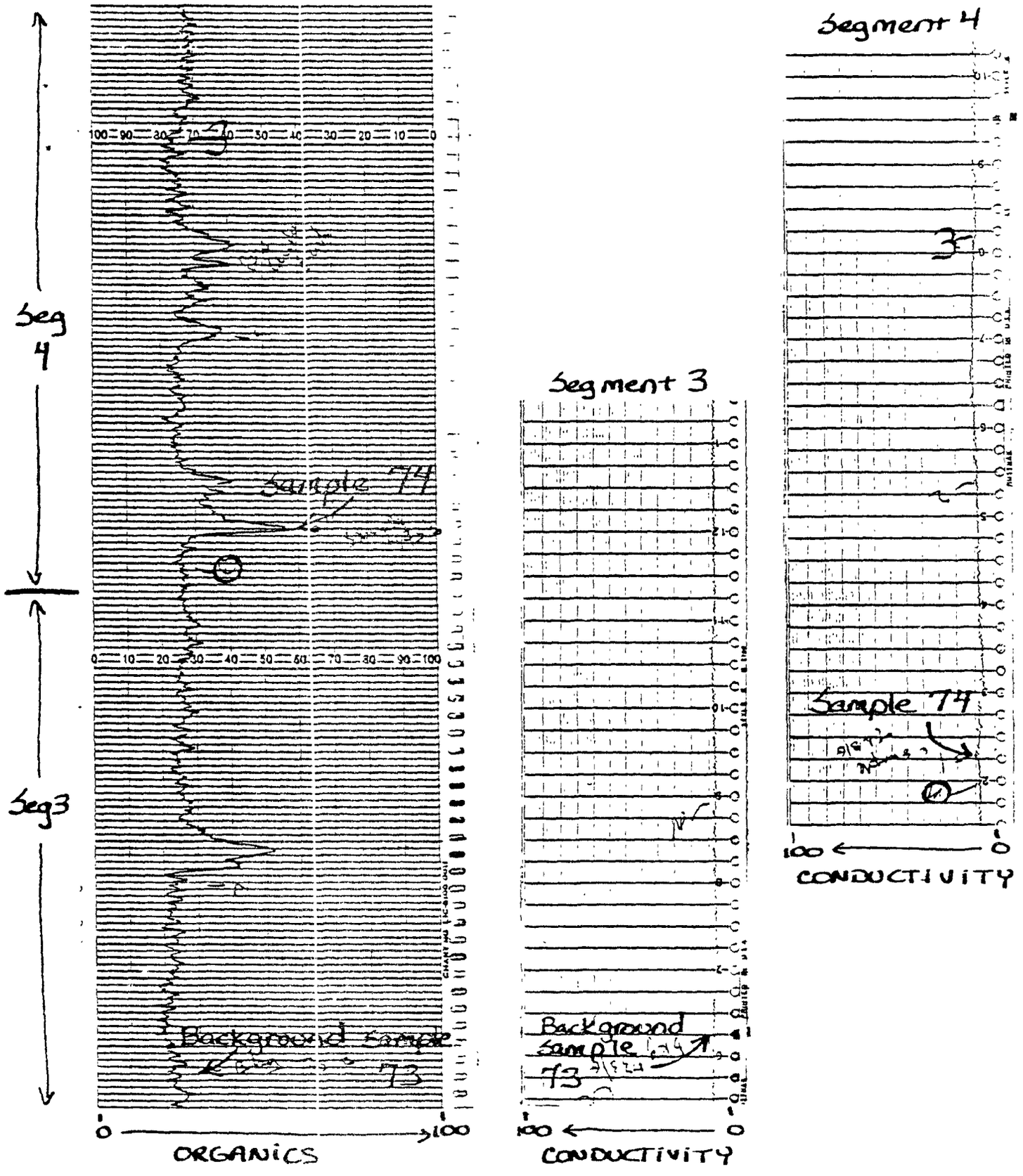
part 2


SEG 1
SEG 2
ROUND LAKE
SEG 3
SEG 4



ROUND LAKE

part 1



ROUND LAKE

part 2

APPENDIX C

ESTIMATED ON-SITE SYSTEMS TO BE UPGRADED

UNDER ALTERNATIVES 8A, 8B, AND 9

METHODOLOGY FOR ESTIMATION OF ON-SITE SYSTEMS TO BE UPGRADED UNDER ALTERNATIVES 8A, 8B, AND 9

1. The number of on-site systems to be upgraded initially was estimated based on the concept of "probable failure" during the planning period. These were estimated from similarity of site limitations and system design to those that have been replaced. Additionally, dry wells would be replaced by drain beds on those parcels where it is feasible. Systems that currently do not meet Code requirements, particularly distance from a water body were assumed to be upgraded in a manner consistent with the Code where it is feasible. The primary site constraints considered were depth to water table especially because the soils in these areas marl and organic soil material is often encountered.

2. Another consideration in estimating the number of systems to be upgraded was that, while conventional, typical systems were designed and costed, a significant number of unusual systems that are higher cost would be required. Rather than attempting to design and cost a large number of unique systems, the number of systems was increased to cover the anticipated additional costs. Typical systems that would result in additional cost include, but are not limited to the following:

   - additional excavation of marl, organic soil or fine-textured soil and sand backfill for placement of soil absorption systems
   - hand labor for construction of system where access for equipment is limited because of proximity to structures or steep slopes
   - pipeline costs for lengths that greatly exceed the estimated lengths
   - purchase of property or easements for soil absorption systems where constructed off-site
   - dewatering costs where excavation must take place within the water table

- blackwater holding tanks with associated plumbing changes on parcels that require off-site treatment that are not presently identified (Alternatives 8A and 8B)

- holding tanks for all household wastewater where site conditions are severely limiting for a greywater disposal systems

- on-site systems for commercial establishments that have significantly greater waste flows than residences do.

3. The number of on-site systems to be upgraded during the planning period after the initial upgrades was based on probable likelihood of failures. Where site constraints were greatest, a higher proportion of future replacements was estimated. Another consideration was the likelihood that seasonal to permanent occupancy shifts would require more future replacements. Age of the systems was considered a factor in replacements also. Those systems that were constructed prior to 1970 were estimated to have a higher percentage of replacements than those constructed subsequent to 1970.

4. Because future upgrades are not grant-eligible, the on-site systems that may be questionable were assumed to be replaced in the initial effort.

5. The Municipal Wastewater Treatment Construction Grants Amendments of 1981 specifies that the design engineer be involved with the project for a year and certify that the project is operating as designed. For this reason, it is likely that a design engineer would tend to be conservative when deciding whether to upgrade a particular system. Accordingly, the number of system upgrades was estimated conservatively.

Table C-1. Estimated breakdown of on-site systems to be upgraded during the planning period for Alternative 8A and 8B.

			Initial Upgrade							Future Upgrade and New Systems						
	Total Systems		Replace Septic Tank	Drain Bed	Raised Drain Bed	Lift Pump + Drain Bed	Lift Pump + Raised Drain Bed	Dry Well	Lift Pump + Dry Well	New Septic Tank	Drain Bed	Raised Drain Bed	Lift Pump + Drain Bed	Lift Pump + Raised Drain Bed	Dry Well	Lift Pump + Dry Well
District	Existing	Future														
Indian Lake																
1	172	16	25	25	5	5	5	5	5	16	10	5	5	5	5	5
2	75	12	15	7	5	10	2	5	10	12	10	2	10	2	2	5
3	65	14	15	10	10	5	3	2	2	14	10	2	5	1	0	2
Sister Lakes																
1	101	21	16	20	5	5	10	3	3	21	10	3	5	7	2	2
4	110	26	24	10	7	7	15	5	5	26	15	5	5	5	2	2
5	78	11	20	10	5	5	2	2	2	11	7	5	5	0	0	0
6	173	30	26	15	5	15	5	10	10	30	25	5	5	5	5	10
7	87	10	12	5	5	13	5	5	12	10	7	2	3	2	0	7
8	140	30	14	20	7	12	5	5	5	30	17	5	7	5	5	2
9	139	25	27	25	10	15	5	5	15	25	15	5	10	5	5	10
10	88	14	16	15	5	18	5	5	5	14	10	5	8	3	3	5
11	57	5	6	5	7	10	5	0	5	5	5	2	5	2	0	5
12	81	10	21	10	5	10	10	5	10	10	7	3	3	10	0	5
13	123	30	34	15	5	15	20	7	15	30	12	10	10	7	5	13
14	24	3	4	0	3	5	7	2	0	3	5	0	2	0	0	2
15	146	26	23	20	15	17	12	7	15	26	15	5	7	10	5	7

Table C-2. Estimated breakdown of on-site systems to be upgraded during the planning period for Alternative 7.

			Initial Upgrade										Future Upgrade and New Systems						
	Total Systems			Holding Tank															
District	Existing	Future	Low-flow Toilet	Seasonal	Permanent	Replace Septic Tank	Drain Bed	Lift Pump + Drain Bed	Raised Drain Bed	Lift Pump + Raised Drain Bed	Dry Well	Lift Pump + Dry Well	New Septic Tank	Drain Bed	Lift Pump + Drain Bed	Raised Drain Bed	Lift Pump + Raised Drain Bed	Dry Well	Lift Pump + Dry Well
Indian Lake																			
1	263	18	32	27	5	53	18	10	12	15	5	12	18	12	5	8	12	5	5
2	101	13	6	6	0	21	7	10	5	7	5	10	13	10	10	2	2	0	2
3	170	19	22	20	2	46	10	7	15	18	2	10	19	10	5	5	8	3	7
Sister Lakes																			
1	114	21	9	9	0	20	20	5	5	15	3	4	21	10	5	5	7	2	4
2	29	0	9	5	4	8	2	1	3	7	0	0	0	0	2	0	3	0	0
3	41	0	17	7	10	10	0	2	5	7	0	1	0	0	0	0	5	0	2
4	123	29	12	8	4	27	10	7	7	15	5	5	29	15	5	5	7	2	2
5	255	21	35	15	20	61	25	15	10	15	5	12	21	15	5	7	5	2	5
6	237	30	21	18	3	44	15	15	18	15	7	15	30	25	5	7	5	5	10
7	87	10	0	0	0	12	3	5	13	5	5	12	10	7	2	3	2	0	7
8	147	32	4	4	0	17	20	7	12	7	5	5	32	17	7	5	7	5	2
9	207	27	17	12	5	44	25	15	12	15	5	15	27	15	10	7	10	5	10
10	143	27	9	7	2	33	15	18	10	15	5	5	27	10	10	7	5	3	5
11	146	9	22	15	7	38	5	15	15	20	2	15	9	5	5	5	5	0	5
12	81	10	0	0	0	21	5	10	5	7	2	10	10	7	5	0	5	0	3
13	155	12	20	15	5	45	5	15	10	15	7	15	32	12	5	5	7	3	12
14	14	3	5	5	0	7	0	5	3	2	2	0	3	2	2	1	1	0	2
15	180	29	14	8	6	32	20	17	15	15	7	15	29	15	7	5	10	5	7

APPENDIX D

PRELIMINARY COST ESTIMATES FOR ALTERNATIVES

COST METHODOLOGY

1. Costs for the conventional gravity sewer system were determined from published cost data. The general layout of the system outlined in the Facilities Plan was used. The sizes of the sewers were not changed because design flows used in this study were not significantly different. Costs represented were updated to June 1981 price levels.

2. Costs forthe pressure sewer system and on-site system components were either obtained from the local contractors or from the published cost data. All costs were updated to June 1981 price levels.

3. Costs for materials, construction, and O&M were updated to June 1981 price levels. Construction costs for treatment units and sewers were based on USEPA indexes for Detroit of 416.9 (STP) and 223 (CUSS), respectively. The Engineering News Record Construction Cost Index of 3,560 for June 1981 also was used.

4. Salvage values were determined using straight-line depreciation for a planning period of 20 years. The service life of land was considered to appreciate by 3 percent. The service life of structures, including buildings, concrete process units, etc., was assumed to be 40 years. The service life of conveyance pipelines was assumed to be 50 years. The service life of process and auxiliary equipment such as clarifier mechanisms, standby generators, pumps, electric motors, etc. is assumed to be 20 years.

5. Capital costs were based on construction costs plus a service factor for engineering, administration, legal and contingencies (Table).

6. Present worth of salvage value, O&M costs, and average annual equivalent costs were determined for 20 years using a discount rate of 7.625%.

7. Present worth of salvage values was determined using a single payment present worth factor of 0.2300 (Salvage value x 0.2300 = present worth of salvage).

8. Present worth of O&M costs were determined using a uniform or equal payment series factor of 10.0983 (average annual O&M cost x 10.0983 = present worth of O&M).

9. Average annual equivalent costs were determined usng a capital recovery factor of 0.0990 (total present worth x 0.0990 = average annual equivalent cost).

References to cost tables

The relation of the various cost tables to each alternative is as follows:

Alternative 2

- Collection System - Summary - Table D-1
  Details of collection - Tables D-2 thru D-19
- Conveyance - Table D-58
- Treatment - Tables D-64 and D-67

Alternative 3

- Collection System - Summary - Table D-1
  Details of collection - Tables D-2 thru D-19
- Conveyance - Table D-59
- Treatment - Table D-73

Alternative 4

- Collection System - Summary - Table D-1
  Details of collection - Table D-2 thru D-19
- Conveyance - Table D-60
- Treatment - Table D-70

Alternative 5A

- Collection System - Summary - Table D-1
  Details of collection - Tables D-2 thru D-19
- Conveynace - Table D-61
- Treatment - Table D-70

Alternative 5B

- Collection System - Summary - Table D-20
  Details of collection - Tables D-21 thru D-38

- Conveyance – Table D-61
- Treatment – Table D-70

Alternative 6

- Collection System – Summary - Table D-1
  Details of collection - Tables D-2 thru D-19
- Conveyance – Table D-62
- Treatment – Tables D67 and D-75

Alternative 7

- Collection system – Summary - Table D-1
  Details of collection - Tables D-2 thru D-19
- Conveyance – Table D-63
- Treatment – Table D-74

Alternative 8A

- Collection system and clusters – Summary - Table D-76
  Details of collection and cluster - Tables D-77 thru D-92
- On-site Systems – Tables D-93 thru D-108
- Administration and laboratory – Table D-145

Alternative 8B

- Collection system and clusters – Summary - Table D-109
  Details of collecton and cluster - Tables D110 thru D-125
- On-site systems – Tables D-93 thru D-108
- Administration and laboratory – Table D-145

Alternative 9

- On-Site Systems – Summary - Table D-126
  Details of on-site system - Tables D-127 thru D-144.
- Administration and laboratory – Table D-145

Table D-1. Summary and present worth of costs of the collection portion for Alternatives 2, 3, 4, 5A, 6, and 7-septic tank effluent pumps and pressure sewers with some gravity sewers (June 1981 costs).

	Initial Cost						Future Connections Cost							
				Present Worth			Annual	Total	Incremental	Present Worth				
District	Capital	Salvage	O&M	Salvage	O&M	Total	Construction	Salvage	Annual O&M	Construction	Salvage	O&M	Total	Total Present Worth
Indian Lake														
1	1,521,570	446,275	16,450	102,643	166,117	1,585,044	3,765	22,885	66	38,020	5,264	4,759	37,516	1,622,560
2	679,825	207,532	6,913	47,732	69,810	701,903	4,601	27,971	80	46,462	6,433	5,769	45,798	747,701
3	1,276,397	384,232	13,272	88,373	134,025	1,322,049	5,647	34,328	99	57,025	7,895	7,139	56,269	1,378,318
Subtotal:	3,477,792	1,038,039	36,635	238,748	369,952	3,608,996	14,013	85,184	245	141,507	19,592	17,667	139,583	3,748,579
Pipestone Lake														
2	347,437	124,594	2,273	28,657	22,953	341,733	--	--	--	--	--	--	--	341,733
3	429,447	143,544	4,267	33,015	43,089	439,521	--	--	--	--	--	--	--	439,521
Subtotal:	776,884	268,138	6,540	61,672	66,042	781,254	--	--	--	--	--	--	--	781,254
Sister Lakes														
1	739,264	217,494	8,099	50,024	81,786	771,026	4,392	26,699	77	44,352	6,141	5,552	43,763	814,789
4	995,420	337,139	8,319	77,542	84,008	1,001,886	5,510	37,637	87	55,642	8,657	6,273	53,258	1,055,144
5	1,911,885	580,027	23,851	133,406	240,855	2,019,334	4,022	27,211	64	40,615	6,259	4,615	38,971	2,058,305
6	2,251,718	821,990	12,352	189,058	124,734	2,187,394	4,423	39,708	46	44,665	9,133	3,317	38,849	2,226,243
7	562,916	165,856	6,155	38,147	62,155	586,924	2,091	12,714	36	21,115	2,924	2,596	20,787	607,711
8	1,101,330	446,662	10,608	102,732	107,123	1,105,721	6,415	41,069	107	64,781	9,446	7,716	63,051	1,168,772
9	1,239,604	353,482	14,372	81,301	145,133	1,303,436	5,647	34,328	99	57,025	7,895	7,139	56,269	1,359,705
10	857,488	259,754	9,057	59,743	91,460	889,205	5,647	34,328	99	57,025	7,895	7,139	56,269	945,474
11	899,432	272,226	9,448	62,612	95,409	932,229	1,882	11,443	33	19,005	2,632	2,380	18,753	950,982
12	564,747	179,010	5,379	41,172	54,319	577,894	1,906	12,969	30	19,247	2,983	2,163	18,427	596,321
13	2,162,113	696,486	15,517	160,192	156,695	2,158,616	6,137	41,451	98	61,973	9,534	7,067	59,506	2,218,122
14	242,754	77,039	2,302	17,719	23,246	248,281	627	3,814	11	6,332	877	793	6,248	254,529
15	1,130,544	367,743	10,379	84,581	104,810	1,150,773	5,973	36,998	103	60,317	8,510	7,427	59,234	1,210,007
Subtotal:	14,659,215	4,774,908	135,838	1,098,229	1,371,733	14,932,719	54,672	360,369	890	552,094	82,886	64,177	533,385	15,466,104
Total	18,913,891	6,081,085	179,013	1,398,649	1,807,727	19,322,969	68,685	445,553	1,135	693,601	102,478	81,844	672,968	19,995,917

Table D-2. Quantities and costs of septic tank effluent pressure sewers for District #1 Indian Lake.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	3,230	$ 17.00	$ 54,910	$ 32,946	$ 61
2½"	5,875	17.35	101,931	61,158	111
3"	2,470	18.20	44,954	26,972	47
4"	4,350	19.50	84,825	50,895	83
6"	1,900	22.40	42,560	25,536	36
Service connections					
STE pump	214	3,428	733,592	220,078	13,482
Septic tank					
upgrade	219	143	31,317	18,790	2,190
replace	44	750	33,000	9,900	440
Subtotal initial cost			1,127,089	446,275	16,450
Service factor (35%)			394,481	--	--
Subtotal initial capital cost			1,521,570	--	--
Future connections cost					
Building sewer	18	55	990	594	--
Septic tank + STE pump	18	4,128	74,304	22,291	1,314
Subtotal future connection cost			75,294	22,885	1,314
Annual future connection cost			3,765	--	66

Table D-3. Quantities and costs of septic tank effluent pressure sewers for District #2 Indian Lake.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	700	$ 17.00	$ 11,900	$ 7,140	$ 13
2½"	3,200	17.35	55,520	33,312	61
3"	2,250	18.20	40,950	24,570	43
4"	2,650	19.50	51,675	31,005	50
Service connections					
STE pump	92	3,428	315,376	94,613	5,796
Septic tank					
upgrade	71	143	10,153	6,092	710
replace	24	750	18,000	10,800	240
Subtotal initial cost			503,574	207,532	6,913
Service factor (35%)			176,251	--	--
Subtotal initial capital cost			679,825	--	--
Future connections cost					
Building sewer	22	55	1,210	726	--
Septic tank + STE pump	22	4,128	90,816	27,245	1,606
Subtotal future connection cost			92,026	27,971	1,606
Annual future connection cost			4,601	--	80

Table D-4. Quantities and costs of septic tank effluent pressure sewers for District #3 Indian Lake.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	920	$ 17.00	$ 15,640	$ 9,384	$ 17
2½"	3,850	17.35	66,797	40,078	73
4"	3,660	19.50	71,370	42,822	69
6"	5,740	22.40	128,576	77,146	109
Service connection					
STE pump	178	3,428	610,184	183,055	11,214
Septic tank					
upgrade	134	143	19,162	11,497	1,340
replace	45	750	33,750	20,250	450
Subtotal initial cost			945,479	384,232	13,272
Service factor (35%)			330,918	--	--
Subtotal initial capital cost			1,276,397	--	--
Future connections cost					
Building sewer	27	55	1,485	891	--
Septic tank + STE pump	27	4,128	111,456	33,437	1,971
Subtotal future connection cost			112,941	34,328	1,971
Annual future connection cost			5,647	--	99

Table D-5. Quantities and costs of septic tank effluent pressure sewers for District #2 Pipestone Lake.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	700	$ 17.00	$ 11,900	$ 7,140	$ 13
3"	7,530	18.20	137,046	82,228	143
Service connections					
STE pump	29	3,428	99,412	29,824	1,827
Septic tank					
upgrade	21	143	3,003	1,802	210
replace	8	750	6,000	3,600	80
Subtotal initial cost			257,361	124,594	2,273
Service factor (35%)			90,076	--	--
Subtotal initial capital cost			347,437	--	--

Table D-6. Quantities and costs of septic tank effluent pressure sewers for District #3 Pipestone Lake.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	250	$ 17.00	$ 4,250	$ 2,550	$ 5
2½"	450	17.35	7,807	4,684	8
3"	700	18.20	12,740	7,644	13
4"	1,900	19.50	37,050	22,230	36
Lift station					
#4 40 gpm TDH-126 ft			30,900	9,270	1,530
Force main, individual trench					
3"	6,150	14.15	87,022	52,213	--
Service connections					
STE pump	37	3,428	126,836	38,051	2,331
Septic tank					
upgrade	28	143	4,004	2,402	280
replace	10	750	7,500	4,500	100
Subtotal initial cost			318,109	143,544	4,267
Service factor (35%)			111,338	--	--
Subtotal initial capital cost			429,447	--	--

Table D-7. Quantities and costs of septic tank effluent pressure sewers for District #1 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	800	$ 17.00	$ 13,600	$ 8,160	$ 15
2½"	1,800	17.35	31,230	18,738	34
3"	2,050	18.20	37,310	22,386	39
4"	3,550	19.50	69,225	41,535	67
Service connections					
STE pump	108	3,428	370,224	111,067	6,804
Septic tank					
upgrade	98	143	14,014	8,408	980
replace	16	750	12,000	7,200	160
Subtotal initial cost			547,603	217,494	8,099
Service factor (35%)			191,661	--	--
Subtotal initial capital cost			739,264	--	--
Future connections cost					
Building sewer	21	55	1,155	693	--
Septic tank + STE pump	21	4,128	86,688	26,006	1,533
Subtotal future connection cost			87,843	26,699	1,533
Annual future connections cost			4,392		77

Table D-8. Quantities and costs of septic tank effluent pressure sewers for District #4 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	2,200	$ 17.00	$ 37,400	$ 22,440	$ 42
2½"	2,400	17.35	41,640	24,984	46
3"	2,200	18.20	40,040	24,024	42
STE gravity sewer pipe					
4"	450	35.30	15,885	9,531	17
6"	1,500	37.00	55,500	33,300	57
8"	1,900	38.90	73,910	44,346	72
Lift station					
#6 110 gpm TDH-77 ft			93,800	28,140	2,088
Force main, common trench					
4"	1,500	6.50	9,750	5,850	--
Force main, individual trench					
4"	300	14.90	4,470	2,682	--
Service connection					
gravity	48	1,577	75,696	45,418	--
STE pump	75	3,428	257,100	77,130	4,725
Septic tank					
upgrade	99	143	14,157	8,494	990
replace	24	750	18,000	10,800	240
Subtotal initial cost			737,348	337,139	8,319
Service factor (35%)			258,072	--	--
Subtotal initial capital cost			995,420	--	--
Future connections cost					
Building sewer	29	55	1,595	957	--
Septic tank + gravity	6	2,277	13,662	8,197	60
Septic tank + STE pump	23	4,128	94,944	28,483	1,679
Subtotal future connection cost			110,201	37,637	1,739
Annual future connection cost			5,510	--	87

Table D-9. Quantities and costs of septic tank effluent pressure sewers for District #5 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	1,650	$ 17.00	$ 28,050	$ 16,830	$ 31
2½"	2,150	17.35	37,302	22,381	41
3"	6,920	18.20	125,944	75,566	131
4"	1,850	19.50	36,075	21,645	35
STE gravity sewer pipe					
6"	1,200	37.00	44,400	26,640	46
10"	1,450	41.80	60,610	36,366	55
Lift station					
#8 309 gpm TDH-63 ft			189,400	56,820	2,871
Force main, common trench					
6"	2,150	8.80	18,920	11,352	--
Force main, individual trench					
6"	1,600	17.75	28,400	17,040	--
Service connection					
gravity	42	1,577	66,234	39,740	--
STE pump	207	3,428	709,596	212,879	13,041
Septic tank					
upgrade	210	143	30,030	18,018	2,100
replace	55	750	41,250	24,750	5,500
Subtotal initial cost			1,416,211	580,027	23,851
Service factor (35%)			495,674	--	--
Subtotal initial capital cost			1,911,885	--	--
Future connections cost					
Building sewer	21	55	1,155	693	--
Septic tank + gravity	4	2,277	9,108	5,465	40
Septic tank + STE pump	17	4,128	70,176	21,053	1,241
Subtotal future connection cost			80,439	27,211	1,281
Annual future connection cost			4,022	--	64

Table D-10. Quantities and costs of septic tank effluent pressure sewers for District #6 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	2,950	$ 17.00	$ 50,150	$ 30,090	$ 56
2½"	2,500	17.35	43,375	26,025	47
3"	850	18.20	15,470	9,282	16
STE gravity sewer pipe					
4"	11,150	35.30	393,595	236,157	424
6"	1,100	37.00	40,700	24,420	42
8"	1,000	38.90	38,900	23,340	38
10"	2,000	41.80	83,600	50,160	76
Lift station					
#11 145 gpm TDH-36 ft			93,800	28,140	2,004
#12 510 gpm TDH-53 ft			293,000	87,900	3,436
Force main, common trench					
6"	1,050	8.80	9,240	5,544	--
8"	300	12.50	3,750	2,250	--
Force main, individual trench					
8"	2,850	22.10	62,985	37,791	--
Service connection					
gravity	171	1,577	269,667	161,800	--
STE pump	61	3,428	209,108	62,732	3,843
Septic tank					
upgrade	193	143	27,599	16,559	1,930
replace	44	750	33,000	19,800	440
Subtotal initial cost			1,667,939	821,990	12,352
Service factor (35%)			583,779	--	--
Subtotal initial capital cost			2,251,718	--	--
Future connections cost					
Building sewer	30	55	1,650	990	--
Septic tank + gravity	20	2,277	45,540	27,324	200
Septic tank + STE pump	10	4,128	41,280	12,384	730
Subtotal future connection cost			88,470	39,708	930
Annual future connection cost			4,423	--	46

Table D-11. Quantities and costs of septic tank effluent pressure sewers for District #7 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	900	$ 17.00	$ 15,300	$ 9,180	$ 17
3"	3,270	18.20	59,514	36,708	62
4"	2,120	19.50	41,340	24,804	40
Service connection					
STE pump	82	3,428	281,096	84,329	5,166
Septic tank					
upgrade	75	143	10,725	6,435	750
replace	12	750	9,000	5,400	120
Subtotal initial cost			416,975	165,856	6,155
Service factor (35%)			145,941	--	--
Subtotal initial capital cost			562,916	--	--
Future connections cost					
Building sewer	10	55	550	330	--
Septic tank + STE pump	10	4,128	41,280	12,384	730
Subtotal future connection cost			41,830	12,714	730
Annual future connection cost			2,091	--	36

Table D-12. Quantities and costs of septic tank effluent pressure sewers for District #8 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	1,750	$ 17.00	$ 29,750	$ 17,850	$ 33
2½"	5,750	17.35	99,762	59,857	109
3"	2,270	18.20	41,314	24,788	43
4"	2,710	19.50	52,845	31,707	52
STE gravity sewer pipe					
4"	200	35.30	7,060	4,236	8
6"	1,650	37.00	61,050	36,630	63
Service connection					
gravity	8	1,577	12,616	7,570	--
STE pump	140	3,428	479,920	143,976	8,820
Septic tank					
upgrade	131	143	18,733	112,398	1,310
replace	17	750	12,750	7,650	170
Subtotal initial cost			815,800	446,662	10,608
Service factor (35%)			285,530	--	--
Subtotal initial capital cost			1,101,330	--	--
Future connections cost					
Building sewer	32	55	1,760	1,056	--
Septic tank + gravity	3	2,277	6,831	4,099	30
Septic tank + STE pump	29	4,128	119,712	35,914	2,117
Subtotal future connection cost			128,303	41,069	2,147
Annual future connection cost			6,415	--	107

Table D-13. Quantities and costs of septic tank effluent pressure sewers for District #9 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2½"	1,800	$ 17.35	$ 31,230	$ 18,738	$ 34
3"	3,500	18.20	63,700	38,220	66
4"	5,580	19.50	108,810	65,286	106
Service connection					
STE pump	192	3,428	658,176	197,453	12,096
Septic tank					
upgrade	163	143	23,309	13,985	1,630
replace	44	750	33,000	19,800	440
Subtotal initial cost			918,225	353,482	14,372
Service factor (35%)			321,379	--	--
Subtotal initial capital cost			1,239,604	--	--
Future connections cost					
Building sewer	27	55	1,485	891	--
Septic tank + STE pump	27	4,128	111,456	33,437	1,971
Subtotal future connection cost			112,941	34,328	1,971
Annual future connection cost			5,647	--	99

Table D-14. Quantities and costs of septic tank effluent pressure sewers for District #10 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2½"	1,450	$ 17.35	$ 25,157	$ 15,094	$ 27
3"	4,300	18.20	78,260	46,956	82
4"	4,450	19.50	86,775	52,065	84
Service connection					
STE pump	118	3,428	404,504	121,351	7,434
Septic tank					
upgrade	110	143	15,730	9,438	1,100
replace	33	750	24,750	14,850	330
Subtotal initial cost			635,176	259,754	9,057
Service factor (35%)			222,312		
Subtotal initial capital cost			857,488		
Future connections cost					
Building sewer	27	55	1,485	891	--
Septic tank + STE pump	27	4,128	111,456	33,437	1,971
Subtotal future connection cost			112,941	34,328	1,971
Snnual future connection cost			5,647	--	99

Table D-15. Quantities and costs of septic tank effluent pressure sewers for District #11 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	500	$ 17.00	$ 8,500	$ 5,100	$ 9
2½"	400	17.35	6,940	4,164	8
3"	1,250	18.20	22,750	13,650	24
6"	7,100	22.40	159,040	95,424	135
Service connection					
STE pump	124	3,428	425,072	127,522	7,812
Septic tank					
upgrade	108	143	15,444	9,266	1,080
replace	38	750	28,500	17,100	380
Subtotal initial cost			666,246	272,226	9,448
Service factor (35%)			233,186	--	--
Subtotal initial capital cost			899,432	--	--
Future connections cost					
Building sewer	9	55	495	297	--
Septic tank + STE pump	9	4,128	37,152	11,146	657
Subtotal future connection cost			37,647	11,443	657
Annual future connection cost			1,882	--	33

Table D-16. Quantities and costs of septic tank effluent pressure sewers for District #12 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2½"	1,850	$ 17.35	$ 32,097	$ 19,258	$ 35
3"	5,200	18.20	94,640	56,784	99
4"	100	19.50	1,950	1,170	2
STE gravity sewer pipe					
6"	600	37.00	22,200	13,320	23
Service connection					
gravity	2	1,577	3,154	1,892	--
STE pump	70	3,428	239,960	71,988	4,410
Septic tank					
upgrade	60	143	8,580	5,148	600
replace	21	750	15,750	9,450	210
Subtotal initial cost			418,331	179,010	5,379
Service factor (35%)			146,416	--	--
Subtotal initial capital cost			564,747	--	--
Future connections cost					
Building sewer	10	55	550	330	--
Septic tank + gravity	2	2,277	4,554	2,732	20
Septic tank + STE pump	8	4,128	33,024	9,907	584
Subtotal future connection cost			38,128	12,969	604
Annual future connection cost			1,906	--	30

Table D-17. Quantities and costs of septic tank effluent pressure sewers for District #13 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	1,650	$ 17.00	$ 28,050	$ 16,830	$ 31
2½"	2,550	17.35	44,242	26,545	48
3"	2,830	18.20	51,506	30,904	54
4"	1,200	19.50	23,400	14,040	23
6"	2,550	22.40	57,120	34,272	48
STE gravity sewer pipe					
6"	850	37.00	31,450	18,870	32
8"	2,500	38.90	97,250	58,350	95
12"	800	45.00	36,000	21,600	30
15"	700	51.55	36,085	21,651	27
18"	2,350	60.40	141,940	85,164	89
Lift station					
#23 270 gpm TDH-25 ft			141,000	42,300	2,234
#25 950 gpm TDH-66 ft			384,000	115,200	4,704
Force main, common trench					
6"	750	8.80	6,600	3,960	--
8"	4,000	12.50	50,000	30,000	--
Force main, individual trench					
8"	800	22.10	17,680	10,608	--
Service connection					
gravity	32	1,577	50,464	30,278	--
STE pump	104	3,428	356,512	106,954	6,552
Septic tank					
upgrade	112	143	16,016	9,610	1,120
replace	43	750	32,250	19,350	430
Subtotal initial cost			1,601,565	696,486	15,517
Service factor (35%)			560,548	--	--
Subtotal initial capital cost			2,162,113	--	--
Future connections cost					
Building sewer	32	55	1,760	1,056	--
Septic tank + gravity	6	2,277	13,662	8,197	60
Septic tank + STE pump	26	4,128	107,328	32,198	1,898
Subtotal future connection cost			122,750	41,451	1,958
Annual future connection cost			6,137	--	98

Table D-18. Quantities and costs of septic tank effluent pressure sewers for District #14 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2½"	450	$ 17.35	$ 7,807	$ 4,684	$ 9
3"	3,300	18.20	60,060	36,036	63
Service connection					
STE pump	30	3,428	102,840	30,852	1,890
Septic tank					
upgrade	27	143	3,861	2,317	270
replace	7	750	5,250	3,150	70
Subtotal initial cost			179,818	77,039	2,302
Service factor (35%)			62,936	--	--
Subtotal initial capital cost			242,754	--	--
Future connections cost					
Building sewer	3	55	165	99	--
Septic tank + STE pump	3	4,128	12,384	3,715	219
Subtotal future connection cost			12,549	3,814	219
Annual future connection cost			627	--	11

Table D-19. Quantities and costs of septic tank effluent pressure sewers for District #15 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	1,350	$ 17.00	$ 22,950	$ 13,770	$ 26
2½"	3,000	17.35	52,050	31,230	57
3"	7,000	18.20	127,400	76,440	133
4"	3,800	19.50	74,100	44,460	72
STE gravity sewer pipe					
18"	1,000	60.40	60,400	36,240	38
Service connection					
gravity	4	1,577	6,308	3,785	--
STE pump	131	3,428	449,068	134,720	8,253
Septic tank					
upgrade	148	143	21,164	12,698	1,480
replace	32	750	24,000	14,400	320
Subtotal initial cost			837,440	367,743	10,379
Service factor (35%)			293,104	--	--
Subtotal initial capital cost			1,130,544	--	--
Future connections cost					
Building sewer	29	55	1,595	957	--
Septic tank + gravity	1	2,277	2,277	1,366	10
Septic tank + STE pump	28	4,128	115,584	34,675	2,044
Subtotal future connection cost			119,456	36,998	2,054
Annual future connection cost			5,973	--	103

Table D-20. Summary and present worth of costs of the collection portion for Alternative 5B - conventional gravity sewers (June 1981 costs).

	Initial Cost						Future Connections Cost							
				Present Worth			Annual	Total	Incremental	Present Worth				
District	Capital	Salvage	O&M	Salvage	O&M	Total	Construction	Salvage	Annual O&M	Construction	Salvage	O&M	Total	Total Present Worth
Indian Lake														
1	2,027,396	870,316	10,884	200,177	109,910	1,937,129	1,679	20,142	--	16,955	4,033	--	12,322	1,949,451
2	831,609	349,806	7,194	80,455	72,647	823,801	1,119	13,428	--	11,300	3,088	--	8,212	832,013
3	1,455,953	672,600	7,292	154,698	73,637	1,374,892	1,772	21,261	--	17,894	4,890	--	13,004	1,387,896
Subtotal:	4,314,958	1,892,742	25,370	435,330	256,194	4,135,822	4,570	54,831	--	46,149	12,611	--	33,538	4,169,360
Pipestone Lake														
2	314,153	143,724	1,966	33,057	19,853	300,949	--	--	--	--	--	--	--	300,949
3	585,226	244,241	6,355	56,175	64,175	593,226	--	--	--	--	--	--	--	593,226
Subtotal:	899,179	387,965	8,321	89,232	84,028	894,175	--	--	--	--	--	--	--	894,175
Sister Lakes														
1	1,817,230	408,559	11,693	93,969	118,079	1,841,340	1,958	23,499	--	19,772	5,405	--	14,367	1,855,707
4	1,201,922	488,184	10,380	112,282	104,820	1,194,460	2,704	32,451	--	27,306	7,464	--	19,842	1,214,302
5	2,340,835	838,768	20,202	192,917	204,006	2,351,924	1,958	23,499	--	19,772	5,405	--	14,367	2,366,291
6	2,455,669	1,003,184	15,339	230,732	154,898	2,379,835	2,797	33,570	--	28,245	7,721	--	20,524	2,400,359
7	694,030	281,708	7,484	64,793	75,576	704,813	932	11,190	--	9,412	2,574	--	6,838	711,651
8	1,568,262	644,605	13,326	148,259	134,570	1,554,573	2,984	35,808	--	30,133	8,236	--	21,897	1,576,470
9	1,576,895	641,556	14,950	147,558	150,970	1,580,307	2,518	30,213	--	25,428	6,949	--	18,479	1,598,786
10	1,265,231	517,923	12,139	119,122	122,583	1,268,692	2,518	30,213	--	25,428	6,949	--	18,479	1,287,171
11	1,677,180	589,775	19,177	135,648	193,655	1,735,187	839	10,071	--	8,472	2,316	--	6,156	1,741,343
12	831,721	315,243	15,264	72,506	154,140	913,357	932	11,190	--	9,412	2,574	--	6,838	920,195
13	2,404,909	877,884	20,460	201,913	206,611	2,409,607	2,984	35,808	--	30,133	8,236	--	21,897	2,431,504
14	344,589	142,617	6,218	32,802	62,791	374,578	280	3,357	--	2,828	772	--	2,056	376,634
15	2,306,076	871,283	17,076	200,395	172,439	2,278,120	2,704	32,451	--	27,306	7,464	--	19,842	2,297,962
Subtotal:	19,684,009	7,621,289	183,708	1,752,896	1,855,138	19,786,251	26,108	313,320	--	263,647	72,065	--	191,582	19,977,833
Total	24,898,346	9,901,996	217,399	2,277,458	2,195,360	24,816,248	30,678	368,151	--	309,796	84,676	--	225,120	25,041,368

Table D-21. Quantities and costs for conventional gravity sewers for District #1 Indian Lake.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer pipe					
8"	17,910	$ 44.00	$ 788,040	$472,824	$ 1,343
Lift station					
#7 15 gpm TDH-45 ft			12,750	3,825	1,767
#8 57 gpm TDH-40 ft			54,000	16,200	2,129
#9 115 gpm TDH-47 ft			93,800	28,140	2,629
#10 172 gpm TDH-51 ft			93,800	28,140	2,716
Force main, common trench					
2"	700	4.60	3,220	1,932	--
4"	250	6.50	1,625	975	--
6"	700	8.80	6,160	3,696	--
Force main, individual trench					
2"	330	13.00	4,290	2,574	--
4"	300	14.90	4,470	2,682	--
6"	1,300	17.75	23,075	13,845	--
Wye	263	205	53,915	32,349	--
Service connection	263	500	131,500	78,900	--
House lead					
gravity	260	1,160	301,600	180,960	--
grinder pump	3	3,660	10,980	3,294	300
Septic tank abandonment	263	50	13,150	--	--
Subtotal initial cost			1,596,375	870,336	10,884
Service factor (27%)			431,021	--	--
Subtotal initial capital cost			2,027,396		
Future connections cost					
Wye	18	205	3,690	2,214	--
Service connection	18	500	9,000	5,400	--
House lead, gravity	18	1,160	20,880	12,528	--
Subtotal future connection cost			33,570	20,142	--
Annual future connection cost			1,679	--	--

Table D-22. Quantities and costs for conventional gravity sewers for District #2 Indian Lake.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer pipe					
8"	8,700	$ 44.00	$328,800	$197,280	$ 652
Lift station					
#6 28 gpm TDH-69 ft			30,900	9,270	1,910
#5 41 gpm TDH-50 ft			30,900	9,270	1,913
#4 77 gpm TDH-75 ft			54,000	16,200	2,219
Force main, common trench					
2"	950	4.60	4,370	2,622	--
3"	1,420	5.75	8,165	4,899	--
Force main, individual trench					
2"	250	13.00	3,250	1,950	--
Wye	95	205	19,475	11,685	--
Service connections	95	500	47,500	28,500	--
House lead					
gravity	90	1,160	104,400	62,640	--
grinder pump	5	3,660	18,300	5,490	500
Septic tank abandonment	95	50	4,750	--	--
Subtotal initial cost			654,810	349,806	7,194
Service factor (27%)			176,799	--	--
Subtotal initial capital cost			831,609		
Future connections cost					
Wye	12	205	2,460	1,476	--
Service connection	12	500	6,000	3,600	--
House lead, gravity	12	1,160	13,920	8,352	--
Subtotal future connection cost			22,380	13,428	--
Annual future connection cost			1,119	--	--

Table D-23. Quantities and costs for conventional gravity sewers for District #3 Indian Lake.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer pipe					
8"	13,290	$ 44.00	$ 584,760	$350,856	$ 997
Lift station					
#3 126 gpm TDH-80 ft			93,800	56,280	2,749
#2 144 gpm TDH-42 ft			93,800	56,280	2,646
Force main, common trench					
4"	1,350	6.50	8,775	5,265	--
Wye	179	205	36,695	22,017	--
Service connections	179	500	89,500	53,700	--
House lead					
gravity	170	1,160	197,200	118,320	--
grinder pump	9	3,660	32,940	9,882	900
Septic tank abandonment	179	50	8,950	--	--
Subtotal initial cost			1,146,420	672,600	7,292
Service factor (27%)			309,533	--	--
Subtotal initial capital cost			1,455,953	--	--
Future connections cost					
Wye	19	205	3,895	2,337	--
Service connection	19	500	9,500	5,700	--
House lead, gravity	19	1,160	22,040	13,224	--
Subtotal future connection cost			35,435	21,261	--
Annual future connection cost			1,772	--	--

Table D-24. Quantities and costs for conventional gravity sewers for District #2 Pipestone Lake.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer pipe					
8"	2,510	$ 44.00	$ 110,440	$ 66,264	$ 188
Lift station					
#P3 17 gpm TDH-63 ft			12,750	3,825	1,778
Force main, individual trench					
2"	5,280	13.00	68,640	41,184	--
Wye	29	205	5,945	3,567	--
Service connection	29	500	14,500	8,700	--
House lead					
gravity	29	1,160	33,640	20,184	--
Septic tank abandonment	29	50	1,450	--	--
Subtotal initial cost			247,365	143,724	1,966
Service factor (27%)			66,788	--	--
Subtotal initial capital cost			314,153	--	--

Table D-25. Quantities and costs for conventional gravity sewers for District #3 Pipestone Lake.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer pipe					
8"	3,510	$ 44.00	$ 154,440	$ 92,664	$ 263
Lift station					
#P2 28 gpm TDH-50 ft			30,900	9,270	1,896
#P1 40 gpm TDH-118 ft			30,900	9,270	1,981
#P4 40 gpm TDH-54 ft			30,900	9,270	1,915
Force main, common trench					
3"	1,175	5.75	6,756	4,054	--
Force main, individual trench					
3"	8,950	14.15	126,642	75,985	--
Wye	38	205	7,790	4,674	--
Service connection	38	500	19,000	11,400	--
House lead					
gravity	35	1,160	40,600	24,360	--
grinder pump	3	3,660	10,980	3,294	300
Septic tank abandonment	38	50	1,900	--	--
Subtotal initial cost			460,808	244,241	6,355
Service factor (27%)			124,418	--	--
Subtotal initial capital cost			585,226	--	--

Table D-26. Quantities and costs for conventional gravity sewers for District #1 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer pipe					
8"	7,810	$ 44.00	$ 343,640	$206,184	$ 586
Lift station					
#1 15 gpm TDH-75 ft			12,750	3,825	1,779
#2 15 gpm TDH-45 ft			12,750	3,825	1,767
#3 59 gpm TDH-25 ft			54,000	16,200	2,108
#4 75 gpm TDH-30 ft			54,000	16,200	2,128
#5 86 gpm TDH-25 ft			54,000	16,200	2,125
Force main, common trench					
2"	1,700	4.60	7,820	4,692	--
3"	1,950	5.75	11,212	6,727	--
Force main, individual trench					
3"	400	14.15	5,660	3,396	--
Wye	114	205	23,370	14,022	--
Service connection	114	500	57,000	34,200	--
House lead					
gravity	102	1,160	118,320	70,992	--
grinder pump	12	3,360	40,320	12,096	1,200
Septic tank abandonment	114	50	5,700	--	--
Subtotal initial cost			800,542	408,559	11,693
Service factor (27%)			216,146	--	--
Subtotal initial capital cost			1,817,230	--	--
Future connections cost					
Wye	21	205	4,305	2,583	--
Service connection	21	500	10,500	6,300	--
House lead, gravity	21	1,160	24,360	14,616	--
Subtotal future connection cost			39,165	23,499	--
Annual future connection cost			1,958	--	--

Table D-27. Quantities and costs for conventional gravity sewers for District #4 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer pipe					
8"	10,090	$ 44.00	$ 443,960	$266,376	$ 757
Lift station					
#7 25 gpm TDH-20 ft			30,900	9,270	1,873
#6 140 gpm TDH-90 ft			93,800	28,140	2,814
#8 20 gpm TDH-20 ft			12,750	3,825	1,760
#9 185 gpm TDH-18 ft			93,800	28,140	2,576
Force main, common trench					
2"	700	4.60	3,220	1,932	--
4"	2,380	6.50	15,470	9,282	--
Force main, individual trench					
2"	150	13.00	1,950	1,170	--
Wye	123	205	25,215	15,129	--
Service connection	123	500	61,500	36,900	--
House lead					
gravity	117	1,160	135,720	81,432	--
grinder pump	6	3,660	21,960	6,588	600
Septic tank abandonment	123	50	6,150	--	--
Subtotal initial cost			946,395	488,184	10,380
Service factor (27%)			255,527	--	--
Subtotal initial capital cost			1,201,922	--	--
Future connections cost					
Wye	29	205	5,945	3,567	--
Service connection	29	500	14,500	8,700	--
House lead, gravity	29	1,160	33,640	20,184	--
Subtotal future connection cost			54,085	32,451	--
Annual future connection cost			2,704	--	--

Table D-28. Quantities and costs for conventional gravity sewers for District #5 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer pipe					
8"	14,470	$ 44.00	$ 636,680	$328,008	$ 1,085
Lift station					
#10 12 gpm TDH-15 ft			12,750	3,825	1,755
#11 40 gpm TDH-25 ft			30,900	9,270	1,886
#12 255 gpm TDH-30 ft			141,000	42,300	2,937
#13 315 gpm TDH-35 ft			189,400	56,820	3,444
#15 17 gpm TDH-25 ft			12,750	3,825	1,761
#16 27 gpm TDH-35 ft			30,900	9,270	1,884
#17 370 gpm TDH-20 ft			189,400	56,820	3,350
Force main, common trench					
2"	1,000	4.60	4,600	2,760	--
3"	850	5.75	4,887	2,932	--
6"	1,950	8.80	17,160	10,296	--
Force main, individual trench					
2"	300	13.00	3,900	2,340	--
6"	500	17.75	8,875	5,325	--
Wye	265	205	54,325	32,596	--
Service connection	265	500	132,500	79,500	--
House lead					
gravity	244	1,160	283,040	169,824	--
grinder pump	21	3,660	76,860	23,058	2,100
Septic tank abandonment	265	50	13,250	--	--
Subtotal initial cost			1,843,177	838,768	20,202
Service factor (27%)			497,658	--	--
Subtotal initial capital cost			2,340,835	--	--
Future connections cost					
Wye	21	205	4,305	2,583	--
Service connection	21	500	10,500	6,300	--
House lead, gravity	21	1,160	24,360	14,616	--
Subtotal future connection cost			39,165	23,499	--
Annual future connection cost			1,958	--	--

Table D-29. Quantities and costs for conventional gravity sewers for District #6 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer pipe					
8"	19,400	$ 44.00	$ 853,600	$ 512,160	$ 1,455
10"	1,740	47.20	82,128	49,277	130
Lift station					
#18 18 gpm TDH-25 ft			12,750	3,825	1,761
#19 30 gpm TDH-35 ft			30,900	9,270	1,887
#20 70 gpm TDH-30 ft			54,000	16,200	2,124
#21 77 gpm TDH-20 ft			54,000	16,200	2,110
#22 510 gpm TDH-55 ft			293,000	87,900	4,372
Force main, common trench					
2"	1,030	4.60	4,738	2,843	--
4"	600	6.50	3,900	2,340	--
6"	300	8.80	2,640	1,584	--
Force main, individual trench					
6"	2,850	17.75	50,587	30,352	--
Wye	237	205	48,585	29,151	--
Service connection	237	500	118,500	71,100	--
House lead					
gravity	222	1,160	257,520	154,512	--
grinder pump	15	3,660	54,900	16,470	1,500
Septic tank abandonment	237	50	11,850	--	--
Subtotal initial cost			1,933,598	1,003,184	15,339
Service factor (27%)			522,071	--	--
Subtotal initial capital cost			2,455,669	--	--
Future connections cost					
Wye	30	205	6,150	3,690	--
Service connection	30	500	15,000	9,000	--
House lead, gravity	30	1,160	34,800	20,880	--
Subtotal future connection cost			55,950	33,570	--
Annual future connection cost			2,797	--	--

Table D-30. Quantities and costs for conventional gravity sewers for District #7 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer pipe					
8"	5,490	$ 44.00	$237,160	$142,296	$ 404
Lift stations					
#23 12 gpm TDH-37 ft			12,750	3,825	1,761
#24 38 gpm TDH-30 ft			30,900	9,270	1,889
#25 58 gpm TDH-40 ft			54,000	16,200	2,130
Force main, common trench					
2"	400	4.60	1,840	1,104	--
3"	1,250	5.75	7,188	4,312	--
Force main, individual trench					
3"	250	14.15	3,537	2,122	--
Wye	87	205	17,835	10,701	--
Service connection	87	500	43,500	26,100	--
House lead					
gravity	74	1,160	85,840	51,504	--
grinder pump	13	3,660	47,580	14,274	1,300
Septic tank abandonment	87	50	4,350	--	--
Subtotal initial cost			546,480	281,708	7,484
Service factor (27%)			147,550	--	--
Subtotal initial capital cost			694,030	--	--
Future connections cost					
Wye	10	205	2,050	1,230	--
Service connection	10	500	5,000	3,000	--
House lead, gravity	10	1,160	11,600	6,960	--
Subtotal future connection cost			18,650	11,190	--
Annual future connection cost			932	--	--

Table D-31. Quantities and costs for conventional gravity sewers for District #8 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer pipe					
8"	14,410	$ 44.00	$ 634,040	$380,424	$ 1,081
Lift station					
#14 10 gpm TDH-30 ft			12,750	3,825	1,758
#26 26 gpm TDH-35 ft			30,900	9,270	1,899
#27 130 gpm TDH-35 ft			93,800	28,140	2,496
#29 12 gpm TDH-15 ft			12,750	3,825	1,755
#28 190 gpm TDH-30 ft			93,800	28,140	2,637
Force main, common trench					
2"	1,650	4.60	7,590	4,554	--
3"	520	5.75	2,990	1,794	--
4"	550	6.50	3,575	2,145	--
Force main, individual trench					
2"	150	13.00	1,950	1,170	--
3"	150	14.15	2,122	1,273	--
4"	850	14.90	12,665	7,599	--
Wye	148	205	30,340	18,204	--
Service connection	148	500	74,000	44,400	--
House lead					
gravity	131	1,160	151,960	91,176	--
grinder pump	17	3,660	62,220	18,666	1,700
Septic tank abandonment	148	50	7,400	--	--
Subtotal initial cost			1,234,852	644,605	13,326
Service factor (27%)			333,410	--	--
Subtotal initial capital cost			1,568,262	--	--
Future connections cost					
Wye	32	205	6,560	3,936	--
Service connection	32	500	16,000	9,600	--
House lead, gravity	32	1,160	37,120	22,272	--
Subtotal future connection cost			59,680	35,808	--
Annual future connection cost			2,984	--	--

Table D-32. Quantities and costs for conventional gravity sewers for District #9 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer pipe					
8"	11,380	$ 44.00	$ 500,720	$300,432	$ 853
Lift station					
#30 14 gpm TDH-25 ft			12,750	3,825	1,789
#31 45 gpm TDH-30 ft			30,900	9,270	1,866
#32 77 gpm TDH-28 ft			54,000	16,200	2,125
#33 86 gpm TDH-25 ft			54,000	16,200	2,125
#34 118 gpm TDH-44 ft			93,800	28,140	2,624
#35 18 gpm TDH-40 ft			12,750	3,825	1,768
Force main, common trench					
2"	1,150	4.60	5,290	3,174	--
3"	640	5.75	3,680	2,208	--
4"	1,540	6.50	10,010	6,006	--
Force main, individual trench					
2"	550	13.00	7,150	4,290	--
3"	600	14.15	8,490	5,094	--
4"	450	14.90	6,705	4,023	--
Wye	207	205	42,435	25,461	--
Service connection	207	500	103,500	62,100	--
House lead					
gravity	189	1,160	219,240	131,544	--
grinder pump	18	3,660	65,880	19,764	1,800
Septic tank abandonment	207	50	10,350	--	--
Subtotal initial cost			1,241,650	641,556	14,950
Service factor (27%)			335,245	--	--
Subtotal initial capital cost			1,576,895	--	--
Future connections cost					
Wye	27	205	5,535	3,321	--
Service connection	27	500	13,500	8,100	--
House lead, gravity	27	1,160	31,320	18,792	--
Subtotal future connection cost			50,355	30,213	--
Annual future connection cost			2,518	--	--

Table D-33. Quantities and costs for conventional gravity sewers for District #10 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer pipe					
8"	10,400	$ 44.00	$ 457,600	$274,560	$ 780
Lift station					
#41 8 gpm TDH-30 ft			12,750	3,825	1,756
#42 16 gpm TDH-25 ft			12,750	3,825	1,760
#43 28 gpm TDH-25 ft			30,900	9,270	1,878
#44 82 gpm TDH-25 ft			54,000	16,200	2,123
#45 102 gpm TDH-20 ft			93,800	28,140	2,542
Force main, common trench					
2"	1,000	4.60	4,600	2,760	--
3"	1,760	5.75	10,120	6,072	--
Force main, individual trench					
2"	800	13.00	10,400	6,240	--
4"	200	14.90	2,980	1,788	--
Wye	143	205	29,315	17,589	--
Service connection	143	500	71,500	42,900	--
House lead					
gravity	130	1,160	150,800	90,480	--
grinder pump	13	3,660	47,580	14,274	1,300
Septic tank abandonment	143	50	7,150	--	--
Subtotal initial cost			996,245	517,923	12,139
Service factor (27%)			268,986	--	--
Subtotal initial capital cost			1,265,231	--	--
Future connection cost					
Wye	27	205	5,535	3,321	--
Service connection	27	500	13,500	8,100	--
House lead, gravity	27	1,160	31,320	18,792	--
Subtotal future connection cost			50,355	30,213	--
Annual future connection cost			2,518	--	--

Table D-34. Quantities and costs for conventional gravity sewers for District #11 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer pipe					
8"	8,960	$ 44.00	$ 394,240	$236,544	$ 672
Lift station					
#46 125 gpm TDH-35 ft			93,800	28,140	2,602
#47 132 gpm TDH-30 ft			93,800	28,140	2,592
#48 145 gpm TDH-25 ft			93,800	28,140	2,583
#49 17 gpm TDH-35 ft			12,750	3,825	1,765
#50 167 gpm TDH-35 ft			93,800	28,140	2,640
#52 181 gpm TDH-50 ft			141,000	42,300	2,723
Force main, common trench					
2"	570	4.60	2,622	1,573	--
4"	1,810	6.50	11,765	7,059	--
6"	790	8.80	6,952	4,171	--
Force main, individual trench					
4"	150	14.90	2,235	1,341	--
6"	240	17.75	4,260	2,556	--
Wye	146	205	29,930	17,958	--
Service connection	146	500	73,000	43,800	--
House lead					
gravity	110	1,160	127,600	76,560	--
grinder pump	36	3,660	131,760	39,528	3,600
Septic tank abandonment	146	50	7,300	--	--
Subtotal initial cost			1,320,614	589,775	19,177
Service factor (27%)			356,566	--	--
Subtotal initial capital cost			1,677,180	--	--
Future connections cost					
Wye	9	205	1,845	1,107	--
Service connection	9	500	4,500	2,700	--
House lead, gravity	9	1,160	10,440	6,264	--
Subtotal future connection cost			16,785	10,071	--
Annual future connection cost			839	--	--

Table D-35. Quantities and costs for conventional gravity sewers for District #12 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer pipe					
8"	5,240	$ 44.00	$230,560	$138,336	$ 393
Lift station					
#51 6 gpm TDH-40 ft			12,750	3,825	1,756
#61 14 gpm TDH-45 ft			12,750	3,825	1,766
#60 21 gpm TDH-25 ft			12,750	3,825	1,763
#59 25 gpm TDH-20 ft			30,900	9,270	1,873
#53 37 gpm TDH-50 ft			30,900	9,270	1,908
#56 49 gpm TDH-20 ft			30,900	9,270	1,885
#57 56 gpm TDH-35 ft			54,000	16,200	2,120
Force main, common trench					
2"	2,530	4.60	11,638	6,983	--
3"	730	5.75	4,197	2,518	--
Force main, individual trench					
2"	1,150	13.00	14,950	8,970	--
3"	600	14.15	8,490	5,094	--
Wye	81	205	16,605	9,963	--
Service connection	81	500	40,500	24,300	--
House lead					
gravity	63	1,160	73,080	43,848	--
grinder pump	18	3,660	65,880	19,764	1,800
Septic tank abandonment	81	50	4,050	--	--
Subtotal initial cost			654,900	315,243	15,264
Service factor (27%)			176,823	--	--
Subtotal initial capital cost			831,723	--	--
Future connections cost					
Wye	10	205	2,050	1,230	--
Service connection	10	500	5,000	3,000	--
House lead, gravity	10	1,160	11,600	6,960	--
Subtotal future connection cost			18,650	11,190	--
Annual future connection cost			932	--	--

Table D-36. Quantities and costs for conventional gravity sewers for District #13 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer pipe					
8"	11,100	$ 44.00	$ 488,400	$293,040	$ 832
12"	1,620	50.15	81,243	48,746	121
15"	2,390	56.70	135,513	81,308	179
Lift station					
#54 223 gpm TDH-20 ft			141,000	42,300	2,855
#55 232 gpm TDH-25 ft			141,000	42,300	2,889
#36 160 gpm TDH-40 ft			93,800	28,140	2,655
#37 14 gpm TDH-25 ft			12,750	3,825	1,759
#38 35 gpm TDH-30 ft			30,900	9,270	1,887
#39 6 gpm TDH-15 ft			12,750	3,825	1,752
#40 950 gpm TDH-25 ft			384,000	115,200	4,731
Force main, common trench					
2"	1,710	4.60	7,866	4,720	--
6"	1,790	8.80	15,752	9,451	--
8"	640	12.50	8,000	4,800	--
Force main, individual trench					
2"	200	13.00	2,600	1,560	--
6"	200	17.75	3,550	2,130	--
8"	800	22.10	17,680	10,608	--
Wye	155	205	31,775	19,065	--
Service connection	155	500	77,500	46,500	--
House lead					
gravity	147	1,160	170,520	102,312	--
grinder pump	8	3,660	29,280	8,784	800
Septic tank abandonment	155	50	7,750	--	--
Subtotal initial cost			1,893,629	877,884	20,460
Service factor (27%)			511,280	--	--
Subtotal initial capital cost			2,404,909	--	--
Future connections cost					
Wye	32	205	6,560	3,936	--
Service connection	32	500	16,000	9,600	--
House lead, gravity	32	1,160	37,120	22,272	--
Subtotal future connection cost			59,680	35,808	--
Annual future connection cost			2,984	--	--

Table D-37. Quantities and costs for conventional gravity sewers for District #14 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer pipe					
8"	3,070	$ 44.00	$135,080	$ 81,048	$ 230
Lift station					
#67 7 gpm TDH-15 ft			12,750	3,825	1,753
#68 11 gpm TDH-25 ft			12,750	3,825	1,757
#69 22 gpm TDH-50 ft			12,750	3,825	1,778
Force main, common trench					
2"	1,650	4.60	7,590	4,554	--
Force main, individual trench					
2"	600	13.00	7,800	4,680	--
Wye	34	205	6,970	4,182	--
Service connection	34	500	17,000	10,200	--
House lead					
gravity	27	1,160	31,320	18,792	--
grinder pump	7	3,660	25,620	7,686	700
Septic tank abandonment	34	50	1,700	--	--
Subtotal initial cost			271,330	142,617	6,218
Service factor (27%)			73,259	--	--
Subtotal initial capital cost			344,589	--	--
Future connections cost					
Wye	3	205	615	369	--
Service connection	3	500	1,500	900	--
House lead, gravity	3	1,160	3,480	2,088	--
Subtotal future connection cost			5,595	3,357	--
Annual future connection cost			280	--	--

Table D-38. Quantities and costs for conventional gravity sewers for District #15 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer pipe					
8"	13,620	$ 44.00	$ 599,280	$359,568	$ 1,021
18"	1,940	65.58	127,225	76,335	146
Lift stations					
#63 18 gpm TDH-20 ft			12,750	3,825	1,759
#62 22 gpm TDH-20 ft			12,750	3,825	1,761
#64 45 gpm TDH-40 ft			30,900	9,270	1,901
#65 60 gpm TDH-45 ft			54,000	16,200	2,139
#66 93 gpm TDH-25 ft			54,000	16,200	2,130
#58 1,040 gpm TDH-25 ft			512,000	153,600	5,319
Force main, common trench					
2"	450	4.60	2,070	1,242	--
3"	2,150	5.75	12,362	7,417	--
10"	1,150	18.00	20,700	12,420	--
Force main, individual trench					
2"	800	13.00	10,400	6,240	--
Wye	180	205	36,900	22,140	--
Service connection	180	500	90,000	54,000	--
House lead					
gravity	171	1,160	198,531	119,119	--
grinder pump	9	3,660	32,940	9,882	900
Septic tank abandonment	180	50	9,000	--	--
Subtotal initial cost			1,815,808	871,283	17,076
Service factor (27%)			490,268	--	--
Subtotal initial capital cost			2,306,076	--	--
Future connections cost					
Wye	29	205	5,945	3,567	--
Service connection	29	500	14,500	8,700	--
House lead, gravity	29	1,160	33,640	20,184	--
Subtotal future connection cost			54,085	32,451	--
Annual future connection cost			2,704	--	--

Table D-39. Summary and present worth of costs of the collection portion for septic tank effluent gravity sewers (June 1981 costs).

	Initial Cost						Future Connections Cost							
				Present Worth			Annual	Total	Incremental		Present Worth			
District	Capital	Salvage	O&M	Salvage	O&M	Total	Construction	Salvage	Annual O&M	Construction	Salvage	O&M	Total	Total Present Worth
Indian Lake														
1	1,919,716	773,662	10,541	177,942	106,446	1,848,223	2,099	25,186	9	21,196	5,793	649	16,052	1,864,275
2	849,019	337,202	6,197	77,556	62,579	834,042	2,565	30,782	11	25,902	7,080	793	19,615	853,657
3	1,405,166	558,518	7,017	128,459	70,860	1,347,567	4,198	50,371	18	42,393	11,585	1,298	32,106	1,379,673
Subtotal:	4,173,901	1,669,382	23,755	383,957	239,885	4,029,832	9,911	118,931	38	89,491	24,498	2,740	67,773	4,097,605
Pipestone Lake														
2	303,384	131,013	1,722	30,133	17,389	290,640	--	--	--	--	--	--	--	290,640
3	577,125	225,450	5,098	51,853	51,481	576,753	--	--	--	--	--	--	--	576,753
Subtotal:	880,509	356,463	6,820	81,986	68,870	867,393	--	--	--	--	--	--	--	867,393
Sister Lakes														
1	973,299	363,366	9,659	83,574	97,539	987,264	2,449	29,383	10	24,731	6,758	721	18,694	1,005,958
4	1,155,900	506,956	8,875	116,600	89,622	1,128,922	3,381	40,577	14	34,142	9,333	1,010	25,819	1,154,741
5	2,314,736	826,100	17,479	190,003	176,508	2,321,241	2,449	29,383	10	24,731	6,758	721	18,694	2,339,935
6	2,339,229	890,061	13,126	204,714	132,550	2,267,065	3,498	41,976	15	35,324	9,654	1,082	26,752	2,293,817
7	650,596	242,579	6,254	55,793	63,155	657,958	1,166	13,992	5	11,775	3,218	360	8,917	666,875
8	1,473,534	563,376	11,159	129,576	112,687	1,456,645	3,731	44,774	16	37,677	10,298	1,154	28,533	1,485,178
9	1,523,062	580,016	12,932	133,404	130,591	1,520,249	3,148	37,778	13	31,789	8,689	937	24,037	1,544,286
10	1,213,141	463,874	10,223	106,691	103,235	1,209,685	3,148	37,778	13	31,789	8,689	937	24,037	1,233,722
11	1,674,101	546,479	15,437	125,690	155,887	1,704,298	1,049	12,593	4	10,593	2,896	288	7,985	1,712,283
12	808,357	281,346	11,894	64,710	120,109	863,756	1,166	13,992	5	11,775	3,218	360	8,917	872,673
13	2,444,685	833,027	16,806	191,596	169,712	2,422,801	3,731	44,774	16	37,677	10,298	1,154	28,533	2,451,334
14	322,516	124,306	4,866	28,590	49,138	343,064	350	4,198	1	3,534	966	144	2,712	345,776
15	2,258,847	791,292	14,582	181,997	147,253	2,224,103	3,381	40,577	14	34,142	9,333	1,010	25,819	2,249,922
Subtotal:	19,172,003	7,012,778	153,292	1,612,938	1,547,986	19,107,015	32,647	391,775	137	329,679	90,108	9,878	249,449	19,356,500
Total	24,226,413	9,038,623	183,867	2,078,881	1,856,741	24,004,276	42,558	510,706	175	419,170	114,606	12,618	317,222	24,321,498

Table D-40. Quantities and costs for septic tank effluent gravity sewers for District #1 Indian Lake.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	15,510	$ 35.30	$ 547,503	$328,502	$ 589
6"	620	37.00	22,940	13,764	24
8"	1,780	38.90	69,242	41,545	68
Lift stations					
#7 15 gpm TDH-45 ft			12,750	3,825	1,327
#8 57 gpm TDH-40 ft			54,000	16,200	1,609
#9 115 gpm TDH-47 ft			93,800	28,140	2,009
#10 172 gpm TDH-51 ft			93,800	28,140	2,096
Force main, common trench					
2"	700	4.60	3,220	1,932	--
4"	250	6.50	1,625	975	--
6"	700	8.80	6,160	3,696	--
Force main, individual trench					
2"	330	13.00	4,290	2,574	--
4"	300	14.90	4,470	2,682	--
6"	1,300	17.75	23,075	13,845	--
Service connection					
gravity	260	1,577	410,020	246,012	--
STE pump	3	3,600	10,800	3,240	189
Septic tank					
upgrade	219	143	31,317	18,790	2,190
replace	44	750	33,000	19,800	440
Subtotal initial cost			1,422,012	773,662	10,541
Service factor (35%)			497,704	--	--
Subtotal initial capital cost			1,919,716	--	--
Future connections cost					
Building sewer	18	55	990	594	--
Septic tank + gravity	18	2,277	40,986	24,592	180
Subtotal future connection cost			41,976	25,186	180
Annual future connection cost			2,099	--	9

Table D-41. Quantities and costs for septic tank effluent gravity sewers for District #2 Indian Lake.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	7,450	$ 35.30	$262,985	$157,791	$ 283
6"	1,250	37.00	46,250	27,750	47
Lift station					
#6 28 gpm TDH-69 ft			30,900	9,270	1,450
#5 41 gpm TDH-50 ft			30,900	9,270	1,453
#4 77 gpm TDH-75 ft			54,000	16,200	1,699
Force main, common trench					
2"	950	4.60	4,370	2,622	--
3"	1,420	5.75	8,165	4,899	--
Force main, individual trench					
2"	250	13.00	3,250	1,950	--
Service connection					
gravity	90	1,577	141,930	85,158	--
STE pump	5	3,600	18,000	5,400	315
Septic tank					
upgrade	71	143	10,153	6,092	710
replace	24	750	18,000	10,800	240
Subtotal initial cost			628,903	337,202	6,197
Service factor (35%)			220,116	--	--
Subtotal initial capital cost			849,019	--	--
Future connections cost					
Building sewer	22	55	1,210	726	--
Septic tank + gravity	22	2,277	50,094	30,056	220
Subtotal future connection cost			51,304	30,782	220
Annual future connection cost			2,565	--	11

Table D-42. Quantities and costs for septic tank effluent gravity sewers for District #3 Indian Lake.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	6,190	$ 35.30	$ 218,507	$131,104	$ 235
6"	1,900	37.00	70,300	42,180	72
8"	5,200	38.90	202,280	121,368	198
Lift station					
#3 126 gpm TDH-80 ft			93,800	28,140	2,129
#2 144 gpm TDH-42 ft			93,800	28,140	2,026
Force main, common trench					
4"	1,350	6.50	8,775	5,265	--
Service connection					
gravity	170	1,577	268,090	160,854	--
STE pump	9	3,600	32,400	9,720	567
Septic tank					
upgrade	134	143	19,162	11,497	1,340
replace	45	750	33,750	20,250	450
Subtotal initial cost			1,040,864	558,518	7,017
Service factor (35%)			364,302	--	--
Subtotal initial capital cost			1,405,166	--	--
Future connections cost					
Building sewer	36	55	1,980	1,188	--
Septic tank + gravity	36	2,277	81,972	49,183	360
Subtotal future connection cost			83,952	50,371	360
Annual future connection cost			4,198	--	18

Table D-43. Quantities and costs for septic tank effluent gravity sewers for District #2 Pipestone Lake.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	2,510	$ 35.30	$ 88,603	$ 53,162	$ 95
Lift station					
#P3 17 gpm TDH-63 ft			12,750	3,825	1,337
Force main, individual trench					
2"	5,280	13.00	68,640	41,184	--
Service connection					
gravity	29	1,577	45,733	27,440	--
Septic tank					
upgrade	21	143	3,003	1,802	210
replace	8	750	6,000	3,600	80
Subtotal initial cost			224,729	131,013	1,722
Service factor (35%)			78,655	--	--
Subtotal initial capital cost			303,384	--	--

Table D-44. Quantities and costs for septic tank effluent gravity sewers for District #3 Pipestone Lake.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	3,510	$ 35.30	$123,903	$ 74,342	$ 133
Lift station					
#P2 28 gpm TDH-50 ft			30,900	9,270	1,436
#P1 40 gpm TDH-118 ft			30,900	9,270	1,521
#P4 40 gpm TDH-54 ft			30,900	9,270	1,439
Force main, common trench					
3"	1,175	5.75	6,756	4,054	--
Force main, individual trench					
3"	8,950	14.15	126,642	75,985	--
Service connection					
gravity	35	1,577	55,195	33,117	--
STE pump	3	3,600	10,800	3,240	189
Septic tank					
upgrade	28	143	4,004	2,402	280
replace	10	750	7,500	4,500	100
Subtotal initial cost			427,500	225,450	5,098
Service factor (35%)			149,625	--	--
Subtotal initial capital cost			577,125	--	--

Table-D-45. Quantities and costs for septic tank effluent gravity sewers for District #1 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	6,040	$ 35.30	$ 213,212	$ 127,927	$ 229
6"	1,770	37.00	65,490	39,294	67
Lift stations					
#1 15 gpm TDH-75 ft			12,750	3,825	1,339
#2 15 gpm TDH-45 ft			12,750	3,825	1,327
#3 59 gpm TDH-25 ft			54,000	16,200	1,588
#4 75 gpm TDH-30 ft			54,000	16,200	1,608
#5 86 gpm TDH-25 ft			54,000	16,200	1,605
Force main, common trench					
2"	1,700	4.60	7,820	4,692	--
3"	1,950	5.75	11,212	6,727	--
Force main, individual trench					
3"	400	14.15	5,660	3,396	--
Service connection					
gravity	102	1,577	160,854	96,512	--
STE pump	12	3,600	43,200	12,960	756
Septic tank					
upgrade	98	143	14,014	8,408	980
replace	16	750	12,000	7,200	160
Subtotal initial cost			720,962	363,366	9,659
Service factor (35%)			252,337	--	--
Subtotal initial capital cost			973,299	--	--
Future connections cost					
Building sewer	21	55	1,155	693	--
Septic tank + gravity	21	2,277	47,817	28,690	210
Subtotal future connection cost			48,972	29,383	210
Annual future connection cost			2,449	--	10

Table D-46. Quantities and costs for septic tank effluent gravity sewers for District #4 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	6,620	$ 35.30	$ 233,686	$140,212	$ 252
6"	1,370	37.00	50,690	30,414	52
8"	2,100	38.90	81,690	49,014	80
Lift station					
#7 25 gpm TDH-20 ft			30,900	9,270	1,413
#6 140 gpm TDH-90 ft			93,800	28,140	2,194
#8 20 gpm TDH-20 ft			12,750	3,825	1,320
#9 185 gpm TDH-18 ft			93,800	28,140	1,956
Force main, common trench					
2"	700	4.60	3,220	1,932	--
4"	2,380	6.50	15,470	9,282	--
Force main, individual trench					
2"	150	13.00	1,950	1,170	--
Service connection					
gravity	117	1,577	184,509	110,705	--
STE pump	6	3,600	21,600	6,480	378
Septic tank					
upgrade	99	143	14,157	8,494	990
replace	24	750	18,000	10,800	240
Subtotal initial cost			856,222	506,956	8,875
Service factor (35%)			299,678	--	--
Subtotal initial capital cost			1,155,900	--	--
Future connections cost					
Building sewer	29	55	1,595	957	--
Septic tank + gravity	29	2,277	66,033	39,620	290
Subtotal future connection cost			67,628	40,577	290
Annual future connection cost			3,381	--	14

Table D-47. Quantities and costs for septic tank effluent gravity sewers for District #5 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	11,180	$ 35.30	$ 394,654	$236,972	$ 425
6"	840	37.00	31,080	18,648	32
10"	2,450	41.80	102,410	61,446	93
Lift station					
#10 12 gpm TDH-15 ft			12,750	3,825	1,314
#11 40 gpm TDH-25 ft			54,000	16,200	1,426
#12 255 gpm TDH-30 ft			141,000	42,300	2,257
#13 315 gpm TDH-35 ft			189,400	56,820	2,654
#15 17 gpm TDH-25 ft			12,750	3,825	1,321
#16 27 gpm TDH-35 ft			30,900	9,270	1,424
#17 370 gpm TDH-20 ft			189,400	56,820	2,560
Force main, common trench					
2"	1,000	4.60	4,600	2,750	--
3"	850	5.75	4,887	2,932	--
6"	1,950	8.80	17,160	10,296	--
Force main, individual trench					
2"	300	13.00	3,900	2,340	--
6"	500	17.75	8,875	5,325	--
Service connection					
gravity	244	1,577	384,788	230,873	--
STE pump	21	3,600	75,600	22,680	1,323
Septic tank					
upgrade	210	143	30,030	18,018	2,100
replace	55	750	41,250	24,750	550
Subtotal initial cost			1,729,434	826,100	17,479
Service factor (35%)			605,302	--	--
Subtotal initial capital cost			2,334,736	--	--
Future connections cost					
Building sewer	21	55	1,155	693	--
Septic tank + gravity	21	2,277	47,817	28,690	210
Subtotal future connection cost			48,972	29,383	210
Annual future connection cost			2,449	--	10

Table D-48. Quantities and costs for septic tank effluent gravity sewers for District #6 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	17,750	$ 35.30	$ 626,575	$375,945	$ 674
6"	1,020	37.00	37,740	22,644	39
8"	630	38.90	24,507	14,704	24
10"	1,740	41.80	72,732	43,639	66
Lift station					
#18 18 gpm TDH-25 ft			12,750	3,825	1,321
#19 30 gpm TDH-35 ft			30,900	9,270	1,427
#20 70 gpm TDH-30 ft			54,000	16,200	1,604
#21 77 gpm TDH-20 ft			54,000	16,200	1,590
#22 510 gpm TDH-55 ft			293,000	87,900	3,462
Force main, common trench					
2"	1,030	4.60	4,738	2,843	--
4"	600	6.50	3,900	2,340	--
6"	300	8.80	2,640	1,584	--
Force main, individual trench					
6"	2,850	17.75	50,587	30,352	--
Service connection					
gravity	222	1,577	350,094	210,056	--
STE pump	15	3,600	54,000	16,200	945
Septic tank					
upgrade	193	143	27,599	16,559	1,930
replace	44	750	33,000	19,800	44
Subtotal initial cost			1,732,762	890,061	13,126
Service factor (35%)			606,467	--	--
Subtotal initial capital cost			2,339,229	--	--
Future connections cost					
Building sewer	30	55	1,650	990	--
Septic tank + gravity	30	2,277	68,310	40,986	300
Subtotal future connection cost			69,960	41,976	300
Annual future connection cost			3,498	--	15

Table D-49. Quantities and costs for septic tank effluent gravity sewers for District #7 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	4,320	$ 35.30	$ 152,496	$ 91,498	$ 164
6"	1,070	37.00	39,590	23,754	41
Lift station					
#23 12 gpm TDH-37 ft			12,750	3,825	1,321
#24 38 gpm TDH-30 ft			30,900	9,270	1,429
#25 58 gpm TDH-40 ft			54,000	16,200	1,610
Force main, common trench					
2"	400	4.60	1,840	1,104	--
3"	1,250	5.75	7,187	4,312	--
Force main, individual trench					
3"	250	14.15	3,537	2,122	--
Service connection					
gravity	74	1,577	116,698	70,019	--
STE pump	13	3,600	46,800	14,040	819
Septic tank					
upgrade	75	143	10,725	6,435	750
replace	12	750	5,400	--	120
Subtotal initial cost			481,923	242,579	6,254
Service factor (35%)			168,673	--	--
Subtotal initial capital cost			650,596	--	--
Future connections cost					
Building sewer	10	55	550	330	--
Septic tank + gravity	10	2,277	22,770	13,662	100
Subtotal future connection cost			23,320	13,992	100
Annual future connection cost			1,166	--	5

Table D-50. Quantities and costs for septic tank effluent gravity sewers for District #8 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	11,680	$ 35.30	$ 412,304	$247,382	$ 444
6"	580	37.00	21,406	12,876	22
8"	2,150	38.90	83,635	50,181	82
Lift station					
#14 10 gpm TDH-30 ft			12,750	3,825	1,318
#26 26 gpm TDH-35 ft			30,900	9,270	1,423
#27 130 gpm TDH-35 ft			93,800	28,140	1,987
#29 12 gpm TDH-15 ft			12,750	3,825	1,315
#28 190 gpm TDH-30 ft			93,800	28,140	2,017
Force main, common trench					
2"	1,650	4.60	7,590	4,554	--
3"	520	5.75	2,990	1,794	--
4"	550	6.50	3,575	2,145	--
Force main, individual trench					
2"	150	13.00	1,950	1,170	--
3"	150	14.15	2,122	1,273	--
4"	850	14.90	12,665	7,599	--
Service connection					
gravity	131	1,577	206,587	123,952	--
STE pump	17	3,600	61,200	18,360	1,071
Septic tank					
upgrade	131	143	18,733	11,240	1,310
replace	17	750	12,750	7,650	170
Subtotal initial cost			1,091,507	563,376	11,159
Service factor (35%)			382,027	--	--
Subtotal initial capital cost			1,473,534	--	--
Future connections cost					
Building sewer	32	55	1,760	1,056	--
Septic tank + gravity	32	2,277	72,864	43,718	320
Subtotal future connection cost			74,624	44,774	320
Annual future connection cost			3,731	--	16

Table D-51. Quantities and costs for septic tank effluent gravity sewers for District #9 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	7,690	$ 35.30	$ 271,457	$162,874	$ 292
6"	2,890	37.00	106,930	64,158	110
8"	800	38.90	31,120	18,672	30
Lift station					
#30 14 gpm TDH-25 ft			12,750	3,825	1,319
#31 45 gpm TDH-30 ft			30,900	9,270	1,435
#32 77 gpm TDH-28 ft			54,000	16,200	1,605
#33 86 gpm TDH-25 ft			54,000	16,200	1,605
#34 118 gpm TDH-44 ft			93,800	28,140	2,004
#35 18 gpm TDH-40 ft			12,750	3,825	1,328
Force main, common trench					
2"	1,150	4.60	5,290	3,174	--
3"	640	5.75	3,680	2,208	--
4"	1,540	6.50	10,010	6,006	--
Force main, individual trench					
2"	550	13.00	7,150	4,290	--
3"	600	14.15	8,490	5,094	--
4"	450	14.90	6,705	4,023	--
Service connection					
gravity	189	1,577	298,053	178,832	--
STE pump	18	3,600	64,800	19,440	1,134
Septic tank					
upgrade	163	143	23,309	13,985	1,630
replace	44	750	33,000	19,800	440
Subtotal initial cost			1,128,194	580,016	12,932
Service factor (35%)			394,868	--	--
Subtotal initial capital cost			1,523,062	--	--
Future connections cost					
Building sewer	27	55	1,485	891	--
Septic tank + gravity	27	2,277	61,479	36,887	270
Subtotal future connection cost			62,964	37,778	270
Annual future connection cost			3,148	--	13

Table D-52. Quantities and costs for septic tank effluent gravity sewers for District #10 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	7,820	$ 35.30	$ 276,046	$165,628	$ 297
6"	1,250	37.00	46,250	27,750	47
8"	1,330	38.90	51,737	31,042	51
Lift station					
#41 8 gpm TDH-30 ft			12,750	3,825	1,316
#42 16 gpm TDH-25 ft			12,750	3,825	1,320
#43 28 gpm TDH-25 ft			30,900	9,270	1,418
#44 82 gpm TDH-25 ft			54,000	16,200	1,603
#45 102 gpm TDH-20 ft			93,800	28,140	1,922
Force main, common trench					
2"	1,000	4.60	4,600	2,760	--
3"	1,760	5.75	10,120	6,072	--
Force main, individual trench					
2"	800	13.00	10,400	6,240	--
4"	200	14.90	2,980	1,788	--
Service connection					
gravity	130	1,577	205,010	123,006	--
STE pump	13	3,600	46,800	14,040	819
Septic tank					
upgrade	110	143	15,730	9,438	1,100
replace	33	750	24,750	14,850	330
Subtotal initial cost			898,623	463,874	10,223
Service factor (35%)			314,518	--	--
Subtotal initial capital cost			1,213,141	--	--
Future connections cost					
Building sewer	27	55	1,485	891	--
Septic tank + gravity	27	2,277	61,479	36,887	270
Subtotal future connection cost			62,964	37,778	270
Annual future connection cost			3,148	--	13

Table D-53. Quantities and costs for septic tank effluent gravity sewers for District #11 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	4,380	$ 35.30	$ 154,614	$ 92,768	$ 166
8"	4,670	38.90	181,663	108,998	177
Lift station					
#46 125 gpm TDH-35 ft			93,800	28,140	1,983
#47 132 gpm TDH-30 ft			93,800	28,140	1,972
#48 145 gpm TDH-25 ft			93,800	28,140	1,963
#49 17 gpm TDH-35 ft			12,750	3,825	1,325
#50 167 gpm TDH-35 ft			93,800	28,140	2,020
#52 181 gpm TDH-50 ft			141,000	42,300	2,103
Force main, common trench					
2"	570	4.60	2,622	1,573	--
4"	1,810	6.50	11,765	7,059	--
6"	790	8.80	6,952	4,171	--
Force main, individual trench					
4"	150	14.90	2,235	1,341	--
6"	240	17.75	4,260	2,556	--
Service connection					
gravity	110	1,577	173,470	104,082	--
STE pump	36	3,600	129,600	38,880	2,268
Septic tank					
upgrade	108	143	15,444	9,266	1,080
replace	38	750	28,500	17,100	380
Subtotal initial cost			1,240,075	546,479	15,437
Service factor (35%)			434,026	--	--
Subtotal initial capital cost			1,674,101	--	--
Future connections cost					
Building sewer	9	55	495	297	--
Septic tank + gravity	9	2,277	20,493	12,296	90
Subtotal future connection cost			20,988	12,593	90
Annual future connection cost			1,049	--	4

Table D-54. Quantities and costs for septic tank effluent gravity sewers for District #12 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	4,590	$ 35.30	$ 162,027	$ 97,216	$ 87
6"	650	37.00	24,050	14,430	12
Lift station					
#51 6 gpm TDH-40 ft			12,750	3,825	1,316
#61 14 gpm TDH-45 ft			12,750	3,825	1,326
#60 21 gpm TDH-25 ft			12,750	3,825	1,323
#59 25 gpm TDH-20 ft			30,900	9,270	1,413
#53 37 gpm TDH-50 ft			30,900	9,270	1,448
#56 49 gpm TDH-20 ft			30,900	9,270	1,425
#57 56 gpm TDH-35 ft			54,000	16,200	1,600
Force main, common trench					
2"	2,530	4.60	11,638	6,983	--
3"	730	5.75	4,197	2,519	--
Force main, individual trench					
2"	1,150	13.00	14,950	8,970	--
3"	600	14.15	8,490	5,094	--
Service connection					
gravity	63	1,577	99,351	56,611	--
STE pump	18	3,600	64,800	19,440	1,134
Septic tank					
upgrade	60	143	8,580	5,148	600
replace	21	750	15,750	9,450	210
Subtotal initial cost			598,783	281,346	11,894
Service factor (35%)			209,574	--	--
Subtotal initial capital cost			808,357	--	--
Future connections cost					
Building sewer	10	55	550	330	--
Septic tank + gravity	10	2,277	22,770	13,662	100
Subtotal future connection cost			23,200	13,992	100
Annual future connection cost			1,166	--	5

Table D-55. Quantities and costs for septic tank effluent gravity sewers for District #13 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	6,730	$ 35.30	$ 237,569	$142,541	$ 256
6"	640	37.00	23,680	14,208	24
8"	1,890	38.90	73,521	44,113	72
10"	1,840	41.80	76,912	46,147	70
15"	2,660	51.55	137,123	82,274	101
18"	1,350	60.40	81,540	48,924	51
Lift station					
#54 223 gpm TDH-20 ft			141,000	42,300	2,175
#55 232 gpm TDH-25 ft			141,000	42,300	2,209
#36 160 gpm TDH-40 ft			93,800	28,140	2,035
#37 14 gpm TDH-25 ft			12,750	3,825	1,319
#38 35 gpm TDH-30 ft			30,900	9,270	1,427
#39 6 gpm TDH-15 ft			12,750	3,825	1,312
#40 950 gpm TDH-25 ft			384,000	115,200	3,701
Force main, common trench					
2"	1,710	4.60	7,866	4,720	--
6"	1,790	8.80	15,752	9,451	--
8"	640	12.50	8,000	4,800	--
Force main, individual trench					
2"	200	13.00	2,600	1,560	--
6"	200	17.75	3,550	2,130	--
8"	800	22.10	17,680	10,608	--
Service connection					
gravity	147	1,577	231,819	139,091	--
STE pump	8	3,600	28,800	8,640	504
Septic tank					
upgrade	112	143	16,016	9,610	1,120
replace	43	750	32,250	19,350	430
Subtotal initial cost			1,810,878	853,027	16,806
Service factor (35%)			633,807	--	--
Subtotal initial capital cost			2,444,685	--	--
Future connections cost					
Building sewer	32	55	1,760	1,056	--
Septic tank + gravity	32	2,277	72,864	43,718	320
Subtotal future connection cost			74,624	44,774	320
Annual future connection cost			3,731	--	16

Table D-56. Quantities and costs for septic tank effluent gravity sewers for District #14 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	3,070	$ 35.30	$ 108,371	$ 65,023	$ 117
Lift station					
#67 7 gpm TDH-15 ft			12,750	3,825	1,313
#68 11 gpm TDH-25 ft			12,750	3,825	1,317
#69 22 gpm TDH-50 ft			12,750	3,825	1,338
Force main, common trench					
2"	1,650	4.60	7,590	4,554	--
Force main, individual trench					
2"	600	13.00	7,800	4,680	--
Service connection					
gravity	27	1,577	42,579	25,547	--
STE pump	7	3,600	25,200	7,560	441
Septic tank					
upgrade	27	143	3,861	2,317	270
replace	7	750	5,250	3,150	70
Subtotal initial cost			238,901	124,306	4,866
Service factor (35%)			83,615	--	--
Subtotal initial capital cost			322,516	--	--
Future connections cost					
Building sewer	3	55	165	99	--
Septic tank + gravity	3	2,277	6,831	4,099	30
Subtotal future connection cost			6,996	4,198	30
Annual future connection cost			350	--	2

Table D-57. Quantities and costs for septic tank effluent gravity sewers for District #15 Sister Lakes.

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	10,560	$ 35.30	$ 372,768	$223,661	$ 401
6"	2,590	37.00	95,830	57,498	98
8"	470	38.90	18,283	10,970	18
18"	1,940	60.40	117,176	70,306	74
Lift station					
#63 18 gpm TDH-20 ft			12,750	3,825	1,319
#62 22 gpm TDH-20 ft			12,750	3,825	1,321
#64 45 gpm TDH-40 ft			30,900	9,270	1,596
#65 60 gpm TDH-45 ft			54,000	16,200	1,619
#66 93 gpm TDH-25 ft			54,000	16,200	1,610
#58 1,040 gpm TDH-25 ft			512,000	153,600	4,159
Force main, common trench					
2"	450	4.60	2,070	1,242	--
3"	2,150	5.75	12,362	7,417	--
10"	1,150	18.00	20,700	12,420	--
Force main, individual trench					
2"	800	13.00	10,400	6,240	--
Service connection					
gravity	171	1,577	269,667	161,800	--
STE pump	9	3,600	32,400	9,720	567
Septic tank					
upgrade	148	143	21,164	12,698	1,480
replace	32	750	24,000	14,400	320
Subtotal initial cost			1,673,220	791,292	14,582
Service factor (35%)			585,627	--	--
Subtotal initial capital cost			2,258,847	--	--
Future connections cost					
Building sewer	29	55	1,595	957	--
Septic tank + gravity	29	2,277	66,033	39,620	290
Subtotal future connection cost			67,628	40,577	290
Annual future connection cost			3,381	--	14

Table D-58. Quantities and costs of conveyance portion for Alternative 2 (June 1981 costs).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Lift station					
Sister Lakes 1,040 gpm TDH-56 ft			$ 512,000	$153,600	$ 6,790
Indian Lake 302 gpm TDH-74 ft			189,400	56,820	3,855
Force main					
Sister Lakes 12"	21,900	$ 33.60	735,840	441,504	--
Indian Lake 6"	6,100	17.75	108,275	64,965	--
Total initial cost			1,545,515	716,889	10,645
Service factor (27%)			417,289	--	--
Total initial capital cost			1,962,804	--	--

Present worth cost (@ 7-5/8% over 20 years)

Capital cost	$1,962,804
O&M cost	107,496
Salvage value	(164,884)
Total present worth	$1,905,416

Table D-59. Quantities and costs of the conveyance portion for Alternative 3 (June 1981 costs).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Lift station					
Sister Lakes 1,040 gpm					
TDH-61 ft			$ 512,000	$153,600	$ 6,980
Indian Lake 302 gpm					
TDH-131 ft			189,400	56,820	4,390
Force main					
Sister Lakes 12"	5,600	$ 33.60	188,160	112,896	--
Indian Lake 6"	24,750	17.75	439,313	263,588	--
Total initial cost			1,328,873	586,904	11,370
Service factor (27%)			358,796	--	--
Total initial capital cost			1,687,669	--	--

Present worth cost (@ 7-5/8% over 20 years)

Capital cost	$1,687,669
O&M cost	114,818
Salvage value	(134,988)
Total present worth	$1,667,499

Table D-60. Quantities and costs of the conveyance portion for Alternative 4 (June 1981 costs).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Lift station					
Sister Lakes 1,040 gpm					
TDH-48 ft			$ 512,000	$ 153,600	$ 6,485
Indian Lake 302 gpm					
TDH-111 ft			189,400	56,820	4,200
Combined 1,273 gpm					
TDH-29 ft			512,000	153,600	6,030
Force main					
Sister Lakes 12"	5,650	$ 33.60	189,840	113,904	--
Indian Lake 6"	25,120	17.75	445,880	267,528	--
Combined 12"	16,250	33.60	546,000	327,600	--
Total initial cost			2,395,120	1,073,052	16,715
Service factor (27%)			646,682	--	--
Total initial capital cost			3,041,802	--	--

Present worth cost (@ 7-5/8% over 20 years)

Capital cost	$3,041,802
O&M cost	168,793
Salvage value	(246,802)
Total present worth	$2,963,793

Table D-61. Quantities and costs of the conveyance portion for Alternatives 5A and 5B (June 1981 costs).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Lift station					
Sister Lakes 1,040 gpm					
TDH-73 ft			$ 512,000	$153,600	$ 7,440
Inidan Lake 302 gpm					
TDH-74 ft			189,400	56,820	3,855
Force main					
Sister Lakes 12"	24,700	$ 33.60	829,920	497,952	--
Indian Lake 6"	6,100	17.75	108,275	64,965	--
Total initial cost			1,639,595	773,337	11,295
Service factor (27%)			442,691	--	--
Total initial capital cost			2,082,286	--	--

Present worth cost (@ 7-5/8% over 20 years)

Capital cost	$2,082,286
O&M cost	114,060
Salvage value	(177,868)
Total present worth	$2,018,478

Table D-62. Quantities and costs of the conveyance portion for Alternative 6 (June 1981 costs).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Lift station					
Sister Lakes 1,040 gpm TDH-56 ft			$ 512,000	$153,600	$ 6,790
Indian Lake 302 gpm TDH-61 ft			189,400	56,820	3,734
Force main					
Sister Lakes 12"	21,900	$ 33.60	735,840	441,504	--
Indian Lake 6"	23,760	17.75	421,740	253,044	--
Total initial cost			1,858,980	904,968	10,524
Service factor (27%)			501,925	--	--
Total initial capital cost			2,360,905	--	--

Present worth cost (@ 7-5/8% over 20 years)

Capital cost	$2,360,905
O&M cost	106,275
Salvage value	(208,143)
Total present worth	$2,259,037

Table D-63. Quantities and costs of the conveyance portion for Alternative 7 (June 1981 costs).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Lift station					
Sister Lakes 1,040 gpm TDH-73 ft			$ 512,000	$ 153,600	$ 7,440
Indian Lake 1,273 gpm TDH-58 ft			512,000	153,600	7,410
Force main					
Sister Lakes 12"	28,800	$ 33.60	967,680	580,608	--
Indian Lake 12"	23,760	33.60	798,336	479,002	--
Total initial cost			2,790,016	1,059,610	14,850
Service factor (27%)			753,304	--	--
Total initial capital cost			3,543,320	--	--

Present worth cost (@ 7-5/8% over 20 years)

Capital cost	$3,543,320
O&M cost	149,960
Salvage value	(243,710)
Total present worth	$3,449,570

Table D-64. Waste stabilization ponds WWTP for Indian Lake with discharge to Indian Lake outlet (Alternative No. 2)

Item	Cost $ (x1,000) Construction Cost	Salvage Value	O&M Cost
Flow meter assembly	$ 10.0	$ --	$ 2.0
Waste stabilization ponds	323.6	194.1	5.0
Storage lagoons	152.5	91.5	1.0
Chlorination system	35.9	10.7	7.0
Land: 25 acres	50.0	90.3	--
Site clearing	0.6	--	--
Administration & laboratory building	93.0	33.5	7.4
Service roads and fencing	51.5	--	1.1
Monitoring systems, controls, and instrumentation	15.7	--	--
Electrical	26.1	--	--
Process piping and outfall	41.8	25.0	--
Total	$ 800.7	$ 445.1	$ 23.5
Service factor (27%)	216.2		
Total capital cost	$ 1,016.9		

Present worth cost (@ 7-5/8% over 20 years)

Capital cost	$1,016.9
O&M cost	237.3
Salvage value	(102.4)
Total Present Worth	$1,151.8

Table D-65. Aerated lagoons with storage ponds WWTP for Indian Lake with discharge to Indian Lake outlet.

Item	Cost $ (x1,000) Construction Cost	Salvage Value	O&M Cost
Flow meter assembly	$ 10.0	$ --	$ 2.0
Aerated lagoons	129.5	21.4	17.3
Storage lagoons	309.1	185.4	2.2
Chlorination system	35.9	10.7	7.0
Land: 25 acres	50.0	90.3	--
Site clearing	0.6	--	--
Administration & laboratory building	93.0	33.5	7.4
Service roads and fencing	51.5	--	1.1
Monitoring systems, controls, and instrumentation	14.5	--	--
Electrical	24.2	--	--
Process piping and outfall	38.8	23.2	--
Total	$ 757.1	$ 364.5	$ 37.0
Service factor (27%)	204.4		
Total capital cost	$ 961.5		

Present worth cost (@ 7-5/8% over 20 years)

Capital cost	$ 961.5
O&M cost	373.6
Salvage value	(83.8)
Total Present Worth	$1,251.3

Table D-66. Oxidation ditch with storage ponds WWTP for Indian Lake with discharge to Indian Lake outlet.

Item	Cost $ (x1,000) Construction Cost	Salvage Value	O&M Cost
Preliminary treatment	$ 20.1	$ 6.0	$ 11.5
Oxidation ditch plant including oxidation ditch, clarifier and sludge drying beds	305.8	91.7	36.4
Storage lagoons	365.0	219.0	2.4
Chlorination system	35.9	10.7	7.0
Land: 25 acres	50.0	90.3	--
Site clearing	0.6	--	--
Administration & laboratory building	93.0	33.5	7.4
Service roads and fencing	51.5	--	--
Monitoring system, controls, and instrumentation	21.8	--	--
Electrical	36.3	--	--
Process piping and outfall	72.7	43.6	--
Total	$ 1,052.7	$ 494.8	$ 64.7
Service factor (27%)	284.2		
Total capital cost	$ 1,336.9		

Present worth cost (@ 7-5/8% over 20 years)

Capital cost	$1,336.9
O&M cost	653.4
Salvage value	(113.8)
Total Present Worth	$1,876.5

Table D-67. Waste stabilization ponds WWTP for Sister Lakes with discharge to Silver Creek (Alternative Nos. 2 and 6).

Item	Cost $ (x1,000) Construction Cost	Salvage Value	O&M Cost
Flow meter assembly	$ 10.0	$ --	$ 2.0
Waste stabilization ponds	827.0	496.2	10.0
Storage lagoons	309.1	185.4	2.2
Chlorination system	57.5	17.2	13.0
Land: 80 acres	160.0	289.0	--
Site clearing	2.0	--	--
Administration & laboratory building	99.0	35.6	12.0
Service roads and fencing	85.0	--	2.1
Monitoring system, controls, and instrumentation	36.1	--	--
Electrical	60.2	--	--
Process piping and outfall	96.3	57.7	--
Total	$1,742.2	$1,081.1	$ 41.3
Service factor (27%)	470.4		
Total capital cost	$2,212.6		

Present worth cost (@ 7-5/8% over 20 years)

Capital cost	$2,212.6
O&M cost	417.1
Salvage value	(248.6)
Total Present Worth	$2,381.1

Table D-68. Aerated lagoons with storage ponds WWTP for Sister Lakes with discharge to Silver Creek.

Item	Cost $ (x1,000) Construction Cost	Salvage Value	O&M Cost
Flow meter assembly	$ 10.0	$ --	$ 2.0
Aerated lagoons	288.0	47.5	38.0
Storage lagoons	906.0	543.6	4.7
Chlorination systems	57.5	17.2	13.0
Land: 80 acres	160.0	289.0	--
Site clearing	2.0	--	--
Administration & laboratory building	99.0	35.6	12.0
Service roads and fencing	85.0	--	2.1
Monitoring system, controls, and instrumentation	37.8	--	--
Electrical	63.0	--	--
Process piping and outfall	126.0	75.6	--
Total	$1,834.3	$1,008.5	$ 71.8
Service factor (27%)	495.3		
Total capital cost	$2,329.6		

Present worth cost (@ 7-5/8% over 20 years)

Capital cost	$2,329.6
O&M cost	725.0
Salvage value	(231.9)
Total Present Worth	$2,822.7

Table D-69. Oxidation ditch with storage ponds WWTP for Sister Lakes with discharge to Silver Creek.

Item	Cost $ (x1,000) Construction Cost	Salvage Value	O&M Cost
Preliminary treatment	$ 43.2	$ 12.9	$ 14.0
Oxidation ditch plant including oxidation ditch, clarifier and sludge drying beds	553.5	165.0	61.0
Storage lagoons	1,051.9	631.1	5.8
Chlorination system	57.5	17.2	13.0
Land: 80 acres	160.0	289.0	--
Site clearing	2.0	--	--
Administration & laboratory building	99.0	35.6	12.0
Service roads and fencing	85.0	--	2.1
Monitoring system, controls, and instrumentation	51.2	--	--
Electrical	85.3	--	--
Process piping and outfall	170.6	102.4	--
Total	$2,359.2	$1,253.2	$ 107.9
Service factor (27%)	637.0		
Total capital cost	$2,996.2		

Present worth cost (@ 7-5/8% over 20 years)

Capital cost	$2,996.2
O&M cost	1,089.6
Salvage value	(288.2)
Total Present Worth	$3,797.6

Table D-70. Waste stabilization ponds regional WWTP for Indian Lake and Sister Lakes (Alternative Nos. 4, 5A, and 5B).

Item	Cost $ (x1,000) Construction Cost	Salvage Value	O&M Cost
Flow meter assembly	$ 10.0	$ --	$ 2.0
Waste stabilization ponds	1,006.8	604.0	12.0
Storage lagoons	343.5	206.1	2.6
Chlorination system	62.0	18.6	16.0
Land: 100 acres	200.0	361.2	--
Site clearing	2.5	--	--
Administration & laboratory building	106.0	38.2	14.4
Service roads and fencing	103.0	--	2.5
Monitoring system, controls, and instrumentation	42.7	--	--
Electrical	71.1	--	--
Process piping and outfall	113.8	68.3	--
Total	$2,061.4	$1,296.4	$ 49.5
Service factor (27%)	556.6		
Total capital cost	$2,618.0		

Present worth cost (@ 7-5/8% over 20 years)

Capital cost	$2,618.0
O&M cost	499.9
Salvage value	(298.2)
Total Present Worth	$2,819.7

Table D-71. Aerated lagoons with storage ponds regional WWTP for Indian Lake and Sister Lakes.

Item	Cost $ (x1,000) Construction Cost	Salvage Value	O&M Cost
Flow meter assembly	$ 10.0	$ --	$ 2.2
Aerated lagoons	331.0	54.6	46.0
Storage lagoons	1,095.0	656.9	6.0
Chlorination system	62.0	18.6	16.0
Land: 100 acres	200.0	361.2	--
Site clearing	2.5	--	--
Administration & laboratory building	106.0	38.2	14.4
Service roads and fencing	103.0	--	2.5
Monitoring systems, controls, and instrumentation	44.9	--	--
Electrical	74.9	--	--
Process piping and outfall	119.8	71.9	--
Total	$2,149.1	$1,201.4	$ 87.1
Service factor (27%)	580.2		
Total capital cost	$2,729.3		

Present worth cost (@ 7-5/8% over 20 years)

Capital Cost	$2,729.3
O&M cost	879.6
Salvage value	(276.3)
Total Present Worth	$3,332.6

Table D-72. Oxidation ditch with storage ponds regional WWTP for Indian Lake and Sister Lakes.

Item	Cost $ (x1,000) Construction Cost	Salvage Value	O&M Cost
Preliminary treatment	$ 51.8	$ 15.5	$ 15.8
Oxidation ditch plant including oxidation ditch, clarifier and sludge drying beds	611.5	183.5	72.8
Storage lagoons	1,288.0	772.8	6.2
Chlorination system	62.0	18.6	16.0
Land: 100 acres	200.0	361.2	--
Site clearing	2.5	--	--
Administration & laboratory building	106.0	38.2	14.4
Service roads and fencing	103.0	--	2.5
Monitoring system, controls, and instrumentation	60.4	--	--
Electrical	100.7	--	--
Process piping and outfall	201.3	120.8	--
Total	$2,787.2	$1,510.6	$127.7
Service factor (27%)	752.5		
Total capital cost	$3,539.7		

Present worth cost (@ 7-5/8% over 20 years)

Capital cost	$3,539.7
O&M cost	1,289.5
Salvage value	(347.4)
Total Present Worth	$4,481.8

Table D-73. Waste stabilization ponds regional WWTP with land disposal site located in Section 8 in Silver Creek Township for Indian Lake and Sister Lakes (Alternative No. 3).

Item	Cost $ (x1,000) Construction Cost	Salvage Value	O&M Cost
Flow meter assembly	$ 10.0	$ --	$ 2.2
Waste stabilization ponds	1,006.8	604.0	12.0
Chlorination system	62.0	18.6	16.0
Pumping	234.9	70.5	9.6
Transmission - force main	102.0	61.2	0.3
Land: 255 acres	510.0	921.0	--
Field preparation	3.9	--	--
Distribution- center pivot	131.0	--	25.4
Underdrains	90.2	54.1	8.6
Monitoring wells	12.0	--	1.5
Administration and laboratory building	106.0	38.2	14.4
Service roads and fencing	184.6	--	4.8
Electrical	50.3	--	--
Monitoring system, controls, and instrumentation	30.2	--	--
Lease of land crop production	--	--	(6.5)
Total	$2,533.9	$1,767.6	$ 88.3
Service factor (27%)	684.1		
Total capital cost	$3,218.0		

Present worth cost (@ 7-5/8% over 20 years)

Capital cost	$3,218.0
O&M cost	891.7
Salvage value	(406.5)
Total Present Worth	$3,703.2

Table D-74. Treatment of Indian Lake and Sister Lakes areas wastewater at the existing Dowagiac WWTP (Alternative No. 7).

Service Charge = $4.65/month x 12 months =	$ 56
User Charge = $0.084/100 gal. x 660,000 x 365 =	$202,356
Debt Service Charge = $0.026/100 gal. x 660,000 x 365 =	$ 62,634
Total:	$265,046

Total Present Worth = $265,046 x 10.0983

= $2,676,500

Table D-75. Treatment of Indian Lake area wastewater at the existing Dowagiac WWTP (Alternative No. 6).

Service Charge = $4.65/month x 12 months =	$ 56
User Charge = 0.084/100 x 140,000 x 365 =	$42,924
Debt Service Charge = 0.026/100 x 140,000 x 365 =	$13,286
Total:	$56,266

Total Present Worth = $56,266 x 10.0983

= $568,200

Table D-76. Summary and present worth of costs for Alternative 8A - septic tank effluent pumps and pressure sewers with cluster drainfields and upgraded on-site systems (June 1981 costs).

	Initial Cost			Present Worth			Future Connections Cost			Present Worth				
District	Capital	Salvage	O&M	Salvage	O&M	Total	Annual Construction	Total Salvage	Incremental Annual O&M	Construction	Salvage	O&M	Total	Total Present Worth
Indian Lake														
1	982,795	234,883	16,283	54,023	164,431	1,093,199	3,303	9,827	70	33,355	2,260	5,048	36,143	1,129,342
2	285,114	58,526	9,770	13,461	98,660	370,313	2,747	6,707	69	27,740	1,543	4,975	31,172	401,485
3	1,006,241	225,703	16,146	51,912	163,047	1,117,376	2,777	12,699	58	28,043	2,921	4,182	29,304	1,146,680
Subtotal	2,274,150	519,112	42,199	119,396	426,138	2,580,888	8,827	29,233	197	89,138	6,724	14,205	96,619	2,677,507
Pipestone Lake														
2	280,812	71,463	5,452	16,436	55,056	319,432	--	--	--	--	--	--	--	319,432
3	386,768	137,502	6,383	31,625	64,457	419,600	--	--	--	--	--	--	--	419,600
Subtotal:	667,580	208,965	11,835	48,061	119,513	739,032	--	--	--	--	--	--	--	739,032
Sister Lakes														
1	209,924	45,533	5,875	10,473	59,328	258,779	2,858	9,513	64	28,861	2,188	4,615	31,288	290,067
4	231,109	39,024	4,527	8,976	45,715	267,848	3,775	15,592	74	38,121	3,586	5,336	39,871	307,719
5	1,564,534	332,980	21,359	76,585	215,690	1,703,639	3,564	17,697	62	35,990	4,070	4,471	36,391	1,740,030
6	738,667	162,868	15,453	37,460	156,049	857,256	4,340	13,590	92	43,827	3,126	6,634	47,335	904,591
7	114,282	11,835	3,600	2,722	36,354	139,128	1,787	4,530	47	18,046	1,042	3,389	20,393	159,521
8	215,279	42,659	6,785	9,812	68,517	273,984	4,041	16,133	80	40,807	3,711	5,769	42,865	316,849
9	832,984	179,171	16,609	41,209	167,723	959,498	4,598	13,868	109	46,432	3,190	7,860	51,102	1,010,600
10	647,957	142,736	10,954	32,829	110,617	725,745	5,472	22,870	111	55,258	5,260	8,004	58,002	783,747
11	910,505	205,245	15,791	47,206	159,462	1,022,761	2,378	7,351	57	24,014	1,691	4,110	26,433	1,049,194
12	131,470	14,598	3,480	3,358	35,142	163,254	3,094	4,530	81	31,244	1,042	5,841	36,043	199,297
13	510,757	95,763	13,426	22,025	135,580	624,312	5,521	16,133	134	55,753	3,711	9,662	61,704	686,016
14	131,178	21,997	4,045	5,059	40,848	166,967	608	1,359	15	6,140	313	1,081	6,908	173,875
15	503,399	104,069	11,172	24,051	112,818	592,166	4,990	15,592	111	50,391	3,586	8,004	54,809	646,975
Subtotal:	6,742,045	1,398,978	132,206	321,765	1,335,057	7,755,337	47,026	158,758	1,037	474,884	36,516	74,776	513,144	8,268,481
Total	9,683,775	2,127,055	186,240	489,222	1,888,623	11,075,257	55,853	187,991	1,234	564,022	43,240	88,981	609,763	11,685,020

Table D-77. Quantities and costs for septic tank effluent pressure sewers and cluster drainfields serving limited areas for District #1 Indian Lake (Alternative 8A).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2½"	2,400	$ 17.35	$ 41,640	$ 24,984	$ 46
3"	4,990	18.20	90,818	54,491	95
4"	1,200	19.50	23,400	14,040	23
Service connections					
STE pump	81	3,428	277,668	83,300	5,103
Septic tank					
upgrade	63	143	9,009	5,405	630
replace	28	750	21,000	12,600	280
Cluster drainfield					
Edgewood-Tice	82	1,250	102,500	--	2,080
Lift station 51 gpm TDH-20 ft			54,000	16,200	1,576
Oak Grove	9	1,250	11,250	--	2,080
Subtotal initial cost			631,285	211,020	11,913
Service factor (35%)			220,950	--	--
Subtotal initial capital cost			852,235	--	--
Future connections cost					
Building sewer	2	55	110	66	--
Septic tank + STE pump	2	4,128	8,256	2,477	146
Subtotal future connection cost			8,366	2,543	146
Annual future connection cost			418	--	7

Table D-78. Quantities and costs for septic tank effluent pressure sewers and cluster drainfields serving limited areas for District #2 Indian Lake (Alternative 8A).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	750	$ 17.00	$ 12,750	$ 7,650	$ 14
2½"	650	17.35	11,277	6,766	12
3"	500	18.20	9,100	5,460	10
Service connections					
STE pump	18	3,428	61,704	18,511	1,134
Septic tank					
upgrade	20	143	2,860	1,716	200
replace	6	750	4,500	2,700	60
Cluster drainfield					
Indian Trail cul de sac	5	1,250	6,250	--	2,080
Forest Beach Blk 2,3,4	15	1,250	18,750	--	2,080
Lift station 9 gpm TDH-25 ft			12,750	3,825	1,316
Subtotal initial cost			139,941	46,628	6,906
Servcie factor (35%)			48,979	--	--
Subtotal initial capital cost			188,920	--	--
Future connections cost					
Building sewer	1	55	55	33	--
Septic tank + STE pump	1	4,128	4,128	1,238	73
Subtotal future connection cost			4,183	1,271	73
Annual future connection cost			291	--	4

Table D-79. Quantities and costs for septic tank effluent pressure sewers and cluster drainfields serving limited areas for District #3 Indian Lake (Alternative 8A).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2½"	850	$ 17.35	$ 14,747	$ 8,848	$ 16
3"	6,250	18.20	113,750	68,250	119
Service connections					
STE pump	96	3,428	329,088	98,726	6,048
Septic tank					
upgrade	74	143	10,582	6,349	740
replace	31	750	23,250	13,950	310
Cluster drainfield					
South lake area	57	1,250	71,250	--	2,080
Lift station 35 gpm TDH-20 ft			30,900	9,270	1,418
Indian Lake Club	48	1,250	60,000	--	2,080
Lift station 29 gpm TDH-20 ft			30,900	9,270	1,415
Subtotal initial cost			684,467	214,663	14,226
Service factor (35%)			239,563	--	--
Subtotal initial capital cost			924,030	--	--
Future connection cost					
Building sewer	5	55	275	165	--
Septic tank + STE pump	5	4,128	20,640	6,192	365
Subtotal future connection cost			20,915	6,357	365
Annual future connection cost			1,046	--	18

Table D-80. Quantities and costs for septic tank effluent pressure sewers and cluster drainfields serving limited areas for District #2 Pipestone Lake (Alternative 8A).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	900	$ 17.00	$ 15,300	$ 9,180	$ 17
2½"	1,800	17.35	31,230	18,738	34
3"	600	18.20	10,920	6,552	11
Service connections					
STE pump	27	3,428	92,556	27,767	1,701
Septic tank					
upgrade	21	143	3,003	1,801	210
replace	8	750	6,000	3,600	80
Cluster drainfield					
Bass Island Sub.	29	1,250	36,250	--	2,080
Lift station 18 gpm TDH-20 ft			12,750	3,825	1,319
Subtotal initial cost			208,009	71,463	5,452
Service factor (35%)			72,803	--	--
Subtotal initial capital cost			280,812	--	--

Table D-81. Quantities and costs for septic tank effluent pressure sewers and cluster drainfields serving limited areas for District #3 Pipestone Lake (Alternative 8A).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	600	$ 17.00	$ 10,200	$ 6,120	$ 11
2½"	1,680	17.35	29,148	17,489	32
3"	2,250	18.20	40,950	24,570	43
Service connections					
STE pump	38	3,428	130,264	78,158	2,394
Septic tank					
upgrade	31	143	4,433	2,660	310
replace	10	750	7,500	4,500	100
Cluster drainfield					
North lake area	41	1,250	51,250	--	2,080
Lift station 25 gpm TDH-20 ft			12,750	3,825	1,413
Subtotal initial cost			286,495	137,502	6,383
Service factor (35%)			100,273	--	--
Subtotal initial capital cost			386,768	--	--

Table D-82. Quantities and costs for septic tank effluent pressure sewers and cluster drainfields serving limited areas for District #1 Sister Lakes (Alternative 8A).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	1,150	$ 17.00	$ 19,550	$11,730	$ 22
2½"	150	17.35	2,602	1,561	3
Service connections					
STE pump	8	3,428	27,424	8,227	504
Septic tank					
upgrade	9	143	1,287	7,722	90
replace	4	750	3,000	1,800	40
Cluster drainfield					
Oak Park Sub.	13	1,250	16,250	--	2,080
Subtotal initial cost			70,113	31,040	2,739
Service factor (35%)			24,540	--	--
Subtotal initial capital cost			94,653	--	--

Table D-83. Quantities and costs for septic tank effluent pressure sewers and cluster drainfields serving limited areas for District #4 Sister Lakes (Alternative 8A).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2½"	1,000	$ 17.35	$ 17,350	$10,410	$ 19
Service connection					
STE pump	8	3,428	27,424	8,227	504
Septic tank					
upgrade	10	143	1,430	858	100
replace	3	750	2,250	1,350	30
Cluster drainfield					
Ronni St.	13	1,250	16,250	--	--
Subtotal initial cost			64,704	20,845	653
Service factor (35%)			22,646	--	--
Subtotal initial capital cost			87,350	--	--
Future connections cost					
Building sewer	3	55	165	99	--
Septic tank + STE pump	3	4,128	12,384	3,715	219
Subtotal future connection cost			12,549	3,814	219
Annual future connection cost			627	--	11

Table D-84. Quantities and costs for septic tank effluent pressure sewers and cluster drainfields serving limited areas for District #5 Sister Lakes (Alternative 8A).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	450	$ 17.00	$ 7,650	$ 4,590	$ 9
2½"	1,750	17.35	30,362	18,217	33
3"	4,820	18.20	87,724	52,634	92
4"	2,450	19.50	47,775	28,665	47
6"	850	22.40	19,040	11,424	16
Service connections					
STE pump	155	3,428	531,340	159,402	9,765
Septic tank					
upgrade	146	143	20,878	12,527	1,460
replace	41	750	30,750	18,450	410
Cluster drainfield					
Sister Lake	162	1,250	202,500	--	2,080
Lift station 124 gpm TDH-20 ft			93,800	9,270	1,934
Woodlawn Park Add'n.	15	1,250	18,750	--	2,080
Lift station 10 gpm TDH-20 ft			12,750	3,825	1,315
Subtotal initial cost			1,103,319	319,004	19,241
Service factor (35%)			386,162	--	--
Subtotal initial capital cost			1,489,481	--	--
Future connections cost					
Building sewer	10	55	550	330	--
Septic tank + STE pump	10	4,128	41,280	12,384	730
Subtotal future connection cost			41,830	12,714	730
Annual future connection cost			2,091	--	36

Table D-85. Quantities and costs for septic tank effluent pressure sewers and cluster drainfields serving limited areas for District #6 Sister Lakes (Alternative 8A).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	750	$ 17.00	$ 12,750	$ 7,650	$ 14
2½"	700	17.35	12,145	7,287	13
3"	800	18.20	14,560	8,736	15
4"	2,650	19.50	51,675	31,005	50
Service connections					
STE pump	61	3,428	209,108	62,732	3,843
Septic tank					
upgrade	44	143	6,292	3,775	440
replace	18	750	13,500	8,100	180
Cluster drainfield					
SE shore area	8	1,250	10,000	--	2,080
Woodlawn Beach	56	1,250	70,000	--	2,080
Lift station 35 gpm TDH-20 ft			30,900	9,270	1,418
Subtotal initial cost			430,930	138,555	10,133
Service factor (35%)			150,825	--	--
Subtotal initial capital cost			581,755	--	--

Table D-86. Quantities and costs for septic tank effluent pressure sewers and cluster drainfields serving limited areas for District #8 Sister Lakes (Alternative 8A).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2½"	1,600	$ 17.35	$ 27,760	$16,656	$ 30
Service connections					
STE pump	7	3,428	23,996	7,199	441
Septic tank					
upgrade	4	143	572	343	40
replace	3	750	2,250	1,350	30
Cluster drainfield					
Wildwood Sub.	7	1,250	8,750	--	2,080
Subtotal initial cost			63,328	25,548	2,621
Service factor (35%)			22,165	--	--
Subtotal initial capital cost			85,493	--	--
Future connections cost					
Building sewer	2	55	110	66	--
Septic tank + STE pump	2	4,128	8,256	2,477	146
Subtotal future connection cost			8,366	2,543	7
Annual future connection cost			418	--	--

Table D-87. Quantities and costs for septic tank effluent pressure sewers and cluster drainfields serving limited areas for District #9 Sister Lakes (Alternative 8A).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	450	$ 17.00	$ 7,650	$ 4,590	$
2½"	2,350	17.35	40,772	24,463	4
3"	3,050	18.20	55,510	33,306	5
Service connections					
STE pump	68	3,428	233,104	69,931	4,28
Septic tank					
upgrade	51	143	7,293	4,376	51
replace	17	750	12,750	7,650	17
Cluster drainfield					
Magician Lake Woods	26	1,250	32,500	--	2,08
Lift station 17 gpm TDH-20 ft			12,750	3,825	1,31
Krohnes & Oaklands	42	1,250	52,500	--	2,08
Lift station 27 gpm TDH-20 ft			30,900	9,270	1,41
Subtotal initial cost			485,729	157,411	11,96
Service factor (35%)			170,005	--	--
Subtotal initial capital cost			655,734	--	--
Future connections cost					
Building sewer	2	55	110	66	--
Septic tank + STE pump	2	4,128	8,256	2,477	14
Subtotal future connection cost			8,366	2,543	14
Annual future connection cost			418	--	

Table D-88. Quantities and costs for septic tank effluent pressure sewers and cluster drainfields serving limited areas for District #10 Sister Lakes (Alternative 8A).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2½"	1,100	$ 17.35	$ 19,085	$ 11,451	$ 21
3"	1,550	18.20	28,210	16,926	29
4"	2,350	19.50	45,825	27,495	45
Service connections					
STE pump	51	3,428	174,828	52,448	3,213
Septic tank					
upgrade	48	143	6,864	4,118	480
replace	17	750	12,750	7,650	170
Cluster drainfield					
Gilmore & Rainbow Beach	55	1,250	68,750	--	2,080
Lift station 39 gpm TDH-20 ft			30,900	9,270	1,420
Subtotal initial cost			387,212	129,358	7,458
Service factor (35%)			135,524	--	--
Subtotal initial capital cost			522,736	--	--
Future connections cost					
Building sewer	13	55	715	429	--
Septic tank + STE pump	13	4,128	53,664	16,099	949
Subtotal future connection cost			54,379	16,528	949
Annual future connection cost			2,719	--	47

Table D-89. Quantities and costs for septic tank effluent pressure sewers and cluster drainfields serving limited areas for District #11 Sister Lakes (Alternative 8A).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	900	$ 17.00	$ 15,300	$ 9,180	$ 17
2½"	400	17.35	6,940	4,164	8
3"	4,800	18.20	87,360	52,416	91
4"	1,400	19.50	27,300	16,380	27
Service connections					
STE pump	87	3,428	298,236	89,471	5,481
Septic tank					
upgrade	73	143	10,439	6,263	730
replace	16	750	12,000	7,200	160
Cluster drainfield					
Polk's Landing-east end	15	1,250	18,750	--	2,080
Lift station 10 gpm TDH-20 ft			12,750	3,825	1,315
Polk's Landing- west end	4	1,250	5,000	--	--
Curran's & Maple Island	70	1,250	87,500	--	2,080
Lift station 42 gpm TDH-20 ft			30,900	9,270	1,422
Subtotal initial cost			612,475	198,169	13,411
Service factor (35%)			214,366	--	--
Subtotal initial capital cost			826,841	--	--
Future connections cost					
Building sewer	4	55	220	132	--
Septic tank + STE pump	4	4,128	16,512	4,954	292
Subtotal future connection cost			16,732	5,086	292
Annual future connection cost			837	--	15

Table D-90. Quantities and costs for septic tank effluent pressure sewers and cluster drainfields serving limited areas for District #13 Sister Lakes (Alternative 8A).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2½"	1,350	$ 17.35	$ 23,422	$14,053	$ 26
3"	1,400	18.20	25,480	15,288	27
Service connections					
STE pump	32	3,428	109,696	32,909	2,016
Septic tank					
upgrade	21	143	3,003	1,802	210
replace	11	750	8,250	4,950	110
Cluster drainfield					
Oaklands	10	1,250	12,500	--	2,080
Magician Bay Park	22	1,250	27,500	--	2,080
Lift station 14 gpm TDH-20 ft			12,750	3,825	1,317
Subtotal initial cost			222,601	72,827	7,866
Service factor (35%)			77,910	--	--
Subtotal initial capital cost			300,511	--	--
Future connections cost					
Building sewer	2	55	110	66	--
Septic tank + STE pump	2	4,128	8,256	2,477	219
Subtotal future connection cost			8,366	2,543	219
Annual future connection cost			418	--	11

Table D-91. Quantities and costs for septic tank effluent pressure sewers and cluster drainfields serving limited areas for District #14 Sister Lakes (Alternative 8A).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2½"	600	$ 17.35	$ 10,410	$ 6,246	$ 11
Service connections					
STE pump	10	3,428	34,280	10,284	630
Septic tank					
upgrade	7	143	1,001	601	70
replace	3	750	2,250	1,350	30
Cluster drainfield					
Cable Park Beach	10	1,250	12,500	--	2,080
Subtotal initial cost			60,441	18,481	2,821
Service factor (35%)			21,154	--	--
Subtotal initial capital cost			81,595	--	--

Table D-92. Quantities and costs for septic tank effluent pressure sewers and cluster drainfields serving limited areas for District #15 Sister Lakes (Alternative 8A).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe					
2"	100	$ 17.00	$ 1,700	$ 1,020	$ 2
2½"	900	17.35	15,615	9,369	17
3"	3,250	18.20	59,150	35,490	62
Service connections					
STE pump	27	3,428	92,556	27,767	1,701
Septic tank					
upgrade	25	143	3,575	2,145	250
replace	9	750	6,750	4,050	90
Cluster drainfield					
Swishers & Sandy Beach Resort	34	1,250	42,500	—	2,080
Lift station 23 gpm TDH-20 ft			12,750	3,825	1,322
Subtotal initial cost			234,596	83,666	5,524
Service factor (35%)			82,109	--	--
Subtotal initial capital cost			316,705	--	--
Future connections cost					
Building sewer	3	55	165	99	--
Septic tank + STE pump	3	4,128	12,384	3,715	219
Subtotal future connection cost			12,549	3,814	219
Annual future connection cost			627	--	11

Table D-93. Quantities and costs for upgrading and operating on-site systems in areas not served by cluster systems for District #1 Indian Lake (Alternatives 8A and 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	147	$ 143	$ 21,021	$12,613	$1,470
replace	25	750	18,750	11,250	250
Soil absorption system	172		--	--	1,720
drain bed	25	754	18,850	--	--
lift pump + drain bed	5	1,620	8,100	--	310
raised drain bed	5	1,555	7,775	--	--
lift pump + raised drain bed	5	2,421	12,105	--	310
dry well	5	578	2,890	--	--
lift pump + dry well	5	1,444	7,220	--	310
Subtotal initial cost			96,711	23,863	4,370
Service factor (35%)			33,849	--	--
Subtotal initial capital cost			130,560	--	--
Future costs					
Building sewer	16	55	880	528	--
Septic tank	16	700	11,200	6,720	160
Soil absorption systems	16		--	--	160
Drain bed	10	754	7,540	--	--
Lift pump + drain bed	5	1,620	8,100	--	310
Raised drain bed	5	1,555	7,775	--	--
Lift pump + raised drain bed	5	2,421	12,105	--	310
Dry well	5	578	2,890	--	--
Lift pump + dry well	5	1,444	7,220	--	310
Subtotal future costs			57,710	7,248	1,250
Annual future cost			2,885		63

Table D-94. Quantities and costs for upgrading and operating on-site systems in areas not served by cluster systems for District #2 Indian Lake (Alternatives 8A and 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	60	$ 143	$ 8,580	$ 5,148	$ 600
replace	15	750	11,250	6,750	150
Soil absorption system	75		--	--	750
drain bed	7	754	5,278	--	--
lift pump + drain bed	10	1,620	16,200	--	620
raised drain bed	5	1,555	7,775	--	--
lift pump + raised drain bed	2	2,421	4,842	--	124
dry well	5	578	2,890	--	--
lift pump + dry well	10	1,444	14,440	--	620
Subtotal initial cost			71,255	11,898	2,864
Service factor (35%)			24,939	--	--
Subtotal initial capital cost			96,194	--	--
Future costs					
Building sewer	12	55	660	396	--
Septic tank	12	700	8,400	5,040	120
Soil absorption systems	12		--	--	120
Drain bed	10	754	7,540	--	--
Lift pump + drain bed	10	1,620	16,200	--	620
Raised drain bed	2	1,555	3,110	--	--
Lift pump + raised drain bed	2	2,421	4,842	--	124
Dry well	2	578	1,156	--	--
Lift pump + dry well	5	1,444	7,220	--	310
Subtotal future costs			49,128	5,436	1,294
Annual future costs			2,456	--	65

Table D-95. Quantities and costs for upgrading and operating on-site systems in areas not served by cluster systems for District #3 Indian Lake (Alternatives 8A and 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	50	$ 143	$ 7,150	$ 4,290	$ 500
replace	15	750	11,250	6,750	150
Soil absorption system	65	—	--	--	650
drain bed	10	754	7,540	--	--
lift pump + drain bed	5	1,620	8,100	--	310
raised drain bed	10	1,555	15,550	--	--
lift pump + raised drain bed	3	2,421	7,263	--	186
dry well	2	578	1,156	--	--
lift pump + dry well	2	1,444	2,888		124
Subtotal initial cost			60,897	11,040	1,920
Service factor (35%)			21,314	--	--
Subtotal initial capital cost			82,211	--	--
Future costs					
Building sewer	14	55	770	462	--
Septic tank	14	700	9,800	5,880	140
Soil absorption systems	14		--	--	140
Drain bed	10	754	7,540	--	--
Lift pump + drain bed	5	1,620	8,100	--	310
Raised drain bed	2	1,555	3,110	--	--
Lift pump + raised drain bed	1	2,421	2,421	--	62
Dry well		578	--	--	--
Lift pump + dry well	2	1,444	2,888	--	124
Subtotal future costs			34,629	6,342	776
Annual future cost			1,731	--	39

able D-96. Quantities and costs for upgrading and operating on-site systems in areas not served by cluster systems for District #1 Sister Lakes (Alternatives 8A and 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
eptic tank					
upgrade	85	$ 143	$ 12,155	$ 7,293	$ 850
replace	16	750	12,000	7,200	160
oil absorption system	101		--	--	1,010
drain bed	20	754	15,080	--	--
lift pump + drain bed	5	1,620	8,100	--	310
raised drain bed	5	1,555	7,775	--	--
lift pump + raised drain bed	10	2,421	24,210	--	620
dry well	3	578	1,734	--	--
lift pump + dry well	3	1,444	4,332	--	186
ubtotal initial cost			85,386	14,493	3,136
ervice factor (35%)			29,885	--	--
ubtotal initial capital cost			115,271	--	--
uture costs					
Building sewer	21	55	1,155	693	--
Septic tank	21	700	14,700	8,820	210
Soil absorption systems	21		--	--	210
Drain bed	10	754	7,540	--	--
Lift pump + drain bed	5	1,620	8,100	--	310
Raised drain bed	3	1,555	4,665	--	--
Lift pump + raised drain bed	7	2,421	16,947	--	434
Dry well	2	578	1,156	--	--
Lift pump + dry well	2	1,444	2,888	--	124
Subtotal future costs			57,151	9,513	1,288
Annual future cost			2,858	--	64

Table D-97. Quantities and costs for upgrading and operating on-site systems in areas not served by cluster systems for District #4 Sister Lakes (Alternatives 8A and 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	86	$ 143	$ 12,298	$ 7,379	$ 860
replace	24	750	18,000	10,800	240
Soil absorption system	110		--	--	1,100
drain bed	10	754	7,540	--	--
lift pump + drain bed	7	1,620	11,340	--	434
raised drain bed	7	1,555	10,885	--	--
lift pump + raised drain bed	15	2,421	36,315	--	930
dry well	5	578	2,890	--	--
lift pump + dry well	5	1,444	7,220	--	310
Subtotal initial cost			106,488	18,179	3,874
Service factor (35%)			37,271	--	--
Subtotal initial capital cost			143,759	--	--
Future costs					
Building sewer	26	55	1,430	858	--
Septic tank	26	700	18,200	10,920	260
Soil absorption systems	26		--	--	260
Drain bed	15	754	11,310	--	--
Lift pump + drain bed	5	1,620	8,100	--	310
Raised drain bed	5	1,555	7,775	--	--
Lift pump + raised drain bed	5	2,421	12,105	--	310
Dry well	2	578	1,156	--	--
Lift pump + dry well	2	1,444	2,880	--	124
Subtotal future costs			62,956	11,778	1,264
Annual future cost			3,148	--	63

Table D-98. Quantities and costs for upgrading and operating on-site systems in areas not served by cluster systems for District #5 Sister Lakes (Alternatives 8A and 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	58	$ 143	$ 8,294	$ 4,976	$ 580
replace	20	750	15,000	9,000	200
Soil absorption system	78		--	--	780
drain bed	10	754	7,540	--	--
lift pump + drain bed	5	1,620	8,100	--	310
raised drain bed	5	1,555	7,775	--	--
lift pump + raised drain bed	2	2,421	4,842	--	124
dry well	2	578	1,156	--	--
lift pump + dry well	2	1,444	2,888	--	124
Subtotal initial cost			55,595	13,976	2,118
Service factor (35%)			19,458	--	--
Subtotal initial capital cost			75,053	--	--
Future costs					
Building sewer	11	55	605	363	--
Septic tank	11	700	7,700	4,620	110
Soil absorption systems	11		--	--	110
Drain bed	7	754	5,278	--	--
Lift pump + drain bed	5	1,620	8,100	--	310
Raised drain bed	5	1,555	7,775	--	--
Lift pump + raised drain bed		2,421	--	--	--
Dry well		578	--	--	--
Lift pump + dry well		1,444	--	--	--
Subtotal future costs			29,458	4,983	530
Annual future cost			1,473	--	26

Table D-99. Quantities and costs for upgrading and operating on-site systems in areas not served by cluster systems for District #6 Sister Lakes (Alternatives 8A and 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	147	$ 143	$ 21,021	$12,613	$1,470
replace	26	750	19,500	11,700	260
Soil absorption system	173		--	--	1,730
drain bed	15	754	11,310	--	--
lift pump + drain bed	15	1,620	24,300	--	930
raised drain bed	5	1,555	7,775	--	--
lift pump + raised drain bed	5	2,421	12,105	--	310
dry well	10	578	5,780	--	--
lift pump + dry well	10	1,444	14,440	--	620
Subtotal initial cost			116,231	24,313	5,320
Service factor (35%)			40,681	--	--
Subtotal initial capital cost			156,912	--	--
Future costs					
Building sewer	30	55	1,650	990	--
Septic tank	30	700	21,000	12,600	300
Soil absorption systems	30		--	--	300
Drain bed	25	754	18,850	--	--
lift pump + drain bed	5	1,620	8,100	--	310
raised drain bed	5	1,555	7,775	--	--
lift pump + raised drain bed	5	2,421	12,105	--	310
Dry well	5	578	2,890	--	--
Lift pump + dry well	10	1,444	14,440	--	620
Subtotal future costs			86,810	13,590	1,840
Annual future cost			4,340	--	92

Table D-100. Quantities and costs for upgrading and operating on-site systems in areas not served by cluster systems for District #7 Sister Lakes (Alternatives 8A and 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	75	$ 143	$ 10,725	$ 6,435	$ 750
replace	12	750	9,000	5,400	120
Soil absorption system	87		--	--	870
drain bed	5	754	3,770	--	--
lift pump + drain bed	13	1,620	21,060	--	806
raised drain bed	5	1,555	7,775	--	--
lift pump + raised drain bed	5	2,421	12,105	--	310
Dry well	5	578	2,890	--	--
Lift pump + dry well	12	1,444	17,328	--	744
Subtotal initial cost			84,653	11,835	3,600
Service factor (35%)			29,629	--	--
Subtotal initial capital cost			114,282	--	--
Future costs					
Building sewer	10	55	550	330	--
Septic tank	10	700	7,000	4,200	100
Soil absorption systems	10		--	--	100
Drain bed	7	754	5,278	--	--
Lift pump + drain bed	3	1,620	4,860	--	186
Raised drain bed	2	1,555	3,110	--	--
Lift pump + raised drain bed	2	2,421	4,842	--	124
Dry well		578	--	--	--
Lift pump + dry well	7	1,444	10,108	--	434
Subtotal future costs			35,748	4,530	944
Annual future cost			1,787	--	47

Table D-101. Quantities and costs for upgrading and operating on-site systems in areas not served by cluster systems for District #8 Sister Lakes (Alternatives 8A and 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	126	$ 143	$ 18,018	$10,811	$1,260
replace	14	750	10,500	6,300	140
Soil absorption system	140		--	--	1,400
drain bed	20	754	15,080	--	--
lift pump + drain bed	12	1,620	19,440	--	744
raised drain bed	7	1,555	10,885	--	--
lift pump + raised drain bed	5	2,421	12,105	--	310
dry well	5	578	2,890	--	--
lift pump + dry well	5	1,444	7,220	--	310
Subtotal initial cost			96,138	17,111	4,164
Service factor (35%)			33,648	--	--
Subtotal initial capital cost			129,786	--	--
Future costs					
Building sewer	30	55	1,650	990	--
Septic tank	30	700	21,000	--	300
Soil absorption systems	30		--	--	300
Drain bed	17	754	12,818	--	--
Lift pump + drain bed	7	1,620	11,340	--	434
Raised drain bed	5	1,555	7,775	--	--
Lift pump + raised drain bed	5	2,421	12,105	--	310
Dry well	5	578	2,890	--	--
Lift pump + dry well	2	1,444	2,888	--	124
Subtotal future costs			72,466	13,590	1,468
Annual future cost			3,623	--	73

Table D-102. Quantities and costs for upgrading and operating on-site systems in areas not served by cluster systems for District #9 Sister Lakes (Alternatives 8A and 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	112	$ 143	$ 16,016	$ 9,610	$1,120
replace	27	750	20,250	12,150	270
Soil absorption system	139		--	--	1,390
drain bed	25	754	18,850	--	--
lift pump + drain bed	10	1,620	16,200	--	620
raised drain bed	15	1,555	23,325	--	--
lift pump + raised drain bed	5	2,421	12,105	--	310
dry well	5	578	2,890	--	--
lift pump + dry well	15	1,444	21,660	--	930
Subtotal initial cost			131,296	21,760	4,640
Service factor (35%)			45,954	--	--
Subtotal initial capital cost			177,250	--	--
Future costs					
Building sewer	25	55	1,375	825	--
Septic tank	25	700	17,500	10,500	250
Soil absorption systems	25		--	--	250
Drain bed	15	754	11,310	--	--
Lift pump + drain bed	10	1,620	16,200	--	620
Raised drain bed	5	1,555	7,775	--	--
Lift pump + raised drain bed	5	2,421	12,105	--	310
Dry well	5	578	2,890	--	--
Lift pump + dry well	10	1,444	14,440	--	620
Subtotal future costs			83,595	11,325	2,050
Annual future cost			4,180	--	102

Table D-103. Quantities and costs for upgrading and operating on-site systems in areas not served by cluster systems for District #10 Sister Lakes (Alternatives 8A and 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	72	$ 143	$ 10,296	$ 6,178	$ 720
replace	16	750	12,000	7,200	160
Soil absorption system	88		--	--	880
drain bed	15	754	11,310	--	--
lift pump + drain bed	18	1,620	29,160	--	1,116
raised drain bed	5	1,555	7,775	--	--
lift pump + raised drain bed	5	2,421	12,105	--	310
dry well	5	578	2,890	--	--
lift pump + dry well	5	1,444	7,220	--	310
Subtotal initial cost			92,756	13,378	3,496
Service factor (35%)			32,465	--	--
Subtotal initial capital cost			125,221	--	--
Future costs					
Building sewer	14	55	770	462	--
Septic tank	14	700	9,800	5,880	140
Soil absorption systems	14		--	--	140
Drain bed	10	754	7,540	--	--
Lift pump + drain bed	8	1,620	12,960	--	496
Raised drain bed	5	1,555	7,775	--	--
Lift pump + raised drain bed	3	2,421	7,263	--	186
Dry well	3	578	1,734	--	--
Lift pump + dry well	5	1,444	7,220	--	310
Subtotal future costs			55,062	6,342	1,272
Annual future cost			2,753	--	64

Table D-104. Quantities and costs for upgrading and operating on-site systems in areas not served by cluster systems for District #11 Sister Lakes (Alternatives 8A and 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	51	$ 143	$ 7,293	$4,376	$ 510
replace	6	750	4,500	2,700	60
Soil absorption system	57		--	--	570
drain bed	5	754	3,770	--	--
lift pump + drain bed	10	1,620	16,200	--	620
raised drain bed	7	1,555	10,885	--	--
lift pump + raised drain bed	5	2,421	12,105	--	310
dry well		578	--	--	--
lift pump + dry well	5	1,444	7,200	--	310
Subtotal initial cost			61,973	7,076	2,380
Service factor (35%)			21,691	--	--
Subtotal initial capital cost			83,664	--	--
Future costs					
Building sewer	5	55	275	165	--
Septic tank	5	700	3,500	2,100	50
Soil absorption systems	5		--	--	50
Drain bed	5	754	3,770	--	--
Lift pump + drain bed	5	1,620	8,100	--	310
Raised drain bed	2	1,555	3,110	--	--
Lift pump + raised drain bed	2	2,421	4,842	--	124
Dry well		578	--	--	--
Lift pump + dry well	5	1,444	7,220	--	310
Subtotal future costs			30,817	2,265	844
Annual future cost			1,541	--	42

Table D-105. Quantities and costs for upgrading and operating on-site systems in areas not served by cluster systems for District #12 Sister Lakes (Alternatives 8A and 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	60	$ 143	$ 8,580	$ 5,148	$ 600
replace	21	750	15,750	9,450	210
Soil absorption system	81		--	--	810
drain bed	10	754	7,540	--	--
lift pump + drain bed	10	1,620	16,200	--	620
raised drain bed	5	1,555	7,775	--	--
lift pump + raised drain bed	10	2,421	24,210	--	620
dry well	5	578	2,890	--	--
lift pump + dry well	10	1,444	14,440	--	620
Subtotal initial cost			97,385	14,598	3,480
Service factor (35%)			34,085	--	--
Subtotal initial capital cost			131,470	--	--
Future costs					
Building sewer	10	55	550	330	--
Septic tank	10	700	7,000	4,200	100
Soil absorption systems	10		--	--	100
Drain bed	7	754	5,278	--	--
Lift pump + drain bed	8	1,620	12,960	--	496
Raised drain bed	3	1,555	4,665	--	--
Lift pump + raised drain bed	10	2,421	24,210	--	620
Dry well		578	--	--	--
Lift pump + dry well	5	1,444	7,220	--	310
Subtotal future costs			61,883	4,530	1,626
Annual future cost			3,094	--	81

Table D-106. Quantities and costs for upgrading and operating on-site systems in areas not served by cluster systems for District #13 Sister Lakes (Alternatives 8A and 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	89	$ 143	$ 12,727	$ 7,636	$ 890
replace	34	750	25,500	15,300	340
Soil absorption system	123		--	--	1,230
drain bed	15	754	11,310	--	--
lift pump + drain bed	15	1,620	24,300	--	930
raised drain bed	5	1,555	7,775	--	--
lift pump + raised drain bed	20	2,421	48,420	--	1,240
dry well	7	578	4,046	--	--
lift pump + dry well	15	1,444	21,660	--	930
Subtotal initial cost			155,738	22,936	5,560
Service factor (35%)			54,508	--	--
Subtotal initial capital cost			210,246	--	--
Future costs					
Building sewer	30	55	1,650	990	--
Septic tank	30	700	21,000	12,600	300
Soil absorption systems	30		--	--	300
Drain bed	12	754	9,048	--	--
Lift pump + drain bed	10	1,620	16,200	--	620
Raised drain bed	10	1,555	15,550	--	--
Lift pump + raised drain bed	7	2,421	16,947	--	434
Dry well	5	578	2,890	--	--
Lift pump + dry well	13	1,444	18,772	--	806
Subtotal future costs			102,057	13,590	2,460
Annual future cost			5,103	--	123

Table D-107. Quantities and costs for upgrading and operating on-site systems in areas not served by cluster systems for District #14 Sister Lakes (Alternatives 8A and 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	20	$ 143	$ 2,860	$1,716	$ 200
replace	4	750	3,000	1,800	40
Soil absorption system	24		--	--	240
drain bed	--	754	--	--	--
lift pump + drain bed	5	1,620	8,100	--	310
raised drain bed	3	1,555	4,665	--	--
lift pump + raised drain bed	7	2,421	16,947	--	434
dry well	2	578	1,156	--	--
lift pump + dry well		1,444	--	--	--
Subtotal initial cost			36,728	3,516	1,224
Service factor (35%)			12,855	--	--
Subtotal initial capital cost			49,583	--	--
Future costs					
Building sewer	3	55	165	99	--
Septic tank	3	700	2,100	1,260	30
Soil absorption systems	3		--	--	30
Drain bed	5	754	3,770	--	--
Lift pump + drain bed	2	1,620	3,240	--	124
Raised drain bed		1,555	--	--	--
Lift pump + raised drain bed		2,421	--	--	--
Dry well		578	--	--	--
Lift pump + dry well	2	1,444	2,888	--	124
Subtotal future costs			12,163	1,359	308
Annual future cost			608	--	15

Table D-108. Quantities and costs for upgrading and operating on-site systems in areas not served by cluster systems for District #15 Sister Lakes (Alternatives 8A and 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	123	$ 143	$ 17,589	$10,553	$1,230
replace	23	750	17,250	10,350	230
Soil absorption system	146		--	--	1,460
drain bed	20	754	15,080	--	--
lift pump + drain bed	17	1,620	27,540	--	1,054
raised drain bed	15	1,555	23,325	--	--
lift pump + raised drain bed	12	2,421	29,052	--	744
dry well	7	578	4,046	--	--
lift pump + dry well	15	1,444	21,660	--	930
Subtotal initial cost			138,292	20,903	5,648
Service factor (35%)			48,402	--	--
Subtotal initial capital cost			186,694	--	--
Future costs					
Building sewer	26	55	1,430	858	--
Septic tank	26	700	18,200	10,920	260
Soil absorption systems	26		--	--	260
Drain bed	15	754	11,310	--	--
Lift pump + drain bed	7	1,620	11,340	--	434
Raised drain bed	5	1,555	7,775	--	--
Lift pump + raised drain bed	10	2,421	24,210	--	620
Dry well	5	578	2,890	--	--
Lift pump + dry well	7	1,444	10,108	--	434
Subtotal future costs			87,263	11,778	2,008
Annual future cost			4,363	--	100

Table D-109. Summary and present worth of costs for Alternative 8B - septic tank effluent collection sewers with cluster drainfields and upgraded on-site systems (June 1981 costs).

	Initial Cost						Future Connections Cost							
				Present Worth						Present Worth				
District	Capital	Salvage	O&M	Salvage	O&M	Total	Annual Construction	Total Salvage	Incremental Annual O&M	Construction	Salvage	O&M	Total	Total Present Worth
Indian Lake														
1	871,469	264,880	12,559	60,922	126,825	937,367	3,118	10,046	64	31,487	2,311	4,615	33,791	971,158
2	290,810	84,744	9,977	19,491	100,751	372,070	2,573	6,835	66	25,983	1,572	4,759	29,170	401,240
3	932,612	279,653	12,025	64,320	121,432	989,724	2,314	13,338	42	23,367	3,068	3,028	23,327	1,013,051
Subtotal:	2,094,891	629,277	34,561	144,733	349,008	2,299,161	8,005	30,219	172	80,837	6,951	12,402	86,288	2,385,449
Pipestone Lake														
2	485,040	172,031	5,745	39,567	58,015	503,488	--	--	--	--	--	--	--	503,488
3	255,959	87,156	3,837	20,046	38,747	274,660	--	--	--	--	--	--	--	274,660
Subtotal:	740,999	259,187	9,582	59,613	96,762	778,148	--	--	--	--	--	--	--	778,148
Sister Lakes														
1	255,612	67,156	7,011	15,446	70,799	310,965	2,858	9,513	64	28,861	2,188	4,615	31,288	342,253
4	270,705	57,939	5,546	13,326	56,005	313,384	3,498	15,976	65	35,324	3,674	4,687	36,337	349,721
5	1,611,045	493,104	17,023	113,414	171,903	1,669,534	2,639	12,144	31	26,649	2,793	2,235	26,091	1,695,625
6	765,882	211,824	16,642	48,720	168,056	885,218	4,340	13,590	92	43,827	3,126	6,634	47,335	979,888
7	114,282	11,835	3,600	2,722	36,354	139,128	1,787	4,530	47	18,046	1,042	3,389	20,393	159,521
8	220,656	48,422	7,650	11,137	77,252	286,771	3,856	16,388	74	38,939	3,769	5,336	40,506	327,277
9	801,526	219,244	15,511	50,426	156,635	907,735	4,413	14,123	103	44,564	3,248	7,427	48,743	956,478
10	603,913	172,524	7,975	39,681	80,534	644,766	4,269	24,532	70	43,110	5,642	5,048	42,516	687,282
11	887,877	256,729	15,329	59,048	154,797	983,626	2,007	7,862	44	20,267	1,808	3,173	21,632	1,005,258
12	131,470	14,598	3,480	3,358	35,142	163,254	3,094	4,530	81	31,244	1,042	5,841	36,043	199,297
13	502,474	118,080	12,947	27,158	130,743	606,059	5,336	16,388	124	53,885	3,769	8,941	59,057	665,116
14	136,221	30,697	4,735	7,060	47,815	176,976	608	1,359	15	6,140	313	1,082	6,909	183,885
15	506,652	126,871	10,979	29,180	110,869	588,341	4,713	15,976	102	47,593	5,674	7,355	51,274	639,615
Subtotal:	6,808,315	1,829,023	127,558	420,676	1,288,118	7,675,757	61,418	156,911	913	438,449	36,088	65,763	468,124	8,143,881
Total	9,644,205	2,717,487	171,701	625,022	1,733,888	10,753,066	69,423	187,130	1,084	519,286	43,039	78,165	554,412	11,307,478

Table D-110. Quantities and costs for septic tank effluent gravity sewers and cluster drainfields serving limited areas for District #1 Indian Lake (Alternative 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	5,040	$ 35.30	$ 177,912	$106,747	$ 192
Lift station					
51 gpm TDH-48 ft			54,000	16,200	1,613
6 gpm TDH-25 ft			12,750	3,825	1,314
Force main, common trench					
2"	300	4.60	1,380	828	--
3"	680	5.75	3,910	2,346	--
Force main, individual trench					
3"	820	14.15	11,603	6,962	--
Service connection					
gravity	91	1,577	143,507	86,104	--
Septic tank					
upgrade	63	143	9,009	5,405	630
replace	28	750	21,000	12,600	280
Cluster drainfield					
Edgewood-Tice	82	1,250	102,500	--	2,080
Oak Grove	9	1,250	11,250	--	2,080
Subtotal initial cost			548,821	241,017	8,189
Service factor (35%)			192,087	--	--
Subtotal initial capital cost			740,908	--	--
Future connections cost					
Building sewer	2	55	110	66	--
Septic tank + gravity	2	2,277	4,554	2,732	20
Subtotal future connection cost			4,664	2,798	20
Annual future connection cost			233	--	1

Table D-111. Quantities and costs for septic tank effluent gravity sewers and cluster drainfields serving limited areas for District #2 Indian Lake (Alternative 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	1,700	$ 35.30	$ 60,010	$36,006	$ 65
Lift station					
3 gpm TDH-25 ft			12,750	3,825	1,312
9 gpm TDH-25 ft			12,750	3,825	1,316
Force main, individual trench					
2"	750	13.00	9,750	5,850	--
Service connection					
gravity	20	1,577	31,540	18,924	--
Septic tank					
upgrade	20	143	2,860	1,716	200
replace	6	750	4,500	2,700	60
Cluster drainfield					
Indian Trail cul-de-sac	5	1,250	6,250	--	2,080
Forest Beach Blk 2,3,4	15	1,250	3,750	--	2,080
Subtotal initial cost			144,160	72,846	7,113
Service factor (35%)			50,456	--	--
Subtotal initial capital cost			194,616	--	--
Future connections cost					
Building sewer	1	55	55	33	--
Septic tank + gravity	1	2,277	2,277	1,366	10
Subtotal future connection cost			2,332	1,399	10
Annual future connection cost			117	--	0.5

Table D-112. Quantities and costs for septic tank effluent gravity sewers and cluster drainfields serving limited areas for District #3 Indian Lake (Alternative 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	4,900	$ 35.30	$ 172,970	$103,782	$ 186
Lift station					
15 gpm TDH-35 ft			12,750	3,825	1,324
35 gpm TDH-65 ft			30,900	9,270	1,459
29 gpm TDH-30 ft			30,900	9,270	1,422
Force main, common trench					
2"	800	4.60	3,680	2,208	--
Force main, individual trench					
3"	2,350	14.15	33,252	19,951	--
Service connection					
gravity	97	1,577	152,969	91,781	--
STE pump	8	3,428	27,424	8,227	504
Septic tank					
upgrade	74	143	10,582	6,349	740
replace	31	750	23,250	13,950	310
Cluster drainfield					
South lake area	57	1,250	71,250	--	2,080
Indian Lake Club	48	1,250	60,000	--	2,080
Subtotal initial cost			629,927	268,613	10,105
Service factor (35%)			220,474	--	--
Subtotal initial capital cost			850,401	--	--
Future connections cost					
Building sewer	5	55	275	165	--
Septic tank + gravity	5	2,277	11,385	6,831	50
Subtotal future connection cost			11,660	6,996	50
Annual future connection cost			583	--	3

Table D-113. Quantities and costs for septic tank effluent gravity sewers and cluster drainfields serving limited areas for District #2 Pipestone Lake (Alternative 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	2,150	$ 35.30	$ 75,895	$45,537	$ 8:
Lift station					
18 gpm TDH-25 ft			12,750	3,825	1,32:
Force main, common trench					
2"	150	4.60	690	414	--
Force main, individual trench					
2"	450	13.00	5,850	3,510	--
Service connection					
gravity	29	1,577	45,733	27,440	--
STE pump	1	3,428	3,428	1,028	6:
Septic tank					
upgrade	21	143	3,003	1,802	21C
replace	8	750	6,000	3,600	8C
Cluster drainfield					
Bass Island Sub.	29	1,250	36,250	--	2,080
Subtotal initial cost			189,599	87,156	3,837
Service factor (35%)			66,360	--	--
Subtotal initial capital cost			255,959	--	--

Table D-114. Quantities and costs for septic tank effluent gravity sewers and cluster drainfields serving limited areas for District #3 Pipestone Lake (Alternative 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	5,080	$ 35.30	$ 179,324	$107,594	$ 193
Lift station					
16 gpm TDH-35 ft			12,750	3,825	1,324
25 gpm TDH-35 ft			12,750	3,825	1,423
Force main, common trench					
2"	950	4.60	4,370	2,622	--
Force main, individual trench					
2"	1,000	13.00	13,000	7,800	--
Service connection					
gravity	36	1,577	56,772	34,063	--
STE pump	5	3,428	17,140	5,142	315
Septic tank					
upgrade	31	143	4,433	2,660	310
replace	10	750	7,500	4,500	100
Cluster drainfield					
North lake area	41	1,250	51,250	--	2,080
Subtotal initial cost			359,289	172,031	5,745
Service factor (35%)			125,751	--	--
Subtotal initial capital cost			485,040	--	--

Table D-115. Quantities and costs for septic tank effluent gravity sewers and cluster drainfields serving limited areas for District #1 Sister Lakes (Alternative 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	1,150	$ 35.30	$ 40,595	$24,357	$ 44
Lift station					
25 gpm TDH-50 ft			12,750	3,825	1,432
Force main, common trench					
2"	450	4.60	2,070	1,242	--
Force main, individual trench					
2"	150	13.00	1,950	1,170	--
Service connection					
gravity	10	1,577	15,770	9,462	--
STE pump	3	3,428	10,284	3,085	189
Septic tank					
upgrade	9	143	1,287	7,722	90
replace	4	750	3,000	1,800	40
Cluster drainfield					
Oak Park Sub.	13	1,250	16,250	--	2,080
Subtotal initial cost			103,956	52,663	3,875
Service factor (35%)			36,385	--	--
Subtotal initial capital cost			140,341	--	--

Table D-116. Quantities and costs for septic tank effluent gravity sewers and cluster drainfields serving limited areas for District #4 Sister Lakes (Alternative 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	1,000	$ 35.30	$ 35,300	$21,180	$ 38
Lift station					
9 gpm TDH-20 ft			12,750	3,825	1,315
Service connection					
gravity	10	1,577	15,770	9,462	--
STE pump	3	3,428	10,284	3,085	189
Septic tank					
upgrade	10	143	1,430	858	100
replace	3	750	2,250	1,350	30
Cluster drainfield					
Ronni St.	13	1,250	16,250	--	--
Subtotal initial cost			94,034	39,760	1,672
Service factor (35%)			32,912	--	--
Subtotal initial capital cost			126,946	--	--
Future connections cost					
Building sewer	3	55	165	99	--
Septic tank + gravity	3	2,277	6,831	4,099	30
Subtotal future connection cost			6,996	4,198	30
Annual future connection cost			350	--	1.5

Table D-117. Quantities and costs for septic tank effluent gravity sewers and cluster drainfields serving limited areas for District #5 Sister Lakes (Alternative 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	6,850	$ 35.30	$ 241,805	$145,083	$ 260
6"	2,010	37.00	74,370	44,622	76
Lift station					
30 gpm TDH-30 ft			30,900	9,270	1,423
13 gpm TDH-20 ft			12,750	3,825	1,317
29 gpm TDH-30 ft			30,900	9,270	1,422
124 gpm TDH-55 ft			93,800	28,140	2,046
10 gpm TDH-50 ft			12,750	3,825	1,323
Force main, common trench					
2"	2,590	4.60	11,914	7,148	--
4"	1,750	6.50	11,375	6,825	--
Force main, individual trench					
2"	550	13.00	7,150	4,290	--
4"	850	14.90	12,665	7,599	--
Service connection					
gravity	171	1,577	269,667	161,800	--
STE pump	16	3,428	54,848	16,454	1,008
Septic tank					
upgrade	146	143	20,878	12,527	1,460
replace	41	750	30,750	18,450	410
Cluster drainfield					
Sister Lake	162	1,250	202,500	--	2,080
Woodlawn Park Addition	15	1,250	18,750	--	2,080
Subtotal initial cost			1,137,772	479,128	14,905
Service factor (35%)			398,220	--	--
Subtotal initial capital cost			1,535,992	--	--
Future connections cost					
Building sewer	10	55	550	330	--
Septic tank + gravity	10	2,277	22,770	6,831	100
Subtotal future connection cost			23,320	7,161	100
Annual future connection cost			1,166	--	5

Table D-118. Quantities and costs for septic tank effluent gravity sewers and cluster drainfields serving limited areas for District #6 Sister Lakes (Alternative 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	3,800	$ 35.30	$ 134,140	$ 80,484	$ 144
Lift station					
5 gpm TDH-30 ft			12,750	3,825	1,314
10 gpm TDH-35 ft			12,750	3,825	1,319
25 gpm TDH-65 ft			12,750	3,825	1,442
35 gpm TDH-45 ft			30,900	9,270	1,441
Force main, common trench					
2"	1,600	4.60	7,360	4,416	--
Force main, individual trench					
2"	300	13.00	3,900	2,340	--
3"	700	14.15	9,905	5,943	--
Service connection					
gravity	50	1,577	78,850	47,310	--
STE pump	14	3,428	47,992	14,398	882
Septic tank					
upgrade	44	143	6,292	3,775	440
replace	18	750	13,500	8,100	180
Cluster drainfield					
SE shore area	8	1,250	10,000	--	2,080
Woodlawn Beach	56	1,250	70,000	--	2,080
Subtotal initial cost			451,089	187,511	11,322
Service factor (35%)			157,881	--	--
Subtotal initial capital cost			608,970	--	--

Table D-119. Quantities and costs for septic tank effluent gravity sewers and cluster drainfields serving limited areas for District #8 Sister Lakes (Alternative 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	500	$ 35.30	$ 17,650	$10,590	$ 19
Lift station					
5 gpm TDH-55 ft			12,750	3,825	1,317
Force main, individual trench					
2"	1,100	13.00	14,300	8,580	--
Service connection					
gravity	7	1,577	11,039	6,623	--
Septic tank					
upgrade	4	143	572	343	40
replace	3	750	2,250	1,350	30
Cluster drainfield					
Wildwood Sub.	7	1,250	8,750	--	2,080
Subtotal initial cost			67,311	31,311	3,486
Service factor (35%)			23,559	--	--
Subtotal initial capital cost			90,870	--	--
Future connections cost					
Building sewer	2	55	110	66	--
Septic tank + gravity	2	2,277	4,554	2,732	20
Subtotal future connection cost			4,664	2,798	20
Annual future connection cost			233	--	1

Table D-120. Quantities and costs for septic tank effluent gravity sewers and cluster drainfields serving limited areas for District #9 Sister Lakes (Alternative 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	3,800	$ 35.30	$ 134,140	$ 80,484	$ 144
Lift station					
17 gpm TDH-30 ft			12,750	3,825	1,323
6 gpm TDH-35 ft			12,750	3,825	1,315
14 gpm TDH-40 ft			12,750	3,825	1,324
27 gpm TDH-30 ft			30,900	9,270	1,421
Force main, common trench					
2"	750	4.60	3,450	2,070	--
Force main, individual trench					
2"	2,200	13.00	28,600	17,160	--
Service connection					
gravity	60	1,577	94,620	56,772	--
STE pump	8	3,428	27,424	8,227	504
Septic tank					
upgrade	51	143	7,293	4,376	510
replace	17	750	12,750	7,650	170
Cluster drainfield					
Magician Lake Woods	26	1,250	32,500	--	2,080
Krohnes & Oakland	42	1,250	52,500	--	2,080
Subtotal initial cost			462,427	197,484	10,871
Service factor (35%)			161,849	--	--
Subtotal initial capital cost			624,276	--	--
Future connections cost					
Building sewer	2	55	110	66	--
Septic tank + gravity	2	2,277	4,554	2,732	20
Subtotal future connection csst			4,664	2,798	20
Annual future connection cost			233	--	1

Table D-121. Quantities and costs for septic tank effluent gravity sewers and cluster drainfields serving limited areas for District #10 Sister Lakes (Alternative 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	3,150	$ 35.30	$ 111,195	$ 66,717	$ 120
Lift station					
39 gpm TDH-40 ft			30,900	9,270	1,440
Force main, common trench					
3"	1,600	5.75	9,200	5,520	--
Force main, individual trench					
3"	1,600	14.15	22,640	13,584	--
Service connection					
gravity	52	1,577	82,004	49,202	--
STE pump	3	3,428	10,284	3,085	189
Septic tank					
upgrade	48	143	6,864	4,118	480
replace	17	750	12,750	7,650	170
Cluster drainfield					
Gilmore & Rainbow Beach	55	1,250	68,750	--	2,080
Subtotal initial cost			354,587	159,146	4,479
Service factor (35%)			124,105	--	--
Subtotal initial capital cost			478,692	--	--
Future connections cost					
Building sewer	13	55	715	429	--
Septic tank + gravity	13	2,277	29,601	17,761	130
Subtotal future connection cost			30,316	18,190	130
Annual future connection cost			1,516	--	6

Table D-122. Quantities and costs for septic tank effluent gravity sewers and cluster drainfields serving limited areas for District #11 Sister Lakes (Alternative 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	4,430	$ 35.30	$ 156,379	$ 93,827	$ 168
Lift station					
10 gpm TDH-35 ft			12,750	3,825	1,319
3 gpm TDH-30 ft			12,750	3,825	1,312
16 gpm TDH-35 ft			12,750	3,825	1,324
7 gpm TDH-25 ft			12,750	3,825	1,314
42 gpm TDH-50 ft			30,900	9,270	1,454
Force main, common trench					
2"	820	4.60	3,772	2,263	--
3"	670	5.75	3,852	2,311	--
Force main, individual trench					
2"	2,150	13.00	27,950	16,770	--
3"	600	14.15	8,490	5,094	--
Service connection					
gravity	73	1,577	115,121	69,073	--
STE pump	16	3,428	54,848	16,454	1,008
Septic tank					
upgrade	57	143	8,151	4,891	570
replace	32	750	24,000	14,400	320
Cluster drainfield					
Polk's Landing-east end	15	1,250	18,750	--	2,080
Polk's Landing-west end	4	1,250	5,000	--	--
Curran's & Maple Island	70	1,250	87,500	--	2,080
Subtotal initial cost			595,713	249,653	12,949
Service factor (35%)			208,500	--	--
Subtotal initial capital cost			804,213	--	--
Future connections cost					
Building sewer	4	55	220	132	--
Septic tank + gravity	4	2,277	9,108	5,465	40
Subtotal future connection cost			9,328	5,597	40
Annual future connection cost			466	--	2

Table D-123. Quantities and costs for septic tank effluent gravity sewers and cluster drainfields serving limited areas for District #13 Sister Lakes (Alternative 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	2,150	$ 35.30	$ 75,895	$45,537	$ 82
Lift station					
7 gpm TDH-30 ft			12,750	3,825	1,315
14 gpm TDH-30 ft			12,750	3,825	1,321
Force main, individual trench					
2"	600	13.00	7,800	4,680	--
Service connection					
gravity	29	1,577	45,733	27,440	--
STE pump	3	3,428	10,284	3,085	189
Septic tank					
upgrade	21	143	3,003	1,802	210
replace	11	750	8,250	4,950	110
Cluster drainfield					
Oaklands	10	1,250	12,500	--	2,080
Magician Bay Park	22	1,250	27,500	--	2,080
Subtotal initial cost			216,465	95,144	7,387
Service factor (35%)			75,763	--	--
Subtotal initial capital cost			292,228	--	--
Future connections cost					
Building sewer	2	55	110	66	--
Septic tank + gravity	2	2,277	4,554	2,732	20
Subtotal future connection cost			4,664	2,798	20
Annual future connection cost			233	--	1

Table D-124. Quantities and costs for septic tank effluent gravity sewers and cluster drainfields serving limited areas for District #14 Sister Lakes (Alternative 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	450	$ 35.30	$ 15,885	$ 9,531	$ 17
Lift station					
7 gpm TDH-25 ft			12,750	3,825	1,314
Force main, common trench					
2"	450	4.60	2,070	1,242	--
Force main, individual trench					
2"	150	13.00	1,950	1,170	--
Service connection					
gravity	10	1,577	15,770	9,462	--
Septic tank					
upgrade	7	143	1,001	601	70
replace	3	750	2,250	1,350	30
Cluster drainfield					
Cable Park Beach	10	1,250	12,500	--	2,080
Subtotal initial cost			64,176	27,181	3,511
Service factor (35%)			22,462	--	--
Subtotal initial capital cost			86,638	--	--

Table D-125. Quantities and costs for septic tank effluent gravity sewers and cluster drainfields serving limited areas for District #15 Sister Lakes (Alternative 8B).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
STE sewer pipe					
4"	1,600	$ 35.30	$ 56,480	$ 33,888	$ 61
Lift station					
13 gpm TDH-75 ft			12,750	3,825	1,335
10 gpm TDH-63 ft			12,750	3,825	1,326
Force main, common trench					
2"	1,300	4.60	5,980	3,588	--
Force main, individual trench					
2"	2,850	13.00	37,050	22,230	--
Service connection					
gravity	31	1,577	48,887	29,332	--
STE pump	3	3,428	10,284	3,085	189
Septic tank					
upgrade	25	143	3,575	2,145	250
replace	9	750	6,750	4,050	90
Cluster drainfield					
Swishers & Sandy Beach Resort	34	1,250	42,500	--	2,080
Subtotal initial cost			237,006	105,968	5,331
Service factor (35%)			82,952	--	--
Subtotal initial capital cost			319,958	--	--
Future connections cost					
Building sewer	3	55	165	99	--
Septic tank + gravity	3	2,277	6,831	4,099	30
Subtotal future connection cost			6,996	4,198	30
Annual future connection cost			350	--	1.5

Table D-126. Summary and present worth of costs for Alternative 9 - upgraded on-site systems with holding tanks for blackwater for some residences (June 1981 costs).

	Initial Cost						Future Connections Cost							
				Present Worth			Annual	Total	Incremental	Present Worth				
District	Capital	Salvage	O&M	Salvage	O&M	Total	Construction	Salvage	Annual O&M	Construction	Salvage	O&M	Total	Total Present Wor
Indian Lake														
1	333,019	57,900	12,274	13,317	123,947	443,649	4,117	8,154	86	41,575	1,875	6,201	45,901	489,550
2	140,681	19,320	4,354	4,444	43,968	180,205	2,220	5,889	56	22,418	1,354	4,038	25,102	205,307
3	274,140	42,361	8,470	9,743	85,533	349,930	3,448	8,607	81	34,819	1,980	5,841	38,680	388,610
Subtotal:	747,840	119,581	25,098	27,504	253,448	973,784	9,785	22,650	223	98,812	5,209	16,080	109,683	1,083,467
Pipestone Lake														
2	72,066	9,911	3,0[illegible]	2,280	30,557	100,343	525	--	15	5,302	--	1,082	6,384	106,727
3	107,399	15,677	5,610	3,606	56,651	160,444	750	--	22	7,574	--	1,586	9,160	169,604
Subtotal:	179,465	25,588	8,636	5,886	87,208	260,787	1,275	--	37	12,876	--	2,668	15,544	276,331
Sister Lakes														
1	166,663	21,574	4,758	4,962	48,048	209,749	3,157	9,513	71	31,880	2,188	5,120	34,812	244,561
4	157,807	14,249	6,414	3,277	64,771	219,301	3,504	13,137	72	35,384	3,022	5,192	37,554	256,855
5	360,997	61,630	16,354	14,175	165,148	511,970	3,332	9,513	67	33,648	2,188	4,831	36,291	548,261
6	315,128	46,880	10,560	10,782	106,638	410,984	4,496	13,590	92	45,402	3,126	6,634	48,910	459,894
7	111,544	11,835	3,104	2,722	31,345	140,167	1,784	4,530	44	18,015	1,042	3,173	20,146	160,313
8	151,833	20,808	4,558	4,786	46,028	193,075	3,941	14,496	82	39,797	3,334	5,913	42,376	235,451
9	293,220	42,302	10,000	9,729	100,983	384,474	5,016	12,231	120	50,653	2,813	8,653	56,493	440,967
10	220,262	28,797	6,686	6,623	67,517	281,156	3,803	12,231	89	38,404	2,813	6,418	42,009	323,165
11	291,642	37,388	10,120	8,599	102,195	385,238	2,288	4,077	55	23,105	938	3,966	26,133	44,371
12	114,234	14,598	3,294	3,358	33,264	144,140	1,868	4,530	50	18,863	1,042	3,605	21,426	165,566
13	270,109	39,708	9,290	9,133	93,813	354,789	4,255	14,496	106	42,968	3,334	7,643	47,277	402,066
14	52,804	7,972	1,664	1,834	16,804	67,774	694	1,359	19	7,008	313	1,370	8,065	75,839
15	276,213	34,112	9,494	7,846	95,873	364,240	4,476	13,137	103	45,200	3,022	7,427	49,605	413,845
Subtotal:	2,782,456	381,853	96,296	87,826	972,427	3,667,057	42,614	126,840	970	430,327	29,175	69,945	471,097	4,138,154
Total	3,709,761	527,022	130,030	121,126	1,313,083	4,901,628	53,674	149,490	1,230	542,015	34,384	88,693	596,324	5,497,952

Table D-127. Quantities and costs for upgrading and operating on-site systems and blackwater holding tanks for District #1 Indian Lake (Alternative 9).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	210	$ 143	$ 30,030	$18,018	$ 2,100
replace	53	750	39,750	23,850	530
Low flow toilet	32	1,413	45,216	--	--
Blackwater holding tank					
seasonal	27	835	22,545	13,527	3,240
permanent	5	835	4,175	2,505	1,800
Soil absorption system	231		--	--	2,310
drain bed	18	754	13,572	--	--
lift pump + drain bed	10	1,620	16,200	--	620
raised drain bed	12	1,555	18,660	--	--
lift pump + raised drain bed	15	2,421	36,315	--	930
dry well	5	578	2,890	--	--
lift pump + dry well	12	1,444	17,328	--	744
Initial cost			246,681	57,900	12,274
Service factor (35%)			86,338	--	--
Initial capital cost			338,019	--	--
Future costs					
Building sewer	18	55	990	594	--
Septic tank	18	700	12,600	7,560	180
Soil absorption system	18		--	--	180
Drain bed	12	754	9,048	--	--
Lift pump + drain bed	5	1,620	8,100	--	310
Raised drain bed	8	1,555	12,440	--	--
Lift pump + raised drain bed	12	2,421	29,052	--	744
Dry well	5	578	2,890	--	--
Lift pump + dry well	5	1,444	7,220	--	310
Total future costs			82,340	8,154	1,724
Annual future costs			4,117	408	86

Table D-128. Quantities and costs for upgrading and operating on-site systems and blackwater holding tanks for District #2 Indian Lake (Alternative 9).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	80	$ 143	$ 11,440	$ 6,864	$ 800
replace	21	750	15,750	9,450	210
Low flow toilet	6	1,413	8,478	--	--
Blackwater holding tank					
seasonal	6	835	5,010	3,006	720
Soil absorption systems	95		--	--	950
drain bed	7	754	5,278	--	--
lift pump + drain bed	10	1,620	16,200	--	620
raised drain bed	5	1,555	7,775	--	--
lift pump + raised drain bed	7	2,421	16,947	--	434
dry well	5	578	2,890	--	--
lift pump + dry well	10	1,444	14,440	--	620
Initial cost			104,208	19,320	4,354
Service factor (35%)			36,473	--	--
Initial capital cost			140,681	--	--
Future costs					
Building sewer	13	55	715	429	--
Septic tank	13	700	9,100	5,460	130
Soil absorption system	13		--	--	130
Drain bed	10	754	7,540	--	--
Lift pump + drain bed	10	1,620	16,200	--	620
Raised drain bed	2	1,555	3,110	--	--
Lift pump + raised drain bed	2	2,421	4,842	--	124
Lift pump + dry well	2	1,444	2,888	--	124
Total future costs			44,395	5,889	1,128
Annual future costs			2,220	294	56

Table D-129. Quantities and costs for upgrading and operating on-site systems and blackwater holding tanks for District #3 Indian Lake (Alternative 9).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	124	$ 143	$ 17,732	$10,639	$1,240
replace	46	750	34,500	20,700	460
Low flow toilet	22	1,413	31,086	--	--
Blackwater holding tank					
seasonal	20	835	16,700	10,020	2,400
permanent	2	835	1,670	1,002	720
Soil absorption systems	148		--	--	1,480
drain bed	10	754	7,540	--	--
lift pump + drain bed	7	1,620	11,340	--	434
raised drain bed	15	1,555	23,325	--	--
lift pump + raised drain bed	18	2,421	43,578	--	1,116
dry well	2	578	1,156	--	--
lift pump + dry well	10	1,444	14,440	--	620
Initial cost			203,067	42,361	8,470
Service factor (35%)			71,073	--	--
Initial capital cost			274,140	--	--
Future costs					
Building sewer	19	55	1,045	627	--
Septic tank	19	700	13,300	7,980	190
Soil absorption system	19		--	--	190
Drain bed	10	754	7,540	--	--
Lift pump + drain bed	5	1,620	8,100	--	310
Raised drain bed	5	1,555	7,775	--	--
Lift pump + raised drain bed	8	2,421	19,368	--	496
Dry well	3	578	1,734	--	--
Lift pump + dry well	7	1,444	10,108	--	434
Total future costs			68,970	8,607	1,620
Annual future costs			3,448	430	81

Table D-130. Quantities and costs for upgrading and operating on-site systems and blackwater holding tanks for District #2 Pipestone Lake (Alternative 9).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	21	$ 143	$ 3,003	$1,802	$ 210
replace	8	750	6,000	3,600	80
Low flow toilet	9	1,413	12,717	--	--
Blackwater holding tank					
seasonal	5	835	4,175	2,505	600
permanent	4	835	3,340	2,004	1,440
Soil absorption systems	20		--	--	200
drain bed	2	754	1,508	--	--
lift pump + drain bed	1	1,620	1,620	--	62
raised drain bed	3	1,555	4,665	--	--
lift pump + raised drain bed	7	2,421	16,947	--	434
Initial cost			53,975	9,911	3,026
Service factor (35%)			18,891	--	--
Initial capital cost			72,866	--	--
Future costs					
Soil absorption system			--	--	--
Lift pump + drain bed	2	1,620	3,240	--	124
Lift pump + raised drain bed	3	2,421	7,263	--	186
Total future costs			10,503	--	310
Annual future costs			525	--	15

Table D-131. Quantities and costs for upgrading and operating on-site systems and blackwater holding tanks for District #3 Pipestone Lake (Alternative 9).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	31	$ 143	$ 4,433	$ 2,660	$ 310
replace	10	750	7,500	4,500	100
Low flow toilet	17	1,413	24,021	--	--
Blackwater holding tank					
seasonal	7	835	5,845	3,507	840
permanent	10	835	8,350	5,010	3,600
Soil absorption systems	14		--	--	140
lift pump + drain bed	2	1,620	3,240	--	124
raised drain bed	5	1,555	7,775	--	--
lift pump + raised drain bed	7	2,421	16,947	--	434
lift pump + dry well	1	1,444	1,444	--	62
Initial cost			79,555	15,677	5,610
Service factor (35%)			27,844	--	--
Initial capital cost			107,399	--	--
Future costs					
Soil absorption system					
Lift pump + raised drain bed	5	2,421	12,105	--	310
Lift pump + dry well	2	1,444	2,888	--	124
Total future costs			14,993	--	434
Annual future costs			750	--	22

Table D-132. Quantities and costs for upgrading and operating on-site systems and blackwater holding tanks for District #1 Sister Lakes (Alternative 9).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	94	$ 143	$ 13,442	$ 8,065	$ 940
replace	20	750	15,000	9,000	200
Low flow toilet	9	1,413	12,717	--	--
Blackwater holding tank					
seasonal	9	835	7,515	4,509	1,080
Soil absorption systems	105		--	--	1,050
drain bed	20	754	15,080	--	--
lift pump + drain bed	5	1,620	8,100	--	310
raised drain bed	5	1,555	7,775	--	--
lift pump + raised drain bed	15	2,421	36,315	--	930
dry well	3	578	1,734	--	--
lift pump + dry well	4	1,444	5,776	--	248
Initial cost			123,454	21,574	4,758
Service factor (35%)			43,209	--	--
Initial capital cost			166,663	--	--
Future costs					
Building sewer	21	55	1,155	693	--
Septic tank	21	700	14,700	8,820	210
Soil absorption system	21		--	--	210
Drain bed	10	754	7,540	--	--
Lift pump + drain bed	5	1,620	8,100	--	310
Raised drain bed	5	1,555	7,775	--	--
Lift pump + raised drain bed	7	2,421	16,947	--	434
Dry well	2	578	1,156	--	--
Lift pump + dry well	4	1,444	5,776	--	248
Total future costs			63,149	9,513	1,412
Annual future costs			3,157	476	71

Table D-133. Quantities and costs for upgrading and operating on-site systems and blackwater holding tanks for District #4 Sister Lakes (Alternative 9).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	96	$ 143	$ 13,728	$ 8,237	$ 960
replace	27	750	--	--	270
Low flow toilet	12	1,413	16,956	--	--
Blackwater holding tank					
seasonal	8	835	6,680	4,008	960
permanent	4	835	3,340	2,004	1,440
Soil absorption systems	111		--	--	1,110
drain bed	10	754	7,540	--	--
lift pump + drain bed	7	1,620	11,340	--	434
raised drain bed	7	1,555	10,885	--	--
lift pump + raised drain bed	15	2,421	36,315	--	930
dry well	5	578	2,890	--	--
lift pump + dry well	5	1,444	7,220	--	310
Initial cost			116,894	14,249	6,414
Service factor (35%)			40,913	--	--
Initial capital cost			157,807	--	--
Future costs					
Building sewer	29	55	1,595	957	--
Septic tank	29	700	20,300	12,180	290
Soil absorption system	29		--	--	290
Drain bed	15	754	11,310	--	--
Lift pump + drain bed	5	1,620	8,100	--	310
Raised drain bed	5	1,555	7,775	--	--
Lift pump + raised drain bed	7	2,421	16,947	--	434
Dry well	2	578	1,156	--	--
Lift pump + dry well	2	1,444	2,888	--	124
Total future costs			70,071	13,137	1,448
Annual future costs			3,504	657	72

Table D-134. Quantities and costs for upgrading and operating on-site systems and blackwater holding tanks for District #5 Sister Lakes (Alternative 9).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	194	$ 143	$ 27,742	$16,645	$ 1,940
replace	61	750	45,750	27,450	610
Low flow toilet	35	1,413	49,455	--	--
Blackwater holding tank					
seasonal	15	835	12,525	7,515	1,800
permanent	20	835	16,700	10,020	7,200
Soil absorption systems	220		--	--	2,200
drain bed	25	754	18,850	--	--
lift pump + drain bed	15	1,620	24,300	--	930
raised drain bed	10	1,555	15,550	--	--
lift pump + raised drain bed	15	2,421	36,315	--	930
dry well	5	578	2,890	--	--
lift pump + dry well	12	1,444	17,328	--	744
Initial cost			267,405	61,630	16,354
Service factor (35%)			93,592	--	--
Initial capital cost			360,997	--	--
Future costs					
Building sewer	21	55	1,155	693	--
Septic tank	21	700	14,700	8,820	210
Soil absorption system	21		--	--	210
Drain bed	15	754	11,310	--	--
Lift pump + drain bed	5	1,620	8,100	--	310
Raised drain bed	7	1,555	10,885	--	--
Lift pump + raised drain bed	5	2,421	12,105	--	310
Dry well	2	578	1,156	--	--
Lift pump + dry well	5	1,444	7,220	--	310
Total future costs			66,631	9,513	1,350
Annual future costs			3,332	476	67

Table D-135. Quantities and costs for upgrading and operating on-site systems and blackwater holding tanks for District #6 Sister Lakes (Alternative 9).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	193	$ 143	$ 27,599	$16,559	$ 1,930
replace	44	750	33,000	19,800	440
Low flow toilet	21	1,413	29,673	--	--
Blackwater holding tank					
seasonal	18	835	15,030	9,018	2,160
permanent	3	835	2,505	1,503	1,080
Soil absorption systems	216		--	--	2,160
drain bed	15	754	11,310	--	--
lift pump + drain bed	15	1,620	24,300	--	930
raised drain bed	18	1,555	27,990	--	--
lift pump + raised drain bed	15	2,421	36,315	--	930
dry well	7	578	4,046	--	--
lift pump + dry well	15	1,444	21,660	--	930
Initial cost			233,428	46,880	10,560
Service factor (35%)			81,700	--	--
Initial capital cost			315,128	--	--
Future costs					
Building sewer	30	55	1,650	990	--
Septic tank	30	700	21,000	12,600	300
Soil absorption system	30		--	--	300
Drain bed	25	754	18,850	--	--
Lift pump + drain bed	5	1,620	8,100	--	310
Raised drain bed	7	1,555	10,885	--	--
Lift pump + raised drain bed	5	2,421	12,105	--	310
Dry well	5	578	2,890	--	--
Lift pump + dry well	10	1,444	14,440	--	620
Total future costs			89,920	13,590	1,840
Annual future costs			4,496	680	92

Table D-136. Quantities and costs for upgrading and operating on-site systems and blackwater holding tanks for District #7 Sister Lakes (Alternative 9).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	75	$ 143	$ 10,725	$ 6,435	$ 750
replace	12	750	9,000	5,400	120
Soil absorption systems	87		--	--	870
drain bed	3	754	2,262	--	--
lift pump + drain bed	5	1,620	8,100	--	310
raised drain bed	13	1,555	20,215	--	--
lift pump + raised drain bed	5	2,421	12,105	--	310
dry well	5	578	2,890	--	--
lift pump + dry well	12	1,444	17,328	--	744
Initial cost			82,625	11,835	3,104
Service factor (35%)			28,919	--	--
Initial capital cost			111,544	--	--
Future costs					
Building sewer	10	55	550	330	--
Septic tank	10	700	7,000	4,200	100
Soil absorption system	10		--	--	100
Drain bed	7	754	5,278	--	--
Lift pump + drain bed	2	1,620	3,240	--	124
Raised drain bed	3	1,555	4,665	--	--
Lift pump + raised drain bed	2	2,421	4,842	--	124
Lift pump + dry well	7	1,444	10,108	--	434
Total future costs			35,683	4,530	882
Annual future costs			1,784	226	44

Table D-137. Quantities and costs for upgrading and operating on-site systems and blackwater holding tanks for District #8 Sister Lakes (Alternative 9).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	130	$ 143	$ 18,590	$11,154	$1,300
replace	17	750	12,750	7,650	170
Low flow toilet	4	1,413	5,652	--	--
Blackwater holding tank					
seasonal	4	835	3,340	2,004	480
Soil absorption systems	143		--	--	1,430
drain bed	20	754	15,080	--	--
lift pump + drain bed	7	1,620	11,340	--	434
raised drain bed	12	1,555	18,660	--	--
lift pump + raised drain bed	7	2,421	16,947	--	434
dry well	5	578	2,890	--	--
lift pump + dry well	5	1,444	7,220	--	310
Initial cost			112,469	20,808	4,558
Service factor (35%)			39,364	--	--
Initial capital cost			151,833	--	--
Future costs					
Building sewer	32	55	1,760	1,056	--
Septic tank	32	700	22,400	13,440	320
Soil absorption system	32		--	--	320
Drain bed	17	754	12,818	--	--
Lift pump + drain bed	7	1,620	11,340	--	434
Raised drain bed	5	1,555	7,775	--	--
Lift pump + raised drain bed	7	2,421	16,947	--	434
Dry well	5	578	2,890	--	--
Lift pump + dry well	2	1,444	2,888	--	124
Total future costs			78,818	14,496	1,632
Annual future costs			3,941	725	82

Table D-138. Quantities and costs for upgrading and operating on-site systems and blackwater holding tanks for District #9 Sister Lakes (Alternative 9).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	163	$ 143	$ 23,309	$13,985	$ 1,630
replace	44	750	33,000	19,800	440
Low flow toilet	17	1,413	24,021	--	--
Blackwater holding tank					
seasonal	12	835	10,020	6,012	1,440
permanent	5	835	4,175	2,505	1,800
Soil absorption systems	190		--	--	1,900
drain bed	25	754	18,850	--	--
lift pump + drain bed	15	1,620	24,300	--	930
raised drain bed	12	1,555	18,660	--	--
lift pump + raised drain bed	15	2,421	36,315	--	930
dry well	5	578	2,890	--	--
lift pump + dry well	15	1,444	21,660	--	930
Initial cost			217,200	42,302	10,000
Service factor (35%)			76,020	--	--
Initial capital cost			293,220	--	--
Future costs					
Building sewer	27	55	1,485	891	--
Septic tank	27	700	18,900	11,340	270
Soil absorption system	27		--	--	270
Drain bed	15	754	11,310	--	--
Lift pump + drain bed	10	1,620	16,200	--	620
Raised drain bed	7	1,555	10,885	--	--
Lift pump + raised drain bed	10	2,421	24,210	--	620
Dry well	5	578	2,890	--	--
Lift pump + dry well	10	1,444	14,440	--	620
Total future costs			100,320	12,231	2,400
Annual future costs			5,016	612	120

Table D-139. Quantities and costs for upgrading and operating on-site systems and blackwater holding tanks for District #10 Sister Lakes (Alternative 9).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	110	$ 143	$ 15,730	$ 9,438	$1,100
replace	33	750	24,750	14,850	330
Low flow toilet	9	1,413	12,717	--	--
Blackwater holding tank					
seasonal	7	835	5,845	3,507	840
permanent	2	835	1,670	1,002	720
Soil absorption systems	134		--	--	1,340
drain bed	15	754	11,310	--	--
lift pump + drain bed	18	1,620	29,160	--	1,116
raised drain bed	10	1,555	15,550	--	--
lift pump + raised drain bed	15	2,421	36,315	--	930
dry well	5	578	2,890	--	--
lift pump + dry well	5	1,444	7,220	--	310
Initial cost			163,157	28,797	6,686
Service factor (35%)			57,105	--	--
Initial capital cost			220,262	--	--
Future costs					
Building sewer	27	55	1,485	891	--
Septic tank	27	700	18,900	11,340	270
Soil absorption system	27		--	--	270
Drain bed	10	754	7,540	--	--
Lift pump + drain bed	10	1,620	16,200	--	620
Raised drain bed	7	1,555	10,885	--	--
Lift pump + raised drain bed	5	2,421	12,105	--	310
Dry well	3	578	1,734	--	--
Lift pump + dry well	5	1,444	7,220	--	310
Total future costs			76,069	12,231	1,780
Annual future costs			3,803	612	89

Table D-140. Quantities and costs for upgrading and operating on-site systems and blackwater holding tanks for District #11 Sister Lakes (Alternative 9).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	108	$ 143	$ 15,444	$ 9,266	$ 1,080
replace	38	750	28,500	17,100	380
Low flow toilet	22	1,413	31,086	--	--
Blackwater holding tank					
seasonal	15	835	12,525	7,515	1,800
permanent	7	835	5,845	3,507	2,520
Soil absorption systems	124		--	--	1,240
drain bed	5	754	3,770	--	--
lift pump + drain bed	15	1,620	24,300	--	930
raised drain bed	15	1,555	23,325	--	--
lift pump + raised drain bed	20	2,421	48,420	--	1,240
dry well	2	578	1,156	--	--
lift pump + dry well	15	1,444	21,660	--	930
Initial cost			216,031	37,388	10,120
Service factor (35%)			75,611	--	--
Initial capital cost			291,642	--	--
Future costs					
Building sewer	9	55	495	297	--
Septic tank	9	700	6,300	3,780	90
Soil absorption system	9		--	--	90
Drain bed	5	754	3,770	--	--
Lift pump + drain bed	5	1,620	8,100	--	310
Raised drain bed	5	1,555	7,775	--	--
Lift pump + raised drain bed	5	2,421	12,105	--	310
Lift pump + dry well	5	1,444	7,220	--	310
Total future costs			45,765	4,077	1,110
Annual future costs			2,288	204	55

Table D-141. Quantities and costs for upgrading and operating on-site systems and blackwater holding tanks for District #12 Sister Lakes (Alternative 9).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	60	$ 143	$ 8,580	$ 5,148	$ 600
replace	21	750	15,750	9,450	210
Soil absorption systems	81		--	--	810
drain bed	5	754	3,770	--	--
lift pump + drain bed	10	1,620	16,200	--	620
raised drain bed	5	1,555	7,775	--	--
lift pump + raised drain bed	7	2,421	16,947	--	434
dry well	2	578	1,156	--	--
lift pump + dry well	10	1,444	14,440	--	620
Initial cost			84,618	14,598	3,294
Service factor (35%)			29,616	--	--
Initial capital cost			114,234	--	--
Future costs					
Building sewer	10	55	550	330	--
Septic tank	10	700	7,000	4,200	100
Soil absorption system	10		--	--	100
Drain bed	7	754	5,278	--	--
Lift pump + drain bed	5	1,620	8,100	--	310
Lift pump + raised drain bed	5	2,421	12,105	--	310
Lift pump + dry well	3	1,444	4,332	--	186
Total future costs			37,365	4,530	1,006
Annual future costs			1,868	226	50

Table D-142. Quantities and costs for upgrading and operating on-site systems and blackwater holding tanks for District #13 Sister Lakes (Alternative 9).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	110	$ 143	$ 15,730	$ 9,438	$1,100
replace	45	750	33,750	20,250	450
Low flow toilet	20	1,413	28,260	--	--
Blackwater holding tank					
seasonal	15	835	12,525	7,515	1,800
permanent	5	835	4,175	2,505	1,800
Soil absorption systems	135		--	--	1,350
drain bed	5	754	3,770	--	--
lift pump + drain bed	15	1,620	24,300	--	930
raised drain bed	10	1,555	15,550	--	--
lift pump + raised drain bed	15	2,421	36,315	--	930
dry well	7	578	4,046	--	--
lift pump + dry well	15	1,444	21,660	--	930
Initial cost			200,081	39,708	9,290
Service factor (35%)			70,028	--	--
Initial capital cost			270,109	--	--
Future costs					
Building sewer	32	55	1,760	1,056	--
Septic tank	32	700	22,400	13,440	320
Soil absorption system	32		--	--	320
Drain bed	12	754	9,048	--	--
Lift pump + drain bed	5	1,620	8,100	--	310
Raised drain bed	5	1,555	7,775	--	--
Lift pump + raised drain bed	7	2,421	16,947	--	434
Dry well	3	578	1,734	--	--
Lift pump + dry well	12	1,444	17,328	--	744
Total future costs			85,092	14,496	2,128
Annual future costs			4,255	725	106

Table D-143. Quantities and costs for upgrading and operating on-site systems and blackwater holding tanks for District #14 Sister Lakes (Alternative 9).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	27	$ 143	$ 3,861	$2,317	$ 270
replace	7	750	5,250	3,150	70
Low flow toilet	5	1,413	7,065	--	--
Blackwater holding tank					
seasonal	5	835	4,175	2,505	600
Soil absorption systems	29		--	--	290
lift pump + drain bed	5	1,620	8,100	--	310
raised drain bed	3	1,555	4,665	--	--
lift pump + raised drain bed	2	2,421	4,842	--	124
dry well	2	578	1,156	--	--
Initial cost			39,114	7,972	1,664
Service factor (35%)			13,690	--	--
Initial capital cost			52,804	--	--
Future costs					
Building sewer	3	55	165	99	--
Septic tank	3	700	2,100	1,260	30
Soil absorption system	3		--	--	30
Drain bed	2	754	1,508	--	--
Lift pump + drain bed	2	1,620	3,240	--	124
Raised drain bed	1	1,555	1,555	--	--
Lift pump + raised drain bed	1	2,421	2,421	--	62
Lift pump + dry well	2	1,444	2,888	--	124
Total future costs			13,877	1,359	370
Annual future costs			694	68	19

Table D-144. Quantities and costs for upgrading and operating on-site systems and blackwater holding tanks for District #15 Sister Lakes (Alternative 9).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
upgrade	148	$ 143	$ 21,164	$12,698	$1,480
replace	32	750	24,000	14,400	320
Low flow toilet	14	1,413	19,782	--	--
Blackwater holding tank					
seasonal	8	835	6,680	4,008	960
permanent	6	835	5,010	3,006	2,160
Soil absorption systems	166		--	--	1,660
drain bed	20	754	15,080	--	--
lift pump + drain bed	17	1,620	27,540	--	1,054
raised drain bed	15	1,555	23,325	--	--
lift pump + raised drain bed	15	2,421	36,315	--	930
dry well	7	578	4,046	--	--
lift pump + dry well	15	1,444	21,660	--	930
Initial cost			204,602	34,112	9,494
Service factor (35%)			71,611	--	--
Initial capital cost			276,213	--	--
Future costs					
Building sewer	29	55	1,595	957	--
Septic tank	29	700	20,300	12,180	290
Soil absorption system	29		--	--	290
Drain bed	15	754	11,310	--	--
Lift pump + drain bed	7	1,620	11,340	--	434
Raised drain bed	5	1,555	7,775	--	--
Lift pump + raised drain bed	10	2,421	24,210	--	620
Dry well	5	578	2,890	--	--
Lift pump + dry well	7	1,444	10,108	--	434
Total future costs			89,528	13,137	2,068
Annual future costs			4,476	657	103

Table D-145. Laboratory and administration costs for Alternatives 8A, 8B, and 9.

Item	Cost $(x1,000) Construction Cost	Salvage Value	O&M Cost
Administration & laboratory building	$ 106.0	$ 38.2	$ 16.0
Administrative services			78.0
Total	$ 106.0	$ 38.2	$ 94.0
Service factor (27%)	28.6		
Total capital cost	134.6		

Present worth cost (@ 7-5/8% over 20 years)

Capital cost	$ 134.6
O&M cost	949.2
Salvage value	(8.8)
Total present worth	$1,075.0

APPENDIX E

INDIAN LAKE-SISTER LAKES AREA

COMMUNITY ATTITUDE QUESTIONNAIRE

INDIAN LAKE/SISTER LAKES AREA COMMUNITY ATTITUDE QUESTIONNAIRE

As you may know, a public hearing was held regarding the Indian Lake-Sister Lakes Area Facility Plan on November 22, 1977. Pollution problems in the lake areas were summarized at that time, and alternatives were presented for correction of these problems. Comments by the public were also taken and placed into the official transcript of the hearing. The next step now is for each of the Townships involved to determine what, if any, improvements are desired to reduce the pollution of the lake(s) within their jurisdiction. The purpose of this questionnaire then is to get your input to help guide your Township Officials in their decision making. And to help you better assess the existing situation, a summary of pollution problems as presented in the Facility Plan is included with this questionnaire.

1. What area do you reside in? _____ Indian Lake, _____ Magician Lake, _____ Dewey Lake, _____ Cable Lake _____ Round Lake, _____ Crooked Lake, _____ Pipestone
2. Are you a _____ year round or _____ seasonal resident?
3. Do you live on a fixed income? _____ yes _____ no
4. How many years have you lived in the area? _____
5. Number of persons in household? _____
6. Do you _____ own or _____ rent?
7. Do you feel there are pollution problems on your lake? _____ none, _____ mild, _____ moderate, _____ severe
8. If so, do you feel some effort should be made to correct these problems? _____ yes _____ no
9. Have you had any problems with your own septic system? _____ yes _____ no
10. Is your property suitable for expansion or replacement of your septic system, if needed? _____ yes, _____ no, _____ don't know
11. Have you had to replace portions of your septic system in the last ten years? _____ yes _____ no
12. If your septic tank has been malfunctioning, how often? _____
13. What is the primary cause of malfunction? _____
14. Do you think your septic system will last for the next 20 years? _____ yes _____ no
15. Would you like to see a sewer system constructed in your area if grants are available? _____ yes _____ no
16. Would you prefer to see alternate solutions to lake pollution problems investigated? _____ Continued septic tank use with Health Department monitoring, _____ Cluster Systems with several homes connected to one large septic unit, _____ Composting toilets - no flush variety, biological reaction
17. If you would like to see one of the preceding methods used to improve water quality, when would you want implementation? _____ Take immediate action so construction could begin by 1979, _____ Take action in 5 to 10 years, _____ Take action in 10 to 20 years
18. How much would you be willing to pay on an average monthly basis to improve water quality in your lake?
    _____ Less than $12 per month
    _____ $12 to $15 per month
    _____ $15 to $20 per month
    _____ $20 to $25 per month

APPENDIX F

CLIMATOLOGICAL AND AIR QUALITY DATA

Table F-1. Climatological data collected at South Bend, Indiana, from 1941 through 1977 (NOAA 1977).

Month	Mean Temperature (°C)			Mean Number of Days[1]		Mean Precipitation (cm)	Mean Relative Humidity (Percent)				Mean Wind Speed[2] (kph)	Mean Wind Direction[2]
	Daily Maximum	Daily Minimum	Monthly Mean	Below 0°C	Above 0°C		1:00 AM	7:00 AM	1:00 PM	7:00 PM		
January	-0.3	-8.5	-4.4	17	28	6.0	79	80	73	75	19.5	SW
February	1.2	-7.4	-3.1	11	25	4.9	78	80	68	73	19.1	SW
March	6.5	-3.0	1.8	4	20	7.0	77	80	64	67	20.1	NNW
April	14.5	3.2	8.9	0	8	10.2	73	78	57	59	19.5	NNW
May	20.6	8.4	14.5	0	1	8.1	75	77	54	55	17.2	SSW
June	26.1	14.1	20.1	0	0	9.4	78	81	56	59	15.3	SSW
July	92.4	16.3	22.2	0	0	9.3	81	84	57	59	13.4	SSW
August	27.4	15.5	21.5	0	0	8.3	84	88	59	63	12.9	SSW
September	23.5	11.4	17.5	0	0	7.8	84	89	61	68	14.3	SSW
October	17.4	6.1	11.8	0	3	7.8	79	85	61	69	15.8	SSW
November	8.4	- 0.1	4.2	2	14	6.9	80	83	70	75	18.3	SSW
December	1.7	- 5.9	- 2.1	11	25	6.3	82	84	77	79	18.7	SW
Annual	14.6	4.2	9.4	45	124	92.0	79	82	63	67	17.1	SSW

[1]Period of record=14 years.

[2]Period of record=29 years.

Table F-2. National Ambient Air Quality Standards (NAAQS), revised 14 September 1973 (40 CFR 50.4 to 50.11).

Pollutant	Time of Average	Primary Standard[a]	Secondary Standard[a]
Particulate matter	Annual (geometric mean)	75 ug	60 ug
	24 hour	260 ug	150 ug[b]
Sulfur oxides (SO_x) (measured as SO_2)	Annual (arithmetic mean)	80 ug (0.03 ppm)	
	24 hour	365 ug (0.14 ppm)[b]	
	3 hour	--	1,300 ug (0.5 ppm)[b]
Carbon monoxide (CO)	8 hour	10 mg (9 ppm)[b]	Same as primary
	1 hour	40 ug (35 ppm)[b]	Same as primary
Hydrocarbons (HC) (nonmethane measured as CH_4)	3 hour (6 to 9 A.M.)	160 ug (0.24 ppm)[b]	Same as primary
Nitrogen dioxide (NO_2)	Annual (arthmetic mean)	100 ug (0.24 ppm)	Same as primary
Ozone (O_3)	1 hour	240 ug (0.12 ppm)[c]	Same as primary
Lead (Pb^{+2})	Calendar quarter	1.5 ug[d]	Same as primary

[a] Concentration in weight per cubic meter (corrected to 25°C and 760 mm of Hg).

[b] Concentration not to be exceeded more than once per year.

[c] Concentration not to be exceeded more than one day per year (44 FR 8220, 8 February 1979).

[d] Concentration not to be exceeded more than one day per year.

Table F-3. Total suspended particulate data ($\mu l/m^3$) for Cass County, Michigan, from 1971 through 1976 (MDNR 1977).

Year	Number of Samples	24-hour Maximum	24 Hour (2nd Highest)	Annual Geometric Mean
1971	19	111	100	66
1972	52	181	143	56
1973	56	151	111	57
1974	43	120	114	52
1975	18	129	114	54
1976	21	116	107	55

F-3

APPENDIX G

PHOSPHORUS SORPTION AND PARTICLE SIZE ANALYSIS OF SOILS

MEMORANDUM

To: Kathleen Schaub, Project Officer

Date: 20 December 1979

From: Gregg Larson, Project Manager

Ref:

Subject: Results of Phosphate Sorption and Particle Size Analyses Conducted on Soil Samples from the Indian Lake/Sister Lakes Study Area

Cc: #559 P.F.

This memorandum summarizes the results of the particle size and phosphate sorption analyses that were conducted on soil samples collected from the Indian Lake/Sister Lakes study area. The soil samples were collected between 5 June 1979 and 13 July 1979 by Mr. Richard Larson. Mr. Larson, a soil scientist formerly with the Soil Conservation Service, was subcontracted to conduct a detailed soil survey of potential cluster system and land treatment sites. The samples were taken from hand-excavated pits, up to 1.52 meters (60 inches) in depth, and are representative of the three most commonly occurring soils in the study area. Each sample was sealed in a plastic bag and was flown to WAPORA's laboratory in Devon, Pennsylvania, for analysis.

Particle Size Analysis

The particle size analysis provides a measure of soil suitability for wastewater treatment by indicating the rate that moisture (e.g., wastewater) may filter through a given soil horizon (A, B, or C). If the soils are too coarse, the wastewater will pass through the soils too rapidly and will not undergo sufficient renovation/treatment. If the soils are too fine, the level of treatment may not be adequate because of ponding and/or soil saturation.

Particle size was determined by using the 1977 American Society of Testing and Materials (ASTM) standard method. A portion (10.0 grams) of each air-dried sample was subjected to further drying in a circulating oven, at 110°-115° centigrade, and weighed to determine the hygroscopic moisture content. The dried portions then were separated into coarse and fine fractions by a No. 10 (2.0 millimeter) sieve. The coarse fraction (retained on the No. 10 sieve) was weighed and shaken through a series of sieves ranging from a 1.0 inch (25.0 millimeter) sieve to a No. 10 sieve. Approximately 110.0-115.0 grams of the fine fraction (passed through the No. 10 sieve) were dispersed in a 1,000 milliliter glass sedimentation cylinder of distilled water and 5.0 milliliters of 5% (by weight) calgon solution. A hydrometer then was used to measure the solution density to provide data on the fine particles that cannot be measured using sieves. After the hydrometer test was completed, the sediment was resuspended in the cylinder and washed through a No. 200 (0.075 millimeters) sieve. The portion retained was oven dried, weighed, and shaken through a series of sieves ranging from a No. 10 sieve to a No. 200 sieve. The cumulative weight percentage (% finer) was determined for each sieve utilized in the analysis.

The results of the analysis are tabulated in Table 1 and graphed on logarithmic probability paper in Figures 1, 2, and 3. Grain size in the A and B soil horizons is most critical for land treatment because the effluent would be applied to the surface. Grain size in the B and C horizons is most critical for cluster systems because the effluent treatment would commence below the A horizon. Based on accepted standards (Land Treatment of Municipal Wastewater, USEPA 625/1-77-008, 1977 and Manual of Septic Tank Practice, US Public Health Service 1967) for soil texture, all three of the soils are suitable for land treatment or cluster systems. More extensive sampling and additional analyses would be necessary if specific sites are selected.

Phosphate Sorption Test

The phosphate sorption test assesses soil capabilities for orthophosphorus removal from percolating wastewater. The test would provide a measure of the relative differences between the three dominant soils. The methodology employed was a modification of procedures described in Enfield and Bledsoe (1975). An 8.0 milligram per liter phosphate solution was added to a standard amount of soil obtained from each sample. The mixture was shaken for five minutes daily, for five days, and the remaining solution concentration was determined. The long term phosphate sorption capacity was approximated by multiplying the five day test result by a factor of 3.5 (Enfield and Bledsoe 1975).

The results, expressed in terms of concentration and weight per acre, are presented in Table 2. The Kalamazoo soil, the finest grained of the three soils, absorbed the greatest amount of phosphate. The volume for long term phosphate sorption generally correlates with soil texture; fine soils with more surface area are able to absorb greater amounts of orthophosphorus. Because the Ontemo and Spinks soils absorbed less phosphate, the design of land treatment or cluster systems sited on those soils could require larger areas. If specific sites are selected from the general areas that were considered initially suitable for land treatment or cluster systems, additional tests may be necessary. By varying solution concentrations and time intervals, isolines could be developed to provide the detailed and comprehensive data needed for site specific investigations.

Table 1. Particle size analysis data for the three dominant soils in the Indian Lake/Sister Lakes study area.

Sieve size		Cumulative Weight Percent Passing (% finer)							
		Kalamazoo Soil Horizons			Oshtemo Soil Horizons			Spinks Soil Horizons	
Number	mm	A	B	C	A	B	C	A	B
1 inch	25.0	100.0	99.87	100.0	100.0	100.0	100.0	100.0	100.0
1/2 inch	12.7	100.0	93.04	89.3	99.89	100.0	99.6	100.0	100.0
1/4 inch	6.3	99.93	82.3	60.3	96.12	88.9	85.0	100.0	100.0
No. 4	4.75	92.38	69.37	35.7	95.0	82.5	76.0	100.0	100.0
No. 8	2.36	88.26	62.6	29.66	94.34	79.6	72.0	100.0	100.0
No. 10	2.00	83.9	43.27	21.2	92.67	74.6	63.45	99.97	99.95
No. 20	0.850	82.7	39.0	19.9	92.4	73.6	60.66	99.91	99.83
No. 40	0.425	78.8	29.62	15.4	92.27	70.56	49.2	99.89	99.81
No. 60	0.250	74.24	25.6	11.6	86.21	63.0	30.0	99.49	97.68
No. 80	0.180	66.26	23.7	8.8	68.99	39.30	16.35	86.43	79.53
No. 100	0.150	58.9	22.5	7.33	48.36	21.67	4.63	61.60	59.96
No. 140	0.106	55.25	21.9	6.69	37.6	16.48	2.64	45.29	39.66
No. 200	0.075	49.88	20.78	5.77	22.8	11.78	1.02	20.9	15.9
		Hydrometer Analysis (% finer)							
	0.0625	46.0	20.0	5.2	21.8	11.0	0.97	19.5	15.0
	0.0039	9.2	10.0	1.5	3.4	7.2	0.68	13.7	13.4

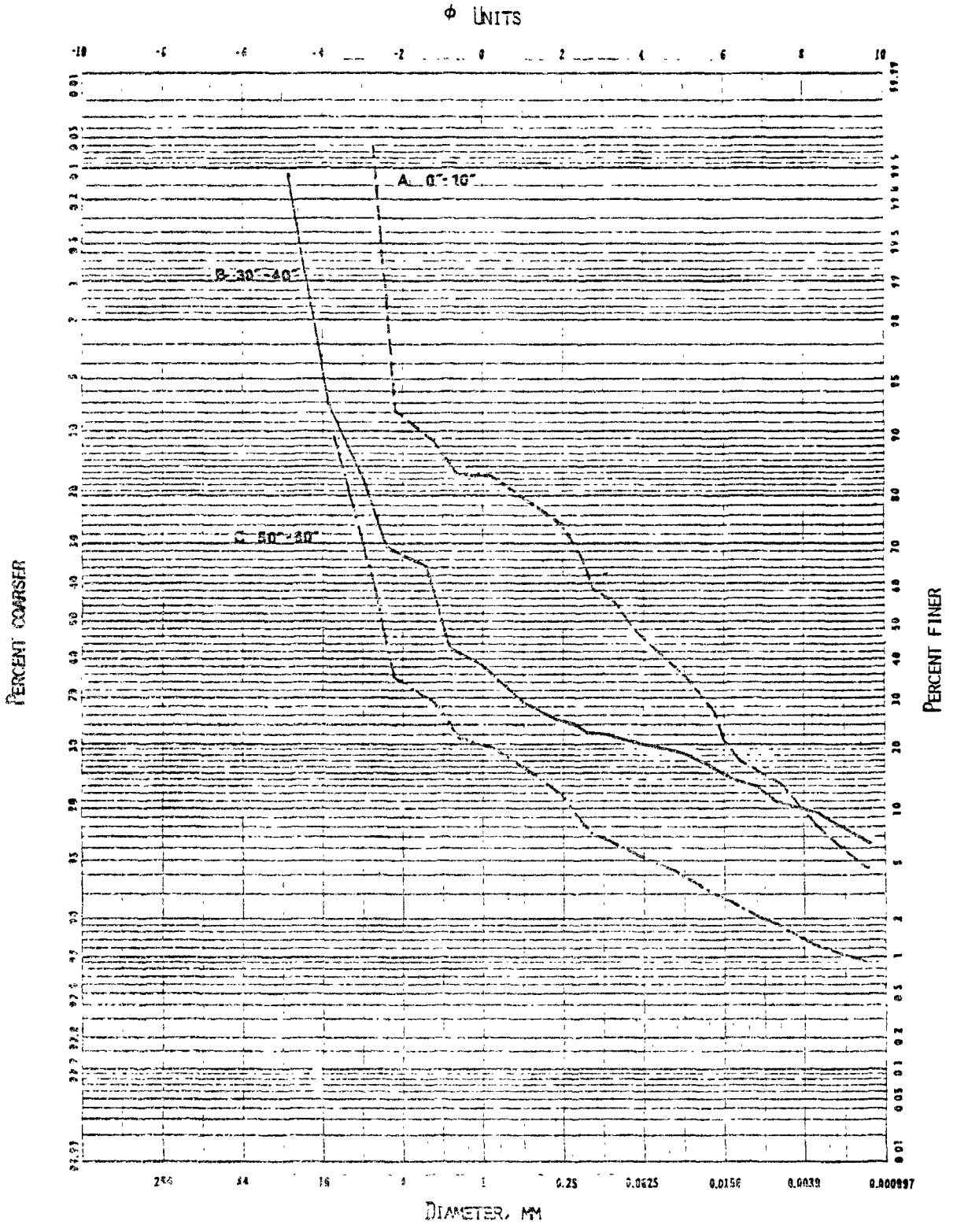


FIGURE 1.

PARTICLE SIZE ANALYSIS DATA FOR KALAMAZOO LOAM.

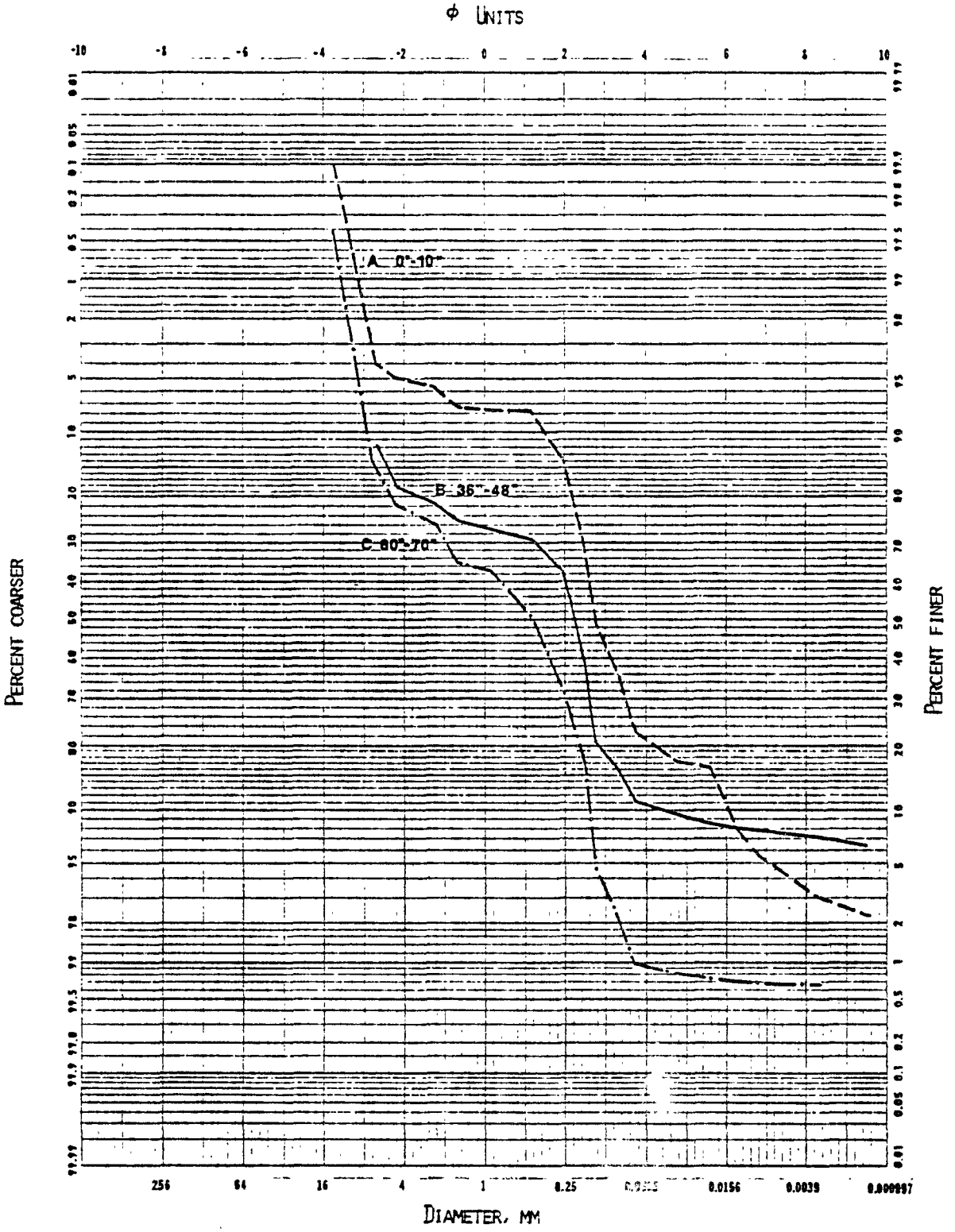


FIGURE 2.

PARTICLE SIZE ANALYSIS DATA FOR OSHTEMO SANDY LOAM.

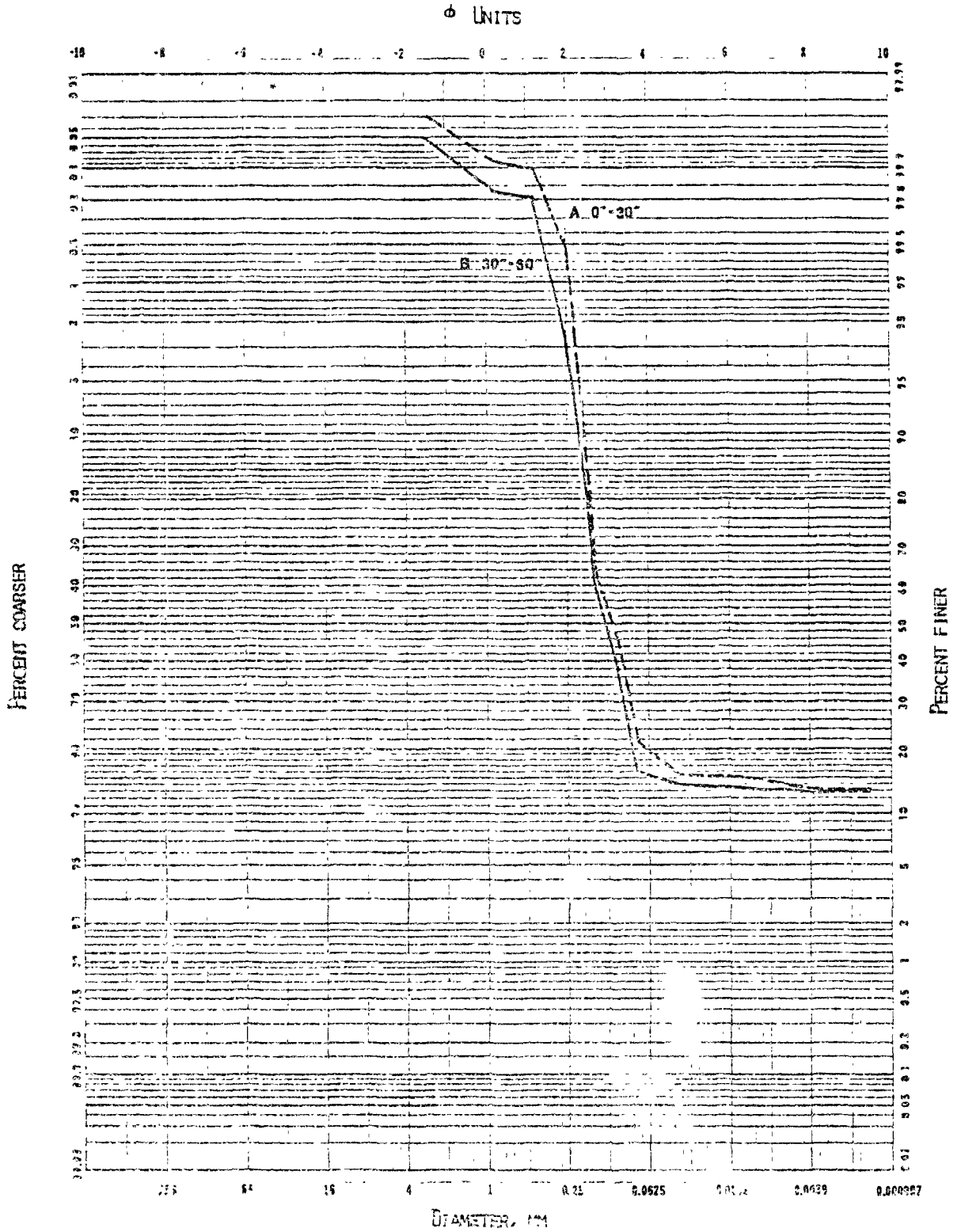


FIGURE 3.

PARTICLE SIZE ANALYSIS DATA FOR SPINKS LOAMY SAND.

Table 2. Phosphate sorption test data for the three dominant soils in the Indian Lake/Sister Lakes study area.

Soil	Horizon	Thickness (inches)	Weight[a] (10^6 lbs/acre)	5 Day Phosphate Sorption (mg/kg)	Long Term Phosphate Sorption[b] (mg/kg)	Total Phosphate Sorption (lbs/acre)
Kalamazoo loam	A	11	3.7	308.3	1,080	4,000
	B	44	14.7	300.8	1,050	15,400
	C	5	1.7	206.2	721	1,220
Total						20,620
Oshtemo sandy loam	A	8	2.7	371.3	1,300	3,500
	B	51	17.0	172.3	604	10,260
	C	9	3.0	94.3	330	990
Total						14,750
Spinks loamy sand	A	10	3.3	129.9	414	1,370
	B	50	16.7	62.1	218	3,640
Total						5,010

[a] Based on an average soil weight of 4×10^6 lbs/ac-ft.

[b] 3.5 times the 5 day value.

Bibliography

ASTM. 1977. Annual book of ASTM standards, Part 19. Philadelphia, Pennsylvania, 494 p.

Enfield, Carl G. and Bert B. Bledsoe. 1975. Kinetic model for orthophosphate reactions in mineral soils. EPA 660/2-75-022.

Folk, Robert L. 1974. The petrology of sedimentary rocks. Hemphill Publishing Co., Austin, Texas, 182 p.

APPENDIX H

SURFACE WATER QUALITY DATA

Table H-1. Physical and chemical characteristics of surface waters in the Dowagiac River at State Highway M-62, Cass County, Pokagon Township, Section 4 (USEPA 1978).

Parameter	Number of Samples	Mean	Maximum	Minimum	Standard Deviation	Sampling Period
Water temperature (^{o}C)	11	19.0	25.0	11.0	4.27	1967-1971
Stream flow (cms)	11	2.9	6.1	1.5	1.3	1967-1971
Turbidity (JTU)	5	6.6	20.0	2.5	7.56	1968-1971
Conductivity at 25°C (micromhos)	4	401.25	450.0	360.0	37.05	1970-1971
Dissolved oxygen (mg/l)	11	7.90	10.4	6.0	1.23	1967-1971
BOD 5 day (mg/l)	11	2.57	4.5	1.4	1.10	1967-1971
pH	9	8.14	8.4	7.9	0.21	1967-1971
Total alkalinity (mg/l)	7	186.14	205.0	160.0	15.56	1968-1971
Total residue (mg/l)	4	301.75	348.0	244.0	42.98	1969-1971
Organic N (mg/l)	2	0.80	0.90	0.70	0.14	1971
NH_3-N (mg/l)	7	0.13	0.20	0.0	0.09	1968-1971
Total NO_3-N (mg/l)	7	0.44	0.90	0.10	0.33	1968-1971
Total phosphorus (mg/l)	7	0.17	0.36	0.04	0.11	1968-1971
Total orthophosphorus (mg/l)	7	0.12	0.26	0.01	0.09	
Total cyanide (mg/l)	5	0.0	0.0	0.0	0.0	1969-1971
Total hardness (mg/l)	7	223.57	270.0	190.0	33.0	1968-1971
Chloride (mg/l)	7	10.0	15.0	3.0	3.96	1968-1971
Sulfate (mg/l)	2	25.0	30.0	20.0	7.07	1970-1971
Total coliform (no./100 ml)	10	8,600.0	30,000.0	500.0	9,142.82	1967-1971
Fecal coliform (no./100 ml)	10	1,066.0	5,000.0	20.0	1,520.43	1967-1971
Total dissolved solids (mg/l)	5	289.0	338.0	256.0	33.27	1969-1971

Table H-2. Physical and chemical characteristics of surface waters in Dowagiac Creek at Highway 62, Cass County, Tokagon township, Section 3 (USEPA 1978).

Parameter	Number of Samples	Mean	Maximum	Minimum	Standard Deviation	Sampling Period
Water temperature (°C)	14	20.12	25.0	13.0	3.59	1967-1974
Stream flow (cms)	13	7.9	9.9	1.3	0.7	1967-1974
Turbidity (JTU)	7	3.86	5.0	1.5	1.18	1968-1973
Conductivity at 25°C (micromhos)	6	389.17	445.0	325.0	39.93	1970-1974
Dissolved oxygen (mg/l)	14	7.24	10.0	4.6	1.77	1967-1974
BOD 5 day (mg/l)	14	3.01	5.0	1.2	1.16	1967-1974
pH	14	8.12	8.3	7.8	0.16	1967-1974
Total alkalinity (mg/l)	10	187.7	205.0	155.0	15.2	1968-1974
Total residue (mg/l)	7	273.86	312.0	222.0	36.27	1969-1974
Organic N (mg/l)	5	0.734	1.1	0.47	0.27	1971-1974
NH_3-N (mg/l)	10	0.09	0.24	0.0	0.80	1968-1974
NO_3+ NO_2 - N (mg/l)	2	0.25	0.25	0.24	.007	1973-1974
Total phosphorus (mg/l)	10	0.13	0,38	0.04	0.11	1968-1974
Total orthophosphorus (mg/l)	10	0.078	0,3	0,0	0,09	
Total cyanide (mg/l)	9	0.004	0.02	0.0	0.007	1967-1974
Total [illegible] (mg/l)	10	210.0	250.0	175.0	23.92	1968-1974
Chloride (mg/l)	10	7.39	17.0	0.0	4.71	1968-1974
Sulfate (mg/l)	5	21.0	25.0	14.0	4.80	1970-1974
Total coliform (no./100 ml)	13	28,361.5	310,000.0	500.0	84,684.2	1967-1974
Fecal coliform (no./100 ml)	13	2,393.85	28,000.0	10.0	7,697.28	1967-1974
Total dissolved solids (mg/l)	8	255.38	304.0	211.0	31.8	1969-1974

Table H-3. Physical and chemical characteristics of the surface waters in Pipestone Creek at River Road, Berrien County, Sodus Township, Section 4 (MDNR 1978b).

Parameter	Number of Samples	Mean	Maximum	Minimum	Sampling Period
Water temperature (°C)	10	17.4	22.5	11.0	1967-1971
Stream flow (cms)	10	1.1	1.1	1.1	1967-1971
Dissolved oxygen (mg/l)	10	8.97	10.2	7.8	1967-1971
BOD 5 day (mg/l)	10	1.69	2.3	1.2	1967-1971
pH	9	8.34	8.7	7.9	1967-1971
Turbidity (JTU)	4	11.6	25.0	6.0	1968,1970-1971
Conductivity at 25°C (micromhos)	3	446.7	450.0	440.0	1970-1971
Total residue (mg/l)	5	370.5	534	301	1969,1971
Organic N (mg/l)	2	0.55	0.6	0.5	1971
Total NH_3-N (mg/l)	6	0.03	0.07	0.0	1967-1971
Total NO_3-N (mg/l)	6	0.54	0.75	0.40	1968-1971
Total phosphorus (mg/l)	6	0.10	0.24	0.04	1968-1971
Total hardness (mg/l)	6	248.33	270	230	1968-1971
Chloride (mg/l)	6	11	15.0	6.0	1968-1971
Sulfate (mg/l)	2	35.5	40.0	31.0	1970-1971
Total coliform (no./100 ml)	9	2,233.3	7,200	1,000	1967-1971
Fecal coliform (no./100 ml)	9	574.4	3,500	30	1967-1971
Total dissolved solids (mg/l)	4	349.25	526	286	1969-1971

Table H-4. Physical and chemical characteristics of the water in Pipestone Lake (Snow 1978).

Date/Depth	Temperature (°C)	Oxygen (mg/l)	Total Phosphorus (mg/l)	Soluble ortho P (mg/l)	$NO_3 + NO_2$ Nitrogen (mg/l)	pH	Chlorophyll a (ug/l)	Secchi Disc (meters)
16 April 1978								
1-2 meter depth	9.4	10.5	0.040	0.003	0.27	8.2	22.8	1.5
6-7 meter depth	8.2	10.0	0.042	0.003	0.27	8.2	28.7	
11 August 1978								
1-2 meter depth	24.0	9.2	0.012	0.003	0.035	8.5	47.0	3.5
6-7 meter depth	11.5	0.0	0.182	0.094	0.005	7.4		
4 September 1979 [a]								
surface	24.9	11.3						1.0
bottom	13.2	0.0						

[a] The data monitored by WAPORA, Inc. was at five locations in the lake with depth of lake at these locations varying from 14-22 feet (4.2-6.6 meters).

Table H-5. Physical and chemical characteristics for Round Lake, Van Buren County, Michigan (USEPA 1978).

Parameter	Number of Samples	Mean	Maximum	Minimum	Standard Deviation	Sampling Period
Water temperature (°C)	6/11	19.8/19.6	20.0/24.0	19.0/14.0	0.41/3.28	1977/1978
Turbidity (JTU)	3	11.9	17.0	9.3	4.42	1977
Secchi depth(m)	1/1	0.6/1.8	---	---	---	1977/1978
Conductivity at 25°C (micromhos)	3/11	98.33/89.7	99.0/92.0	97.0/85.0	1.16/1.68	1977/1978
Dissolved oxygen (mg/l)	6/10	8.58/ 4.33	8.7/8.50	8.4/0.20	0.13/4.55	1977/1978
pH	6/13	8.25/7.48	8.3/8.4	8.2/6.6	0.56/0.65	1977/1978
Total residue (mg/l)	3	62.3	64.0	60.0	2.08	1977
Organic nitrogen (mg/l)	3	0.97	1.05	0.89	0.80	1977
Total NH_3-N (mg/l)	3	0.008	0.009	0.006	0.002	1977
Total phosphorus (mg/l)	3	0.027	0.032	0.023	0.005	1977
Total hardness (mg/l)	3	44.3	45.0	43.0	1.16	1977
Chloride (mg/l)	3	3.5	3.6	3.5	0.058	1977
Sulfate (mg/l)	3	4.5	5.0	4.1	0.45	1977
Chlorophyll *a* (ug/l)	1	52.0				1977

Table II-6. Physical and chemical characteristics of the surface waters in Crooked Lake, Van Buren County and Cass County, Michigan (USEPA 1978).

Parameter	Number of Samples	Mean	Maximum	Minimum	Standard Deviation	Sampling Period
Water temperature (°C)	17	14.79	24.0	7.0	---	1978
Secchi depth(m)	1	4.3	---	---	---	1978
Conductivity at 25°C (micromhos)	17	208.88	240.0	192.0	15.72	1978
Dissolved oxygen (mg/l)	17	5.73	9.8	0.10	6.23	1978
pH	18	7.49	8.70	0.80	1.77	1978
Organic nitrogen (mg/l)	2	0.48	0.50	0.47	8.02	1978
NH_3-N (mg/l)	2	0.0	0.0	0.0	0.0	1978
Total phosphorus (mg/l)	2	0.01	0.01	0.01	0.0	1978
Total hardness (mg/l)	2	125.0	130.0	120.0	7.07	1978
Chloride (mg/l)	2	15.0	15.0	15.0	0.0	1978
Sulfate (mg/l)	2	7.95	8.3	7.6	0.49	1978
Fecal coliform (no./100 ml)	2	3.5	5.0	3.0		1977-1978
Total [illegible] N (mg/l)	2	0.48	0.50	0.47	0.21	1978

Table H-7. Secchi transparency and chlorophyll a concentrations for Dewey Lake (MDNR 1975, 1976, 1977, 1978).

Year	No. of Samples	Mean Secchi depth (meter)(ft)	No. of Samples	Mean Chlorophyll a (ug/l)	Trophic Status[a]
1974	NA	1.11 (3.65)	NA	26.67	Eutrophic
1975	8	1.05 (3.46)	7	35.98	Eutrophic
1976	18	1.66 (5.44)	18	8.97	Eutrophic
1977	19	1.28 (4.21)	NA	NA	Eutrophic

[a] Trophic status based on MDNR Self-Help Survey criteria shown below:

	Chlorophyll a (ug/l)	Transparency (feet)
Oligotrophic	0-4	15
Mesotrophic	4-10	6.5-15
Eutrophic	10	6.5

Lakes are placed in the most productive trophic status indicated by either Secchi transparency or chlorophyll a.

NA - Not available.

APPENDIX I

AQUATIC BIOTA SAMPLING PROGRAM-
PHYTOPLANKTON ANALYSIS

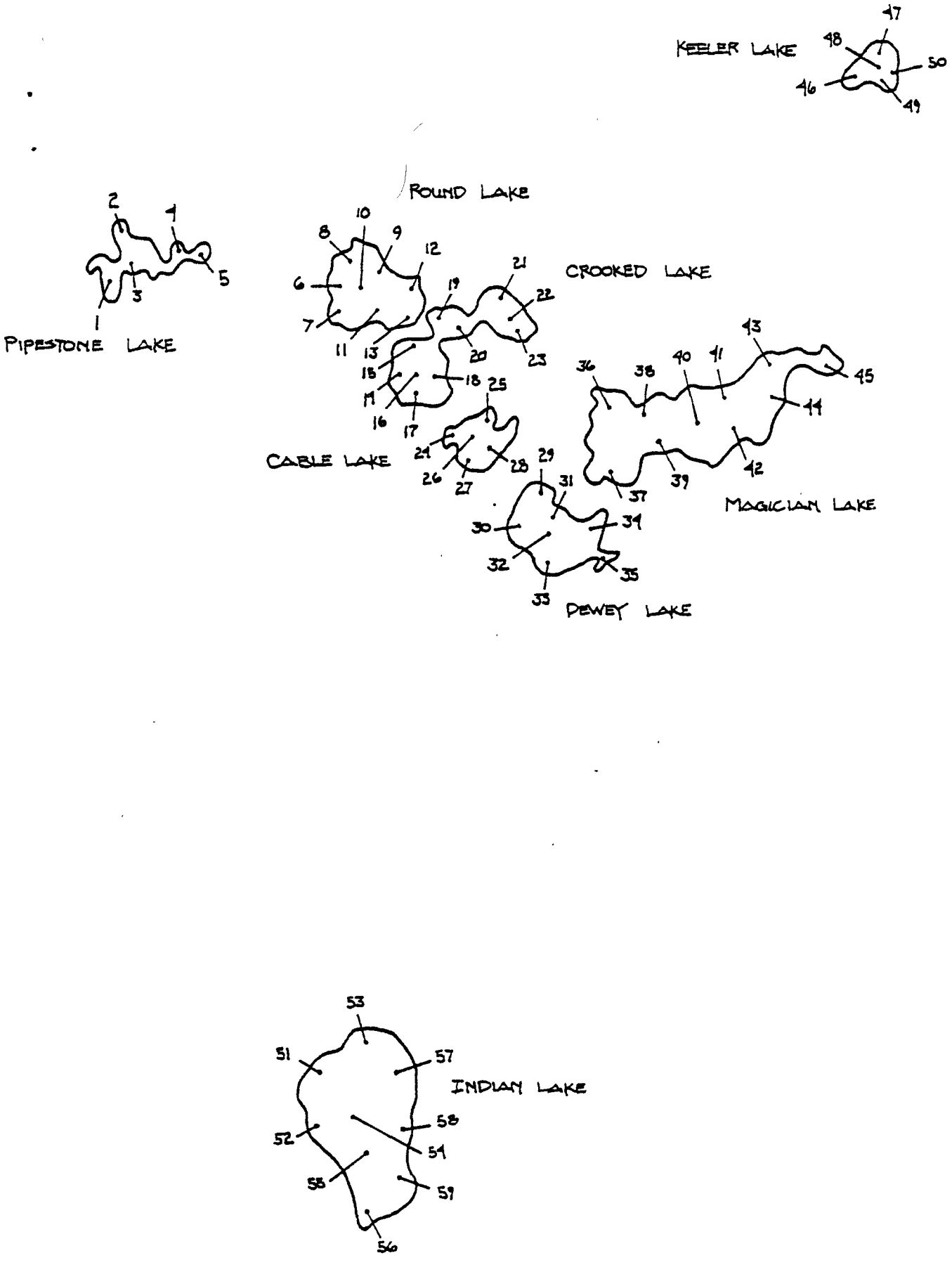


Figure I-1. Aquatic biota sampling program locations.

Phytoplankton Analysis - Laboratory Procedures

Sample bottles were assigned individual code numbers, shipped to the laboratory, and stored in a cool, dark room until analysis. The code numbering system was employed for inventory and for quality assurance purposes. All the data sheets related to each sample contained the code number and the pertinent label information.

Phytoplankton identification and enumeration was conducted with a Wild M-40 inverted microscope and an Olympus BHB phase contrast microscope. The Olympus microscope was utilized for some taxonomic determinations. The Wild M-40 inverted microscope was used for both identification and enumeration of sample populations. Standard taxonomic references were utilized.

Phytoplankton were counted using a plankton chamber. A 2.307 ml aliquot of sample water was poured into the chamber, and the algae settled to the bottom. The settled algae were observed from beneath using the inverted microscope. Enumeration proceeded at X280 magnification. A minimum of 100 units (one unit = one filament, one colony, or one unicellular alga) or 266 fields (unit of area) were counted, whichever was obtained first. Taxa were differentiated to calculate the diversity/trophic status indices. Organisms were identified to the species level when feasible. Data obtained from counts were entered on bench sheets, which also served as computer data sheets. Computer print-outs tabulated the density and the percent occurrence of major groups and individual taxa, the number of taxa, and the Shannon-Weaver diversity index for each replicate sample.

Literature Cited

Morris, Franklin A. et al. 1977. Distribution of phytoplankton in Indiana Lakes. Working Paper No. 682. National Eutrophication Study. USEPA, Office of Research and Development.

Wilhm, Jerry and Troy Doris. 1968. Biological parameters for water quality criteria. Bioscience 18: 477-480.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM PIPESTONE - 5 JUNE 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM PIPESTONE - 5 JUNE 1979.

PIPESTONE

	STN. # 1		STN. # 2		STN. # 3		STN. # 4		STN. # 5		STN. **	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	57	3.1	150	4.5	56	3.2	94	5.3	112	3.8	0	.0
COSMARIUM SP	0	.0	0	.0	0	.0	9	.5	0	.0	0	.0
CRUCIGENIA IRREGULARIS	0	.0	0	.0	0	.0	9	.5	0	.0	0	.0
OULOTRIS SP	9	.5	0	.0	0	.0	19	1.1	0	.0	0	.0
SCENEDESMUS BIJUGA	38	2.1	131	4.0	37	2.1	38	2.1	75	2.6	0	.0
SCENEDESMUS QUADRICAUDA	0	.0	0	.0	19	1.1	19	1.1	19	.6	0	.0
SPHAEROCYSTIS SP	0	.0	0	.0	0	.0	0	.0	19	.6	0	.0
STAURASTRUM SP	9	.5	0	.0	0	.0	0	.0	0	.0	0	.0
TREUBARIA SP	0	.0	19	.6	0	.0	0	.0	0	.0	0	.0
BACILLARIOPHYTA	406	22.2	599	18.1	468	26.3	680	38.5	823	28.2	20692	6.1
COCCONEIS PEDICULUS	0	.0	0	.0	0	.0	0	.0	0	.0	18811	5.5
CYCLOTELLA ANTIQUA	406	22.2	599	18.1	468	26.3	680	38.5	823	28.2	0	.0
NAVICULA CRYPTOCEPHALA	0	.0	0	.0	0	.0	0	.0	0	.0	1881	.6
CYANOPHYTA	416	22.7	131	4.0	468	26.3	38	2.1	187	6.4	316027	92.8
ANABAENA SP	416	22.7	131	4.0	468	26.3	38	2.1	187	6.4	316027	92.8
CRYPTOPHYTA	784	42.8	2302	69.5	618	34.7	803	45.5	1553	53.2	3762	1.1
CHROOMONAS ACUTA	472	25.8	1722	52.0	243	13.7	368	20.9	898	30.8	1881	.6
CRYPTOMONAS EROSA	312	17.0	580	17.5	374	21.1	435	24.6	655	22.4	1881	.6
CHRYSOPHYTA	132	7.2	131	4.0	131	7.4	113	6.4	168	5.8	0	.0
MALLOMONAS TONSURATA	0	.0	19	.6	0	.0	19	1.1	0	.0	0	.0
OCHROMONAS SP	132	7.2	112	3.4	131	7.4	94	5.3	168	5.8	0	.0
EUGLENOPHYTA	0	.0	0	.0	0	.0	0	.0	19	.6	0	.0
EUGLENA SP	0	.0	0	.0	0	.0	0	.0	19	.6	0	.0
PYRRHOPHYTA	38	2.1	0	.0	37	2.1	38	2.1	56	1.9	0	.0
GLENODINIUM SP	38	2.1	0	.0	37	2.1	28	1.6	56	1.9	0	.0
PERIDINIUM SP	0	.0	0	.0	0	.0	9	.5	0	.0	0	.0
TOTAL DENSITY	1832		3312		1777		1766		2919		340401	
TOTAL NUMBER OF TAXA	9		8		8		13		10		5	
SHANNON-WEAVER INDEX	1.73		1.38		1.71		1.68		1.66		.32	

** SHORE NEAR BASS ISLAND INN

RUN COMPLETE.

PROGRAM PHYTO2A

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-DM/DL ANALYZED BY-HEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM ROUND - 5 JUNE 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM ROUND - 5 JUNE 1979.

	ROUND							
	STN. # 6		STN. # 7		STN. # 8		STN. # 9	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	293	20.1	491	38.0	274	22.7	208	31.4
ANKISTRODESMUS FALCATUS	0	.0	0	.0	19	1.6	0	.0
CHLAMYDOMONAS SP	19	1.3	85	6.6	19	1.6	0	.0
CLOSTERIUM SP	9	.6	19	1.5	0	.0	0	.0
ELAKATOTHRIX GELATINOSA	9	.6	9	.7	0	.0	0	.0
EUDORINA ELEGANS	0	.0	0	.0	9	.8	25	3.8
GONIUM SOCIALE	0	.0	9	.7	0	.0	0	.0
NEPHROCYTIUM SP	0	.0	9	.7	0	.0	0	.0
OOCYSTIS SP	0	.0	9	.7	0	.0	6	1.
PEDIASTRUM TETRAS	19	1.3	9	.7	0	.0	6	1.
QUADRIOULA CLOSTERIOIDES	0	.0	0	.0	0	.0	6	1.
SCENEDESMUS BIJUGA	236	16.2	312	24.1	208	17.2	145	21.9
SCENEDESMUS QUADRICAUDA	0	.0	9	.7	9	.8	0	.0
SPHAEROCYSTIS SP	0	.0	19	1.5	0	.0	13	1.9
SPONDYLOSIUM SP	0	.0	0	.0	0	.0	6	1.
TETRASTRUM GLABRUM	0	.0	0	.0	9	.8	0	.0
BACILLARIOPHYTA	350	24.0	283	21.9	94	7.8	195	29.5
CYCLOTELLA ANTIQUA	293	20.1	227	17.5	85	7.0	189	28.6
NITZSCHIA ACICULARIS	0	.0	57	4.4	0	.0	0	.0
NITZSCHIA PALEA	57	3.9	0	.0	9	.8	0	.0
TABELLARIA FENESTRATA	0	.0	0	.0	0	.0	6	1.
CYANOPHYTA	784	53.9	472	36.5	812	67.2	246	37.1
ANABAENA SP	765	52.6	444	34.3	803	66.4	227	34.3
ANACYSTIS SP	19	1.3	28	2.2	0	.0	6	1.
OSCILLATORIA SP	0	.0	0	.0	9	.8	13	1.9
CRYPTOPHYTA	19	1.3	19	1.5	19	1.6	6	1.
CRYPTOMONAS EROSA	19	1.3	19	1.5	19	1.6	6	1.
CHRYSOPHYTA	9	.6	28	2.2	0	.0	6	1.
DINOBRYON SP	9	.6	0	.0	0	.0	6	1.
OCHROMONAS SP	0	.0	28	2.2	0	.0	0	.0
PYRRHOPHYTA	0	.0	0	.0	9	.8	0	.0
GLENODINIUM SP	0	.0	0	.0	9	.8	0	.0
TOTAL DENSITY	1454		1294		1209		661	
TOTAL NUMBER OF TAXA	11		16		12		14	
SHANNON-WEAVER INDEX	1.41		1.90		1.18		1.69	

SRU 7.155 UNTS.

RUN COMPLETE.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM ROUND - 5 JUNE 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM ROUND - 5 JUNE 1979.

	ROUND							
	STN. #10		STN. #11		STN. #12		STN. #13	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	183	26.4	227	24.5	120	20.0	157	25.8
ANKISTRODESMUS FALCATUS	0	.0	9	1.0	0	.0	13	2.1
CHLAMYDOMONAS SP	6	.9	0	.0	0	.0	13	2.1
CLOSTERIUM SP	13	1.8	19	2.0	0	.0	13	2.1
CRUCIGENIA IRREGULARIS	0	.0	0	.0	6	1.1	0	.0
DICTYOSPHAERIUM PULCHELLUM	6	.9	0	.0	0	.0	6	1.0
ELAKATOTHRIX GELATINOSA	6	.9	0	.0	0	.0	0	.0
EUDORINA ELEGANS	0	.0	0	.0	0	.0	6	1.0
GONIUM SOCIALE	0	.0	85	9.2	50	8.4	6	1.0
KIRCHNERIELLA SP	0	.0	0	.0	6	1.1	0	.0
OOCYSTIS SP	13	1.8	9	1.0	0	.0	0	.0
SCENEDESMUS BIJUGA	120	17.3	94	10.2	57	9.5	82	13.4
SCENEDESMUS QUADRICAUDA	13	1.8	9	1.0	0	.0	13	2.1
STAURASTRUM SP	6	.9	0	.0	0	.0	6	1.0
BACILLARIOPHYTA	227	32.7	255	27.6	309	51.6	239	39.2
CYCLOTELLA ANTIQUA	195	28.2	208	22.4	252	42.1	189	30.9
MELOSIRA ISLANDICA	0	.0	9	1.0	0	.0	13	2.1
NAVICULA CRYPTOCEPHALA	0	.0	0	.0	0	.0	6	1.0
NITZSCHIA ACICULARIS	6	.9	0	.0	19	3.2	25	4.1
NITZSCHIA PALEA	25	3.6	19	2.0	38	6.3	6	1.0
SYNEDRA SP	0	.0	19	2.0	0	.0	0	.0
CYANOPHYTA	265	38.2	435	46.9	145	24.2	195	32.0
ANABAENA SP	252	36.4	425	45.9	139	23.2	195	32.0
ANACYSTIS SP	6	.9	9	1.0	6	1.1	0	.0
OSCILLATORIA SP	6	.9	0	.0	0	.0	0	.0
CRYPTOPHYTA	6	.9	0	.0	19	3.2	13	2.1
CRYPTOMONAS EROSA	6	.9	0	.0	19	3.2	13	2.1
CHRYSOPHYTA	13	1.8	9	1.0	6	1.1	6	1.0
DINOBRYON SP	6	.9	9	1.0	6	1.1	6	1.0
OCHROMONAS SP	6	.9	0	.0	0	.0	0	.0
TOTAL DENSITY	692		925		598		610	
TOTAL NUMBER OF TAXA	17		13		11		17	
SHANNON-WEAVER INDEX	1.79		1.66		1.72		1.94	

BRU 7.390 UNITS.

RUN COMPLETE.

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-DH/DL ANALYZED BY-MEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM CROOKED - 6 JUNE 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM CROOKED - 6 JUNE 1979.

CROOKED

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM CROOKED - 6 JUNE 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM CROOKED - 6 JUNE 1979.

	CROOKED									
	STN. #20		STN. #21		STN. #22		STN. #23		STN. **	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	24	11.1	184	37.9	156	42.3	14	42.9	17067	58.8
ANKISTRODESMUS FALCATUS	0	.0	33	6.8	24	6.4	0	.0	299	1.0
CLOSTERIUM SP	0	.0	0	.0	0	.0	0	.0	299	1.0
COELASTRUM SPHAERICUM	0	.0	9	1.9	0	.0	0	.0	0	.0
COSMARIUM SP	0	.0	0	.0	0	.0	0	.0	299	1.0
ELAKATOTHRIX GELATINOSA	0	.0	0	.0	14	3.8	5	14.3	0	.0
EUDORINA ELEGANS	0	.0	0	.0	5	1.3	0	.0	0	.0
HOUGEOTIA SP	0	.0	0	.0	0	.0	0	.0	14671	50.5
OOCYSTIS SP	24	11.1	128	26.2	104	28.2	9	28.6	898	3.1
SCENEDESMUS ARCUATUS	0	.0	5	1.	0	.0	0	.0	0	.0
SCENEDESMUS BIJUGA	0	.0	0	.0	0	.0	0	.0	299	1.0
SCENEDESMUS QUADRICAUDA	0	.0	0	.0	0	.0	0	.0	299	1.0
SPHAEROCYSTIS SP	0	.0	9	1.9	9	2.6	0	.0	0	.0
BACILLARIOPHYTA	0	.0	43	8.7	0	.0	5	14.3	8384	28.9
ACHNANTHES MINUTISSIMA	0	.0	0	.0	0	.0	0	.0	2096	7.2
COCCONEIS PEDICULUS	0	.0	0	.0	0	.0	0	.0	2695	9.3
CYCLOTELLA BODANICA	0	.0	5	1.	0	.0	0	.0	0	.0
CYMBELLA SP	0	.0	0	.0	0	.0	0	.0	299	1.0
DIATOMA ELONGATUM	0	.0	0	.0	0	.0	0	.0	299	1.0
GOMPHONEMA OLIVACEUM	0	.0	0	.0	0	.0	0	.0	1198	4.1
NAVICULA CRYPTOCEPHALA	0	.0	0	.0	0	.0	0	.0	299	1.0
NITZSCHIA SP	0	.0	0	.0	0	.0	0	.0	599	2.1
NITZSCHIA PALEA	0	.0	0	.0	0	.0	5	14.3	898	3.1
TABELLARIA FENESTRATA	0	.0	38	7.8	0	.0	0	.0	0	.0
CYANOPHYTA	9	4.4	9	1.9	19	5.1	0	.0	3593	12.4
ANABAENA SP	9	4.4	9	1.9	19	5.1	0	.0	0	.0
OSCILLATORIA SP	0	.0	0	.0	0	.0	0	.0	3593	12.4
CRYPTOPHYTA	170	80.0	241	49.5	189	51.3	14	42.9	0	.0
CHROOMONAS ACUTA	113	53.3	179	36.9	165	44.9	14	42.9	0	.0
CRYPTOMONAS EROSA	57	26.7	61	12.6	24	6.4	0	.0	0	.0
CHRYSOPHYTA	5	2.2	9	1.9	5	1.3	0	.0	0	.0
DINOBRYON SP	0	.0	9	1.9	5	1.3	0	.0	0	.0
OCHROMONAS SP	5	2.2	0	.0	0	.0	0	.0	0	.0
PYRRHOPHYTA	5	2.2	0	.0	0	.0	0	.0	0	.0
CERATIUM SP	5	2.2	0	.0	0	.0	0	.0	0	.0
TOTAL DENSITY	212		486		368		33		29043	
TOTAL NUMBER OF TAXA	6		11		9		4		16	
SHANNON-WEAVER INDEX	1.24		1.76		1.55		1.28		1.82	

** WEST SHORE

RUN COMPLETE.

PROGRAM PHYTOZA

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-DH/GL ANALYZED BY-MEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM CABLE - 4 JUNE 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM CABLE - 4 JUNE 1979.

CABLE

	STN. #24		STN. #25		STN. #26		STN. #27		STN. #28	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	4761	83.5	2732	85.9	1572	68.9	2115	72.0	33	16.3
ANKISTRODESMUS FALCATUS	34	.6	0	.0	0	.0	19	.6	5	2.3
ANKISTRODESMUS QUATERNATUS	0	.0	19	.6	0	.0	0	.0	0	.0
CHLAMYDOMONAS SP	0	.0	0	.0	0	.0	19	.6	0	.0
CRUCIGENIA IRREGULARIS	34	.6	75	2.4	37	1.6	0	.0	0	.0
ELAKATOTHRIX GELATINOSA	34	.6	19	.6	0	.0	0	.0	0	.0
OOCYSTIS SP	1140	20.0	299	9.4	243	10,7	580	19.7	19	9.3
QUADRIGULA CLOSTERIOIDES	34	.6	0	.0	37	1.6	0	.0	5	2.3
SCENEDESMUS ARCUATUS	0	.0	0	.0	19	.8	0	.0	0	.0
SCENEDESMUS BIJUGA	101	1.8	19	.6	0	.0	19	.6	0	.0
SCENEDESMUS DIMORPHUS	0	.0	19	.6	0	.0	0	.0	0	.0
SCENEDESMUS QUADRICAUDA	34	.6	0	.0	0	.0	0	.0	0	.0
SPHAEROCYSTIS SP	3353	58.8	2283	71.8	1235	54.1	1478	50.3	5	2.3
CYANOPHYTA	0	.0	0	.0	0	.0	19	.6	0	.0
OSCILLATORIA SP	0	.0	0	.0	0	.0	19	.6	0	.0
CRYPTOPHYTA	671	11.8	449	14.1	636	27.9	599	20.4	161	79.1
CHROOMONAS ACUTA	671	11.8	356	11.2	599	26.2	599	20.4	142	69.8
CRYPTOMONAS EROSA	0	.0	94	2.9	37	1.6	0	.0	19	9.3
CHRYSOPHYTA	134	2.4	0	.0	75	3.3	206	7.0	9	4.7
OCHROMONAS SP	134	2.4	0	.0	75	3.3	187	6.4	9	4.7
SYNURA SP	0	.0	0	.0	0	.0	19	.6	0	.0
PYRRHOPHYTA	134	2.4	0	.0	0	.0	0	.0	0	.0
GLENODINIUM SP	34	.6	0	.0	0	.0	0	.0	0	.0
GYMNODINIUM SP	101	1.8	0	.0	0	.0	0	.0	0	.0
TOTAL DENSITY	5700		3181		2283		2938		203	
TOTAL NUMBER OF TAXA	12		9		8		9		7	
SHANNON-WEAVER INDEX	1.30		1.02		1.28		1.33		1.10	

SRU 6.889 UNTS.

RUN COMPLETE.

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-DM/GL ANALYZED BY-MEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM DEWEY - 5 JUNE 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM DEWEY - 5 JUNE 1979.

DEWEY

	STN. #29 NO/ML	STN. #29 % OCCUR	STN. #30 NO/ML	STN. #30 % OCCUR	STN. #31 NO/ML	STN. #31 % OCCUR	STN. #32 NO/ML	STN. #32 % OCCUR
CHLOROPHYTA	916	58.8	1722	58.2	1216	61.3	1347	48.3
COELASTRUM SPHAERICUM	0	.0	0	.0	19	.9	0	.0
COSMARIUM SP	595	38.2	1011	34.2	767	38.7	1067	38.3
CRUCIGENIA IRREGULARIS	123	7.9	225	7.6	168	8.5	75	2.7
CRUCIGENIA TETRAPEDIA	9	.6	19	.6	19	.9	19	.7
DICTYOSPHAERIUM PULCHELLUM	9	.6	0	.0	0	.0	19	.7
EUDORINA ELEGANS	0	.0	19	.6	0	.0	0	.0
LAGERHEIMIA BUDSALSA	47	3.0	150	5.1	94	4.7	37	1.3
OOCYSTIS SP	19	1.2	187	6.3	0	.0	94	3.4
SCENEDESMUS BIJUGA	66	4.2	56	1.9	56	2.8	19	.7
SCENEDESMUS QUADRICAUDA	19	1.2	37	1.3	37	1.9	0	.0
SPHAEROCYSTIS SP	9	.6	0	.0	19	.9	0	.0
TETRAEDRON CAUDATUM	9	.6	0	.0	19	.9	0	.0
TETRASTRUM GLABRUM	9	.6	19	.6	19	.9	19	.7
CYANOPHYTA	19	1.2	150	5.1	19	.9	112	4.0
ANABAENA SP	19	1.2	37	1.3	19	.9	56	2.0
ANACYSTIS SP	0	.0	112	3.8	0	.0	56	2.0
CRYPTOPHYTA	94	6.1	150	5.1	168	8.5	131	4.7
CHROOMONAS ACUTA	0	.0	37	1.3	168	8.5	19	.7
CRYPTOMONAS EROSA	94	6.1	112	3.8	0	.0	112	4.0
CHRYSOPHYTA	123	7.9	412	13.9	356	17.9	917	32.9
MALLOMONAS TONSURATA	38	2.4	0	.0	0	.0	0	.0
OCHROMONAS SP	85	5.5	412	13.9	356	17.9	917	32.9
PYRRHOPHYTA	408	26.1	524	17.7	225	11.3	281	10.1
GLENODINIUM SP	408	26.1	524	17.7	225	11.3	281	10.1
TOTAL DENSITY	1558		2956		1983		2788	
TOTAL NUMBER OF TAXA	16		15		14		14	
SHANNON-WEAVER INDEX	1.09		2.06		1.92		1.69	

BRU 6.923 UNTS.

RUN COMPLETE.

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-DM/BL ANALYZED BY-MEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM DEWEY - 5 JUNE 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM DEWEY - 5 JUNE 1979.

	DEWEY					
	STN. #33		STN. #34		STN. #35	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	1497	53.3	2676	63.0	3069	66.4
ANKISTRODESMUS FALCATUS	0	.0	0	.0	19	.4
CLOSTERIUM SP	19	.7	0	.0	0	.0
COELASTRUM SPHAERICUM	19	.7	0	.0	19	.4
COSMARIUM SP	823	29.3	1722	40.5	1796	38.9
CRUCIGENIA IRREGULARIS	281	10.0	206	4.8	468	10.1
CRUCIGENIA TETRAPEDIA	37	1.3	56	1.3	112	2.4
DICTYOSPHAERIUM PULCHELLUM	0	.0	0	.0	19	.4
LAGERHEIMIA SUBSALSA	187	6.7	262	6.2	281	6.1
OOCYSTIS SP	0	.0	19	.4	206	4.5
PEDIASTRUM TETRAS	0	.0	19	.4	0	.0
SCENEDESMUS BIJUGA	131	4.7	262	6.2	94	2.0
SPHAEROCYSTIS SP	0	.0	94	2.2	37	.8
TETRASTRUM GLABRUM	0	.0	19	.4	19	.4
TREUBARIA SP	0	.0	19	.4	0	.0
BACILLARIOPHYTA	0	.0	19	.4	0	.0
NAVICULA CRYPTOCEPHALA	0	.0	19	.4	0	.0
CYANOPHYTA	19	.7	75	1.8	112	2.4
ANABAENA SP	0	.0	19	.4	0	.0
ANACYSTIS SP	19	.7	56	1.3	112	2.4
CRYPTOPHYTA	206	7.3	299	7.0	356	7.7
CHROOMONAS ACUTA	0	.0	75	1.8	75	1.6
CRYPTOMONAS EROSA	206	7.3	225	5.3	281	6.1
CHRYSOPHYTA	749	26.7	805	18.9	636	13.8
DINOBRYON SP	0	.0	19	.4	0	.0
MALLOMONAS TONBURATA	0	.0	19	.4	0	.0
OCHROMONAS SP	749	26.7	767	18.1	636	13.8
EUGLENOPHYTA	0	.0	19	.4	37	.8
EUGLENA SP	0	.0	0	.0	19	.4
TRACHELOMONAS SP	0	.0	19	.4	19	.4
PYRRHOPHYTA	337	12.0	356	8.4	412	8.9
GLENODINIUM SP	337	12.0	356	8.4	412	8.9
TOTAL DENSITY	2807		4247		4622	
TOTAL NUMBER OF TAXA	11		20		18	
SHANNON-WEAVER INDEX	1.87		2.01		2.07	

BRU 7.084 UNITS.

RUN COMPLETE.

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-DH/GL ANALYZED BY-HEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM MAGICIAN - 4 JUNE 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM MAGICIAN - 4 JUNE 1979.

MAGICIAN

	STN. 036		STN. 037		STN. 038		STN. 039		STN. 040		STN. 041	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCR	NO/ML	% OCCUR
CHLOROPHYTA	28	2.1	104	7.4	66	7.1	94	4.6	19	.7	75	2.8
ANKISTRODESMUS FALCATUS	0	.0	0	.0	9	1.0	0	.0	0	.0	0	.0
COSMARIUM SP	0	.0	9	.7	0	.0	0	.0	0	.0	0	.0
CRUCIGENIA IRREGULARIS	0	.0	0	.0	0	.0	19	.9	0	.0	0	.0
ELAKATOTHRIX GELATINOSA	28	2.1	19	1.3	0	.0	37	1.9	0	.0	19	.7
EUASTRUM	0	.0	0	.0	0	.0	0	.0	0	.0	19	.7
OOCYSTIS SP	0	.0	9	.7	47	5.1	0	.0	19	.7	19	.7
SCENEDESMUS BIJUGA	0	.0	66	4.7	0	.0	37	1.9	0	.0	0	.0
SPHAEROCYSTIS SP	0	.0	0	.0	9	1.0	0	.0	0	.0	19	.7
BACILLARIOPHYTA	1011	75.9	812	57.7	690	73.7	1470	73.1	1815	71.3	2582	97.2
ACHNANTHES MINUTISSIMA	19	1.4	0	.0	0	.0	0	.0	19	.7	0	.0
ASTERIONELLA FORMOSA	0	.0	9	.7	0	.0	0	.0	0	.0	0	.0
CYCLOTELLA ANTIQUA	992	74.5	784	55.7	671	71.7	1460	72.2	1796	70.6	2582	97.2
CYCLOTELLA BODANICA	0	.0	0	.0	9	1.0	19	.9	0	.0	0	.0
CYMBELLA SP	0	.0	9	.7	0	.0	0	.0	0	.0	0	.0
NITZSCHIA SP	0	.0	9	.7	0	.0	0	.0	0	.0	0	.0
NITZSCHIA PALEA	0	.0	0	.0	9	1.0	0	.0	0	.0	0	.0
CYANOPHYTA	0	.0	19	1.3	0	.0	19	.9	0	.0	0	.0
ANACYSTIS SP	0	.0	19	1.3	0	.0	19	.9	0	.0	0	.0
CRYPTOPHYTA	274	20.6	453	32.2	179	19.2	430	21.3	692	27.2	0	.0
CHROOMONAS ACUTA	227	17.0	406	28.9	151	16.2	412	20.4	636	25.0	0	.0
CRYPTOMONAS EROSA	47	3.5	47	3.4	28	3.0	19	.9	56	2.2	0	.0
CHRYSOPHYTA	0	.0	9	.7	0	.0	0	.0	19	.7	0	.0
DINOBRYON SP	0	.0	9	.7	0	.0	0	.0	19	.7	0	.0
EUGLENOPHYTA	19	1.4	0	.0	0	.0	0	.0	0	.0	0	.0
TRACHELOMONAS SP	19	1.4	0	.0	0	.0	0	.0	0	.0	0	.0
PYRRHOPHYTA	0	.0	9	.7	0	.0	0	.0	0	.0	0	.0
CERATIUM SP	0	.0	9	.7	0	.0	0	.0	0	.0	0	.0
TOTAL DENSITY	1331		1407		935		2021		2545		2657	
TOTAL NUMBER OF TAXA	6		13		8		8		6		5	
SHANNON-WEAVER INDEX	.84		1.29		.98		.88		.78		.17	

BRU 7.348 UNITS.

RUN COMPLETE.

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-DM/DL ANALYZED BY-MEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM MAGICIAN - 4 JUNE 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM MAGICIAN - 4 JUNE 1979.

	MAGICIAN							
	STN. 042		STN. 043		STN. 044		STN. 045	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	112	2.7	187	3.4	94	2.2	37	1.2
COSMARIUM SP	0	.0	19	.3	19	.4	0	.0
ELAKATOTHRIX GELATINOSA	0	.0	0	.0	37	.9	19	.6
ELAKATOTHRIX VIRIDIS	0	.0	131	2.4	0	.0	0	.0
OOCYSTIS SP	37	.9	0	.0	0	.0	19	.6
SCENEDESMUS BIJUGA	75	1.8	37	.7	37	.9	0	.0
BACILLARIOPHYTA	3593	86.9	4678	85.3	3743	88.9	2770	91.9
ACHNANTHES MINUTISSIMA	0	.0	0	.0	19	.4	0	.0
CYCLOTELLA ANTIQUA	3593	86.9	4660	85.0	3705	88.0	2770	91.9
CYCLOTELLA BODANICA	0	.0	0	.0	19	.4	0	.0
CYMBELLA SP	0	.0	19	.3	0	.0	0	.0
CYANOPHYTA	0	.0	19	.3	0	.0	0	.0
ANACYSTIS SP	0	.0	19	.3	0	.0	0	.0
CRYPTOPHYTA	412	10.0	599	10.9	356	8.4	206	6.8
CHROOMONAS ACUTA	356	8.6	487	8.9	318	7.6	150	5.0
CRYPTOMONAS EROSA	56	1.4	112	2.0	37	.9	56	1.9
CHRYSOPHYTA	19	.5	0	.0	19	.4	0	.0
DINOBRYON SP	19	.5	0	.0	19	.4	0	.0
TOTAL DENSITY	4135		5483		4210		3012	
TOTAL NUMBER OF TAXA	6		8		9		5	
SHANNON-WEAVER INDEX	.53		.61		.53		.36	

SRU 6.391 UNTS.

RUN COMPLETE.

PROJECT 359 SAMPLE TYPE-WW COLLECTED BY-DH/GL ANALYZED BY-HEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM KEELER - 5 JUNE 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM KEELER - 5 JUNE 1979.

KEELER

	STN. #46		STN. #47		STN. #48		STN. #49		STN. #50		STN. ##	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	25	4.3	71	16.3	47	19.6	107	26.1	90	61.3	1974	11.9
ANKISTRODESMUS FALCATUS	0	.0	0	.0	0	.0	0	.0	0	.0	208	1.3
ARTHRODESMUS INCUS	0	.0	0	.0	0	.0	0	.0	5	3.2	0	.0
COSMARIUM SP	0	.0	0	.0	0	.0	0	.0	5	3.2	831	5.0
ELAKATOTHRIX GELATINOSA	0	.0	0	.0	0	.0	5	1.1	5	3.2	0	.0
EUASTRUM SP	0	.0	0	.0	0	.0	0	.0	0	.0	104	.6
EUDORINA ELEGANS	0	.0	0	.0	0	.0	0	.0	5	3.2	0	.0
GLOEOCYSTIS SP	6	1.1	14	3.3	0	.0	5	1.1	5	3.2	0	.0
HOUBEOTIA SP	0	.0	0	.0	0	.0	0	.0	0	.0	623	3.8
OOCYSTIS SP	13	2.2	38	8.7	33	13.7	52	12.5	47	32.3	0	.0
PEDIASTRUM TETRAS	6	1.1	5	1.1	0	.0	7	2.3	5	3.2	0	.0
SCENEDESMUS BIJUGA	0	.0	9	2.2	9	3.9	0	.0	5	3.2	104	.6
SELENASTRUM SP	0	.0	0	.0	0	.0	14	3.4	0	.0	0	.0
SPHAEROCYSTIS SP	0	.0	5	1.1	5	2.0	14	3.4	5	3.2	0	.0
STAURASTRUM SP	0	.0	0	.0	0	.0	5	1.1	5	3.2	0	.0
TETRAEDRON SP	0	.0	0	.0	0	.0	5	1.1	0	.0	0	.0
ZYGNEMA SP	0	.0	0	.0	0	.0	0	.0	0	.0	104	.6
BACILLARIOPHYTA	0	.0	0	.0	0	.0	0	.0	0	.0	11015	66.7
ACHNANTHES MINUTISSIMA	0	.0	0	.0	0	.0	0	.0	0	.0	7170	43.4
CYMBELLA SP	0	.0	0	.0	0	.0	0	.0	0	.0	104	.6
GOMPHONEMA SP	0	.0	0	.0	0	.0	0	.0	0	.0	104	.6
NAVICULA CRYPTOCEPHALA	0	.0	0	.0	0	.0	0	.0	0	.0	208	1.3
NITZSCHIA PALEA	0	.0	0	.0	0	.0	0	.0	0	.0	3429	20.8
CYANOPHYTA	13	2.2	0	.0	24	9.8	24	5.7	9	6.5	3323	20.1
ANABAENA SP	13	2.2	0	.0	5	2.0	24	5.7	9	6.5	0	.0
ANACYSTIS SP	0	.0	0	.0	19	7.8	0	.0	0	.0	0	.0
OSCILLATORIA SP	0	.0	0	.0	0	.0	0	.0	0	.0	3013	18.2
RHOPODERMA SIGMOIDEA	0	.0	0	.0	0	.0	0	.0	0	.0	312	1.9
CRYPTOPHYTA	542	72.3	359	82.6	165	68.6	283	68.2	47	32.3	104	.6
CHROOMONAS ACUTA	453	77.4	312	71.7	142	58.8	236	56.8	19	12.9	104	.6
CRYPTOMONAS EROSA	88	15.1	47	10.9	24	9.8	47	11.4	28	19.4	0	.0
CHRYSOPHYTA	6	1.1	0	.0	0	.0	0	.0	0	.0	0	.0
OCHROMONAS SP.	6	1.1	0	.0	0	.0	0	.0	0	.0	0	.0
EUGLENOPHYTA	0	.0	5	1.1	5	2.0	0	.0	0	.0	104	.6
TRACHELOMONAS SP	0	.0	5	1.1	5	2.0	0	.0	0	.0	104	.6
TOTAL DENSITY	583		434		240		415		146		16521	
TOTAL NUMBER OF TAXA	7		8		8		11		13		15	
SHANNON-WEAVER INDEX	.79		1.03		1.37		1.51		2.12		1.68	

##

RUN COMPLETE.

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-DH/DL ANALYZED BY-MEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM INDIAN - 5 JUNE 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM INDIAN - 5 JUNE 1979.

	INDIAN											
	STN. #51		STN. #52		STN. #53		STN. #54		STN. #55		STN. #56	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	2470	52.6	2058	71.0	1628	55.8	935	78.6	1909	81.0	1759	69.6
ANKISTRODESMUS FALCATUS	112	2.4	131	4.5	37	1.3	104	8.7	56	2.4	281	11.1
CHLAMYDOMONAS SP	0	.0	0	.0	19	.6	0	.0	0	.0	0	.0
CLOSTERIUM SP	1516	32.3	954	32.9	543	18.6	444	37.3	1160	49.2	973	38.5
CRUCIGENIA IRREGULARIS	0	.0	0	.0	0	.0	0	.0	0	.0	19	.7
ELAKATOTHRIX GELATINOSA	19	.4	0	.0	56	1.9	47	4.0	19	.8	19	.7
ELAKATOTHRIX VIRIDIS	0	.0	94	3.2	0	.0	0	.0	0	.0	0	.0
LAGERHEIMIA SUBSALSA	37	.8	56	1.9	150	5.1	38	3.2	94	4.0	19	.7
OOCYSTIS SP	412	8.8	599	20.6	543	18.6	189	15.9	412	17.5	243	9.6
SCENEDESMUS ARCUATUS	37	.8	19	.6	19	.6	9	.8	19	.8	19	.7
SCENEDESMUS BIJUGA	94	2.0	0	.0	37	1.3	47	4.0	56	2.4	56	2.2
SCENEDESMUS QUADRICAUDA	0	.0	0	.0	0	.0	0	.0	19	.8	0	.0
SELENASTRUM WESTII	37	.8	0	.0	37	1.3	0	.0	0	.0	0	.0
SPHAEROCYSTIS SP	150	3.2	150	5.2	94	3.2	28	2.4	56	2.4	94	3.7
TETRAEDRON CAUDATUM	0	.0	0	.0	0	.0	0	.0	0	.0	37	1.5
TETRAEDRON MINIMUM	0	.0	56	1.9	37	1.3	19	1.6	19	.8	0	.0
TETRASTRUM GLABRUM	56	1.2	0	.0	37	1.3	9	.8	0	.0	0	.0
TREUBARIA SP	0	.0	0	.0	19	.6	0	.0	0	.0	0	.0
BACILLARIOPHYTA	94	2.0	56	1.9	0	.0	19	1.6	131	5.6	37	1.5
ASTERIONELLA FORMOSA	56	1.2	37	1.3	0	.0	0	.0	75	3.2	37	1.5
CYCLOTELLA BODANICA	19	.4	19	.6	0	.0	19	1.6	19	.8	0	.0
FRAGILARIA CROTONENSIS	19	.4	0	.0	0	.0	0	.0	19	.8	0	.0
NITZSCHIA PALEA	0	.0	0	.0	0	.0	0	.0	19	.8	0	.0
CYANOPHYTA	168	3.6	131	4.5	225	7.7	38	3.2	19	.8	56	2.2
ANABAENA SP	75	1.6	56	1.9	37	1.3	9	.8	0	.0	0	.0
ANACYSTIS SP	94	2.0	75	2.6	187	6.4	28	2.4	19	.8	56	2.2
CRYPTOPHYTA	1946	41.4	655	22.6	1067	36.5	198	16.7	299	12.7	674	26.7
CHROOMONAS ACUTA	1778	37.8	599	20.6	1029	35.3	142	11.9	299	12.7	487	19.3
CRYPTOMONAS EROSA	168	3.6	56	1.9	37	1.3	57	4.8	0	.0	187	7.4
EUGLENOPHYTA	19	.4	0	.0	0	.0	0	.0	0	.0	0	.0
EUGLENA SP	19	.4	0	.0	0	.0	0	.0	0	.0	0	.0
TOTAL DENSITY	4697		2900		2919		1190		2357		2526	
TOTAL NUMBER OF TAXA	18		14		17		15		16		14	
SHANNON-WEAVER INDEX	1.80		1.94		2.00		2.06		1.73		1.91	

SRU 8.015 UNTS.

RUN COMPLETE.

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-RM/GL ANALYZED BY-MEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM INDIAN - 5 JUNE 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM INDIAN - 5 JUNE 1979.

	INDIAN							
	STN. #57		STN. #58		STN. #59		STN. **	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	707	72.7	1703	80.5	1521	77.8	318	7.5
ANKISTRODESMUS FALCATUS	66	5.3	56	2.7	94	4.8	0	.0
ANKISTRODESMUS QUATERNATUS	9	.8	0	.0	0	.0	0	.0
CHLAMYDOMONAS SP	0	.0	19	.9	0	.0	0	.0
CLOSTERIUM SP	340	27.3	730	34.5	784	40.1	37	.9
COSMARIUM SP	0	.0	19	.9	9	.5	37	.9
CRUCIGENIA IRREGULARIS	9	.8	19	.9	19	1.	0	.0
ELAKATOTHRIX GELATINOSA	28	2.3	19	.9	28	1.4	0	.0
EUASTRUM SP	0	.0	0	.0	0	.0	56	1.3
LAGERHEIMIA SUBSALSA	28	2.3	75	3.5	57	2.9	0	.0
OOCYSTIS SP	265	21.2	412	19.5	378	19.3	75	1.8
SCENEDESMUS ABUNDANS	0	.0	0	.0	0	.0	19	.4
SCENEDESMUS ARCUATUS	19	1.5	37	1.8	9	.5	0	.0
SCENEDESMUS BIJUGA	47	3.8	37	1.8	47	2.4	19	.4
SCENEDESMUS QUADRICAUDA	9	.8	19	.9	19	1.	37	.9
SELENASTRUM SP	0	.0	19	.9	0	.0	0	.0
SELENASTRUM WESTII	0	.0	0	.0	9	.5	19	.4
SPHAEROCYSTIS SP	76	6.1	150	7.1	47	2.4	0	.0
TETRAEDRON SP	0	.0	75	3.5	0	.0	0	.0
TETRAEDRON MINIMUM	9	.8	0	.0	9	.5	19	.4
TETRASTRUM GLABRUM	0	.0	19	.9	9	.5	0	.0
BACILLARIOPHYTA	38	3.0	37	1.8	76	3.9	3818	89.9
ACHNANTHES MINUTISSIMA	0	.0	0	.0	0	.0	842	19.8
ASTERIONELLA FORMOSA	28	2.3	0	.0	38	1.9	0	.0
COCCONEIS PEDICULUS	0	.0	0	.0	0	.0	880	20.7
CYCLOTELLA BODANICA	0	.0	0	.0	28	1.4	0	.0
FRAGILARIA CROTONENSIS	9	.8	0	.0	0	.0	0	.0
GOMPHONEMA OLIVACEUM	0	.0	0	.0	0	.0	487	11.5
MELOSIRA ISLANDICA	0	.0	19	.9	0	.0	0	.0
NAVICULA SP	0	.0	19	.9	0	.0	0	.0
NAVICULA CRYPTOCEPHALA	0	.0	0	.0	0	.0	1478	34.8
NITZSCHIA PALEA	0	.0	0	.0	9	.5	131	3.1
CYANOPHYTA	94	7.6	150	7.1	161	8.2	94	2.2
ANABAENA SP	38	3.0	37	1.8	47	2.4	94	2.2
ANACYSTIS SP	57	4.5	112	5.3	104	5.3	0	.0
OSCILLATORIA SP	0	.0	0	.0	9	.5	0	.0
CRYPTOPHYTA	209	16.7	206	9.7	189	9.7	19	.4
CHROOMONAS ACUTA	198	15.9	56	2.7	161	8.2	0	.0
CRYPTOMONAS EROSA	9	.8	150	7.1	28	1.4	19	.4
PYRRHOPHYTA	0	.0	19	.9	9	.5	0	.0
CERATIUM SP	0	.0	19	.9	9	.5	0	.0
TOTAL DENSITY	1248		2114		1935		4247	
TOTAL NUMBER OF TAXA	18		22		23		16	
SHANNON-WEAVER INDEX	2.22		2.20		2.12		1.93	

79/09/24. 16.52.51.
PROGRAM PHYTO2A

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-DM/DL ANALYZED BY-MEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM PIPESTONE - 4 SEPTEMBER 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM PIPESTONE - 4 SEPTEMBER 1979.

PIPESTONE

	STN. # 1		STN. # 2		STN. # 3		STN. # 4		STN. # 5	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	138	2.6	318	10.9	468	8.8	1019	12.7	767	18.8
ANKISTRODESMUS FALCATUS	0	.0	19	.6	0	.0	0	.0	112	2.8
CHLAMYDOMONAS SP	0	.0	0	.0	131	2.5	39	.5	94	2.3
CLOSTERIUM SP	28	.5	0	.0	0	.0	78	1.	0	.0
CRUCIGENIA IRREGULARIS	0	.0	0	.0	19	.4	0	.0	0	.0
CRUCIGENIA TETRAPEDIA	0	.0	19	.6	19	.4	39	.5	19	.5
ELAKATOTHRIX VIRIDIS	0	.0	0	.0	19	.4	0	.0	37	.9
EUDORINA ELEGANS	0	.0	0	.0	0	.0	39	.5	0	.0
KIRCHNERIELLA OBESA	0	.0	0	.0	19	.4	0	.0	0	.0
LAGERHEIMIA SUBSALSA	55	1.0	37	1.3	19	.4	118	1.5	37	.9
OOCYSTIS SP	0	.0	37	1.3	75	1.4	0	.0	37	.9
SCENEDESMUS BIJUGA	0	.0	187	6.4	0	.0	509	6.3	337	8.3
SCENEDESMUS QUADRICAUDA	0	.0	0	.0	37	.7	0	.0	37	.9
SCHROEDERIA SETIGERA	0	.0	0	.0	56	1.1	78	1.	0	.0
STAURASTRUM SP	0	.0	0	.0	0	.0	39	.5	0	.0
TETRAEDRON MINIMUM	28	.5	19	.6	19	.4	39	.5	56	1.4
TREUBARIA SP	28	.5	0	.0	56	1.1	39	.5	0	.0
BACILLARIOPHYTA	28	.5	0	.0	337	6.4	0	.0	19	.5
MELOSIRA BINDERANA	0	.0	0	.0	337	6.4	0	.0	0	.0
RHIZOSOLENIA LONGISETA	28	.5	0	.0	0	.0	0	.0	0	.0
SYNEDRA ULNA	0	.0	0	.0	0	.0	0	.0	19	.5
CYANOPHYTA	4862	91.2	2208	75.6	3872	73.5	6114	76.1	2395	58.7
ANACYSTIS SP	1464	27.5	580	19.9	973	18.4	1685	21.0	842	20.6
OSCILLATORIA SP	3398	63.7	1628	55.8	2919	55.1	4428	55.1	1553	38.1
CRYPTOPHYTA	0	.0	94	3.2	168	3.2	78	1.	187	4.6
CHROOMONAS ACUTA	0	.0	0	.0	37	.7	0	.0	56	1.4
CRYPTOMONAS EROSA	0	.0	94	3.2	131	2.5	78	1.	131	3.2
CHRYSOPHYTA	304	5.7	225	7.7	393	7.4	705	8.8	636	15.6
MALLOMONAS TONSURATA	28	.5	0	.0	0	.0	0	.0	0	.0
OCHROMONAS SP	276	5.2	225	7.7	393	7.4	705	8.8	618	15.1
SYNURA SP	0	.0	0	.0	0	.0	0	.0	19	.5
EUGLENOPHYTA	0	.0	37	1.3	0	.0	39	.5	0	.0
EUGLENA SP	0	.0	19	.6	0	.0	0	.0	0	.0
TRACHELOMONAS SP	0	.0	19	.6	0	.0	39	.5	0	.0
PYRRHOPHYTA	0	.0	37	1.3	37	.7	78	1.	75	1.8
PERIDINIUM SP	0	.0	37	1.3	37	.7	78	1.	75	1.8
TOTAL DENSITY	5331		2919		5295		8033		4079	
TOTAL NUMBER OF TAXA	9		13		18		16		17	
SHANNON-WEAVER INDEX	.98		1.46		1.57		1.47		1.92	

79/09/24. 16.34.58.
PROGRAM PHYTO2A

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-DM/BL ANALYZED BY-MEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM ROUND - 5 SEPTEMBER 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM ROUND - 5 SEPTEMBER 1979.

ROUND

	STN. # 6		STN. # 7		STN. # 8		STN. # 9	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	352	9.8	187	6.6	262	7.5	318	9.0
CHLAMYDOMONAS SP	0	.0	0	.0	37	1.1	0	.0
CLOSTERIUM SP	117	3.3	75	2.6	75	2.1	75	2.1
COSMARIUM SP	29	.8	0	.0	0	.0	0	.0
DICTYOSPHAERIUM PULCHELLUM	0	.0	0	.0	19	.5	0	.0
ELAKATOTHRIX VIRIDIS	0	.0	0	.0	0	.0	19	.5
QUADRIGULA SP	0	.0	37	1.3	0	.0	19	.5
SCENEDESMUS BIJUGA	88	2.4	37	1.3	75	2.1	37	1.1
SCENEDESMUS QUADRICAUDA	0	.0	0	.0	0	.0	19	.5
SPONDYLOSIUM SP	59	1.6	19	.7	37	1.1	112	3.2
STAURASTRUM SP	59	1.6	19	.7	19	.5	37	1.1
BACILLARIOPHYTA	176	4.9	56	2.0	168	4.8	94	2.6
CYCLOTELLA ANTIQUA	29	.8	0	.0	0	.0	0	.0
SYNEDRA SP	147	4.1	56	2.0	168	4.8	94	2.6
CYANOPHYTA	2085	57.7	1703	59.9	1796	51.3	2058	58.2
ANABAENA SP	0	.0	19	.7	56	1.6	94	2.6
ANACYSTIS SP	235	6.5	37	1.3	56	1.6	94	2.6
LYNGBYA SP	1850	51.2	1647	57.9	1665	47.6	1871	52.9
OSCILLATORIA SP	0	.0	0	.0	19	.5	0	.0
CRYPTOPHYTA	206	5.7	337	11.8	430	12.3	393	11.1
CHROOMONAS ACUTA	59	1.6	168	5.9	94	2.7	94	2.6
CRYPTOMONAS EROSA	147	4.1	168	5.9	337	9.6	299	8.5
CHRYSOPHYTA	734	20.3	505	17.8	786	22.5	655	18.5
DINOBRYON SP	352	9.8	243	8.6	356	10.2	337	9.5
MALLOMONAS TONSURATA	235	6.5	150	5.3	299	8.6	187	5.3
OCHROMONAS SP	147	4.1	112	3.9	131	3.7	131	3.7
EUGLENOPHYTA	59	1.6	0	.0	19	.5	0	.0
TRACHELOMONAS SP	59	1.6	0	.0	19	.5	0	.0
PYRRHOPHYTA	0	.0	56	2.0	37	1.1	19	.5
PERIDINIUM SP	0	.0	56	2.0	37	1.1	19	.5
TOTAL DENSITY	3612		2844		3499		3536	
TOTAL NUMBER OF TAXA	15		15		18		17	
SHANNON-WEAVER INDEX	1.86		1.66		1.94		1.83	

92 DATA 1,'ROUNDER'
RUN

79/09/24. 16.39.45.
PROGRAM PHYTO2A

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-DM/GL ANALYZED BY-MEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM ROUND - 5 SEPTEMBER 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM ROUND - 5 SEPTEMBER 1979.

	ROUND							
	STN. #10		STN. #11		STN. #12		STN. #13	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	374	12.9	393	9.7	150	4.3	206	8.5
CHLAMYDOMONAS SP	56	1.9	0	.0	0	.0	37	1.6
CLOSTERIUM SP	131	4.5	187	4.6	37	1.1	37	1.6
DICTYOSPHAERIUM PULCHELLUM	0	.0	0	.0	0	.0	19	.8
ELAKATOTHRIX VIRIDIS	19	.6	0	.0	0	.0	0	.0
KIRCHNERIELLA OBESA	0	.0	0	.0	19	.5	0	.0
OOCYSTIS SP	19	.6	0	.0	0	.0	0	.0
QUADRIGULA SP	0	.0	19	.5	0	.0	0	.0
SCENEDESMUS BIJUGA	56	1.9	0	.0	19	.5	19	.8
SPONDYLOSIUM SP	94	3.2	168	4.1	19	.5	75	3.1
STAURASTRUM SP	0	.0	19	.5	56	1.6	19	.8
BACILLARIOPHYTA	206	7.1	94	2.3	56	1.6	112	4.7
CYCLOTELLA ANTIQUA	19	.6	19	.5	37	1.1	0	.0
NAVICULA SP	0	.0	0	.0	0	.0	19	.8
NITZSCHIA ACICULARIS	37	1.3	0	.0	0	.0	0	.0
SYNEDRA SP	150	5.2	56	1.4	19	.5	94	3.9
SYNEDRA ULNA	0	.0	19	.5	0	.0	0	.0
CYANOPHYTA	1553	53.5	2002	49.3	2227	64.0	1347	55.8
ANABAENA SP	0	.0	19	.5	37	1.1	0	.0
ANACYSTIS SP	37	1.3	37	.9	56	1.6	56	2.3
LYNGBYA SP	1516	52.3	1946	47.9	2133	61.3	1291	53.5
CRYPTOPHYTA	112	3.9	561	13.8	337	9.7	131	5.4
CHROOMONAS ACUTA	19	.6	150	3.7	94	2.7	0	.0
CRYPTOMONAS EROSA	94	3.2	412	10.1	243	7.0	131	5.4
CHRYSOPHYTA	618	21.3	992	24.4	636	18.3	561	23.3
DINOBRYON SP	225	7.7	580	14.3	225	6.5	374	15.5
HALLOMONAS TONSURATA	150	5.2	75	1.8	94	2.7	19	.8
OCHROMONAS SP	243	8.4	337	8.3	318	9.1	168	7.0
PYRRHOPHYTA	37	1.3	19	.5	75	2.2	56	2.3
PERIDINIUM SP	37	1.3	19	.5	75	2.2	56	2.3
TOTAL DENSITY	2900		4060		3480		2414	
TOTAL NUMBER OF TAXA	17		16		16		15	
SHANNON-WEAVER INDEX	1.86		1.79		1.55		1.69	

PROJECT 557 SAMPLE TYPE-WW COLLECTED BY-DH/DL ANALYZED BY-MEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM CROOKED - 5 SEPTEMBER 1977.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM CROOKED - 5 SEPTEMBER 1977.

CROOKED

	BIN. #14		BIN. #15		BIN. #16		BIN. #17		BIN. #18		BIN. #19	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	120	16.2	90	18.6	151	21.1	170	23.9	120	19.0	57	3.4
ANKISTRODESMUS FALCATUS	0	.0	0	.0	0	.0	19	2.7	0	.0	0	.0
CHLAMYDOMONAS SP	0	.0	14	2.9	25	3.5	19	2.7	0	.0	0	.0
COSMARIUM SP	6	.7	0	.0	0	.0	0	.0	6	1.0	0	.0
DICTYOSPHAERIUM PULCHELLUM	0	.0	0	.0	0	.0	0	.0	6	1.0	0	.0
ELAKATOTHRIX GELATINOSA	0	.0	0	.0	0	.0	0	.0	0	.0	9	.6
ELAKATOTHRIX VIRIDIS	0	.0	0	.0	6	.9	0	.0	6	1.0	0	.0
LAGERHEIMIA QUADRISETA	0	.0	0	.0	0	.0	6	.9	0	.0	0	.0
LAGERHEIMIA SUBSALSA	50	6.8	24	4.9	6	.9	69	9.7	69	11.0	0	.0
OOCYSTIS SP	38	5.1	24	4.9	50	7.0	19	2.7	13	2.0	38	2.2
SCENEDESMUS BIJUGA	19	2.6	24	4.9	13	1.8	13	1.8	19	3.0	0	.0
TETRAEDRON SP	0	.0	5	1.	0	.0	0	.0	0	.0	0	.0
TETRAEDRON CAUDATUM	0	.0	0	.0	0	.0	6	.9	0	.0	9	.6
TETRAEDRON MINIMUM	6	.9	0	.0	6	.9	19	2.7	0	.0	0	.0
TETRASTRUM STAUROGENIAEFORME	0	.0	0	.0	44	6.1	0	.0	0	.0	0	.0
BACILLARIOPHYTA	6	.9	5	1.	0	.0	6	.9	0	.0	0	.0
NAVICULA RHYNCHOCEPHALA	0	.0	5	1.	0	.0	0	.0	0	.0	0	.0
NITZSCHIA ACICULARIS	0	.0	0	.0	0	.0	6	.9	0	.0	0	.0
SYNEDRA SP	6	.9	0	.0	0	.0	0	.0	0	.0	0	.0
CYANOPHYTA	271	36.8	184	38.2	271	37.7	246	34.5	258	41.0	1578	93.3
ANABAENA SP	157	21.4	85	17.6	126	17.5	126	17.7	139	22.0	0	.0
ANACYSTIS SP	25	3.4	9	2.0	19	2.6	13	1.8	13	2.0	1559	92.2
OSCILLATORIA SP	88	12.0	90	18.6	126	17.5	107	15.0	107	17.0	19	1.1
CRYPTOPHYTA	94	12.8	28	5.9	67	9.6	57	8.0	69	11.0	38	2.2
CHROOMONAS ACUTA	31	4.3	9	2.0	31	4.4	25	3.5	19	3.0	9	.6
CRYPTOMONAS EROSA	63	8.5	19	3.9	38	5.3	31	4.4	50	8.0	28	1.7
CHRYSOPHYTA	214	29.1	142	29.4	139	19.3	193	27.1	151	24.0	9	.6
DINOBRYON SP	82	11.1	47	9.8	38	5.3	101	14.2	94	15.0	0	.0
NALLOMONAS TONSURATA	0	.0	0	.0	0	.0	6	.9	0	.0	0	.0
OCHROMONAS SP	101	13.7	57	11.8	25	3.5	38	5.3	25	4.0	9	.6
UROGLENA SP	31	4.3	38	7.8	76	10.5	50	7.1	31	5.0	0	.0
EUGLENOPHYTA	0	.0	5	1.	13	1.8	0	.0	0	.0	9	.6
EUGLENA SP	0	.0	5	1.	13	1.8	0	.0	0	.0	0	.0
TRACHELOMONAS SP	0	.0	0	.0	0	.0	0	.0	0	.0	9	.6
PYRRHOPHYTA	31	4.3	28	5.9	76	10.5	25	3.5	31	5.0	0	.0
CLEHODINIUM SP	13	1.7	0	.0	25	3.5	0	.0	0	.0	0	.0
PERIDINIUM SP	19	2.6	28	5.9	50	7.0	25	3.5	31	5.0	0	.0
XANTHOPHYTA	0	.0	0	.0	0	.0	13	1.8	0	.0	0	.0
OPHIOCYTIUM CAPITATUM V LONGISPINUM	0	.0	0	.0	0	.0	13	1.8	0	.0	0	.0
TOTAL DENSITY	736		481		717		711		629		1670	
TOTAL NUMBER OF TAXA	16		16		18		20		15		9	
SHANNON-WEAVER INDEX	2.41		2.43		2.55		2.58		2.30		.42	

79/09/24. 14.22.00.
PROGRAM PHYTO2A

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-DH/GL ANALYZED BY-MEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM CROOKED - 5 SEPTEMBER 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM CROOKED - 5 SEPTEMBER 1979.

	CROOKED							
	STN. # 20		STN. # 21		STN. # 22		STN. # 23	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	104	7.5	150	5.5	206	6.6	168	8.7
CARTERIA SP	0	.0	0	.0	19	.6	0	.0
COSMARIUM SP	0	.0	0	.0	56	1.8	0	.0
CRUCIGENIA IRREGULARIS	9	.7	19	.7	0	.0	0	.0
ELAKATOTHRIX GELATINOSA	0	.0	19	.7	0	.0	56	2.9
ELAKATOTHRIX VIRIDIS	0	.0	19	.7	0	.0	0	.0
EUDORINA ELEGANS	9	.7	0	.0	0	.0	0	.0
LAGERHEIMIA SUBSALSA	0	.0	19	.7	0	.0	0	.0
OOCYSTIS SP	57	4.1	56	2.1	94	3.0	75	3.9
QUADRIGULA CLOSTERIOIDES	9	.7	0	.0	0	.0	0	.0
SCENEDESMUS BIJUGA	9	.7	0	.0	19	.6	0	.0
TETRAEDRON CAUDATUM	0	.0	0	.0	19	.6	37	1.9
TETRAEDRON MINIMUM	9	.7	0	.0	0	.0	0	.0
TETRASTRUM STAUROGENIAEFORME	0	.0	19	.7	0	.0	0	.0
BACILLARIOPHYTA	19	1.4	19	.7	19	.6	0	.0
CYCLOTELLA SP	19	1.4	0	.0	0	.0	0	.0
CYCLOTELLA BODANICA	0	.0	19	.7	19	.6	0	.0
CYANOPHYTA	1190	85.7	2414	89.0	2770	88.6	1722	89.3
ANACYSTIS SP	1190	85.7	2395	88.3	2770	88.6	1703	88.3
MERISMOPEDIA SP	0	.0	0	.0	0	.0	19	1.
OSCILLATORIA SP	0	.0	19	.7	0	.0	0	.0
CRYPTOPHYTA	38	2.7	37	1.4	37	1.2	37	1.9
CHROOMONAS ACUTA	19	1.4	19	.7	19	.6	19	1.
CRYPTOMONAS EROSA	19	1.4	19	.7	19	.6	19	1.
CHRYSOPHYTA	9	.7	94	3.4	94	3.0	0	.0
MALLOMONAS TONSURATA	0	.0	0	.0	19	.6	0	.0
OCHROMONAS SP	9	.7	94	3.4	75	2.4	0	.0
EUGLENOPHYTA	9	.7	0	.0	0	.0	0	.0
EUGLENA SP	9	.7	0	.0	0	.0	0	.0
XANTHOPHYTA	19	1.4	0	.0	0	.0	0	.0
OPHIOCYTIUM CAPITATUM V LONGISPINUM	19	1.4	0	.0	0	.0	0	.0
TOTAL DENSITY	1388		2713		3125		1927	
TOTAL NUMBER OF TAXA	13		12		11		7	
SHANNON-WEAVER INDEX	.73		.62		.59		.55	

RUN

79/09/24. 16.07.03.
PROGRAM PHYTOZA

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-DH/GL ANALYZED BY-MEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM CABLE - 6 SEPTEMBER 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM CABLE - 6 SEPTEMBER 1979.

CABLE

	STN. #24		STN. #25		STN. #26		STN. #27		STN. #28	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	9	1.0	6	.9	0	.0	0	.0	5	1.5
OOCYSTIS SP	9	1.0	6	.9	0	.0	0	.0	5	1.5
CYANOPHYTA	321	35.4	239	34.2	76	15.8	350	32.2	47	14.9
ANACYSTIS SP	151	16.7	145	20.7	52	10.9	217	20.0	28	9.0
LYNGBYA SP	170	18.8	94	13.5	24	5.0	132	12.2	19	6.0
CRYPTOPHYTA	510	56.3	321	45.9	354	74.3	642	59.1	156	49.3
CHROOMONAS ACUTA	425	46.9	252	36.0	331	69.3	567	52.2	137	43.3
CRYPTOMONAS EROSA	85	9.4	69	9.9	24	5.0	76	7.0	19	6.0
CHRYSOPHYTA	57	6.3	126	18.0	33	6.9	47	4.3	66	20.9
MALLOMONAS SP	0	.0	19	2.7	14	3.0	28	2.6	38	11.9
MALLOMONAS TONSURATA	0	.0	44	6.3	5	1.	19	1.7	19	6.0
[illegible]S SP	57	6.3	63	9.0	14	3.0	0	.0	9	3.0
PYRRHOPHYTA	0	.0	6	.9	9	2.0	28	2.6	33	10.4
GYMNODINIUM SP	0	.0	0	.0	5	1.	0	.0	0	.0
PERIDINIUM SP	0	.0	6	.9	5	1.	28	2.6	33	10.4
XANTHOPHYTA	9	1.0	0	.0	5	1.	19	1.7	9	3.0
OPHIOCYTIUM CAPITATUM V LONGISPINUM	9	1.0	0	.0	5	1.	19	1.7	9	3.0
TOTAL DENSITY	906		699		477		1086		316	
TOTAL NUMBER OF TAXA	7		9		10		8		10	
SHANNON-WEAVER INDEX	1.46		1.77		1.18		1.43		1.85	

SRU 6.412 UNITS.

RUN COMPLETE.

READY.
RUN

79/09/25. 15.47.32.
PROGRAM PHYTO2A

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-DM/GL ANALYZED BY-HEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM DEWEY - 6 SEPTEMBER 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM DEWEY - 6 SEPTEMBER 1979.

DEWEY

	STN. # 29		STN. # 30		STN. # 31		STN. # 32	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	1085	52.7	805	35.0	482	36.7	805	35.5
CHLAMYDOMONAS SP	19	.9	0	.0	66	5.0	37	1.7
CLOSTERIUM SP	37	1.8	0	.0	0	.0	19	.8
COELASTRUM SPHAERICUM	0	.0	0	.0	9	.7	0	.0
COSMARIUM SP	19	.9	0	.0	0	.0	37	1.7
CRUCIGENIA IRREGULARIS	150	7.3	75	3.3	123	9.4	112	5.0
CRUCIGENIA TETRAPEDIA	0	.0	75	3.3	19	1.4	56	2.5
ELAKATOTHRIX VIRIDIS	19	.9	0	.0	0	.0	0	.0
LAGERHEIMIA SUBSALSA	0	.0	19	.8	0	.0	0	.0
MICRACTINIUM PUSILLUM	0	.0	0	.0	9	.7	0	.0
OOCYSTIS SP	225	10.9	112	4.9	38	2.9	19	.8
QUADRIGULA CLOSTERIOIDES	37	1.8	0	.0	0	.0	37	1.7
SCENEDESMUS BIJUGA	225	10.9	299	13.0	94	7.2	225	9.9
SCENEDESMUS QUADRICAUDA	56	2.7	37	1.6	0	.0	56	2.5
STAURASTRUM SP	56	2.7	37	1.6	19	1.4	75	3.3
TETRAEDRON CAUDATUM	225	10.9	150	6.5	76	5.8	112	5.0
TETRAEDRON MINIMUM	19	.9	0	.0	19	1.4	19	.8
TETRASTRUM STAUROGENIAEFORME	0	.0	0	.0	9	.7	0	.0
BACILLARIOPHYTA	112	5.5	318	13.8	123	9.4	150	6.6
CYCLOTELLA ANTIQUA	112	5.5	318	13.8	123	9.4	150	6.6
CYANOPHYTA	655	31.8	636	27.6	397	30.2	449	19.8
ANABAENA SP	262	12.7	225	9.8	113	8.6	75	3.3
ANACYSTIS SP	393	19.1	412	17.9	236	18.0	374	16.5
OSCILLATORIA SP	0	.0	0	.0	38	2.9	0	.0
RHABDODERMA SIGMOIDEA	0	.0	0	.0	9	.7	0	.0
CRYPTOPHYTA	0	.0	337	14.6	236	18.0	655	28.9
CHROOMONAS ACUTA	0	.0	168	7.3	66	5.0	168	7.4
CRYPTOMONAS EROSA	0	.0	168	7.3	170	12.9	487	21.5
CHRYSOPHYTA	187	9.1	206	8.9	66	5.0	206	9.1
MALLOMONAS TONSURATA	0	.0	0	.0	19	1.4	0	.0
OCHROMONAS SP	187	9.1	206	8.9	47	3.6	206	9.1
EUGLENOPHYTA	19	.9	0	.0	0	.0	0	.0
TRACHELOMONAS SP	19	.9	0	.0	0	.0	0	.0
PYRRHOPHYTA	0	.0	0	.0	9	.7	0	.0
GLENODINIUM SP	0	.0	0	.0	9	.7	0	.0
TOTAL DENSITY	2058		2301		1313		2264	
TOTAL NUMBER OF TAXA	17		14		21		18	
SHANNON-WEAVER INDEX	2.43		2.39		2.63		2.48	

77/09/25. 15.30.33.
PROGRAM PHYTOZA

PROJECT 539 SAMPLE TYPE-WW COLLECTED BY-DM/DL ANALYZED BY-MEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM DEWEY - 6 SEPTEMBER 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM DEWEY - 6 SEPTEMBER 1979.

	DEWEY					
	STN. # 33		STN. # 34		STN. # 35	
	NO/ML	X OCCUR	NO/ML	X OCCUR	NO/ML	X OCCUR
CHLOROPHYTA	1029	38.2	692	47.4	599	31.7
ANKISTRODESMUS FALCATUS	37	1.4	0	.0	0	.0
CHLAMYDOMONAS SP	94	3.5	56	3.8	37	2.0
CLOSTERIUM SP	0	.0	0	.0	37	2.0
COSMARIUM SP	0	.0	19	1.3	19	1.
CRUCIGENIA IRREGULARIS	168	6.3	112	7.7	56	3.0
CRUCIGENIA TETRAPEDIA	19	.7	19	1.3	0	.0
DICTYOSPHAERIUM PULCHELLUM	0	.0	0	.0	19	1.
GONIUM SOCIALE	0	.0	19	1.3	0	.0
LAGERHEIMIA SUBSALSA	37	1.4	0	.0	0	.0
OOCYSTIS SP	0	.0	150	10.3	94	5.0
PEDIASTRUM TETRAS	0	.0	0	.0	19	1.
SCENEDESMUS BIJUGA	187	6.9	150	10.3	112	5.9
SCENEDESMUS QUADRICAUDA	37	1.4	0	.0	37	2.0
SPONDYLOSIUM SP	0	.0	37	2.6	0	.0
STAURASTRUM SP	206	7.6	75	5.1	0	.0
TETRAEDRON CAUDATUM	206	7.6	37	2.6	150	7.9
TETRAEDRON MINIMUM	19	.7	19	1.3	19	1.
TETRASTRUM STAURODENIAEFORME	19	.7	0	.0	0	.0
BACILLARIOPHYTA	281	10.4	131	9.0	112	5.9
CYCLOTELLA ANTIQUA	243	9.0	131	9.0	112	5.9
SYNEDRA SP	37	1.4	0	.0	0	.0
CYANOPHYTA	599	22.2	225	15.4	711	37.6
APHANIZOMENON SP	225	8.3	0	.0	299	15.8
ANACYSTIS SP	374	13.9	225	15.4	412	21.8
CRYPTOPHYTA	655	24.3	337	23.1	356	18.8
CHROOMONAS ACUTA	243	9.0	56	3.8	56	3.0
CRYPTOMONAS EROSA	412	15.3	281	19.2	299	15.8
CHRYSOPHYTA	112	4.2	56	3.8	56	3.0
MALLOMONAS TONSURATA	0	.0	19	1.3	0	.0
OCHROMONAS SP	112	4.2	37	2.6	56	3.0
EUGLENOPHYTA	19	.7	0	.0	0	.0
TRACHELOMONAS SP	19	.7	0	.0	0	.0
PYRRHOPHYTA	0	.0	19	1.3	56	3.0
GYMNODINIUM SP	0	.0	19	1.3	56	3.0
TOTAL DENSITY	2694		1459		1890	
TOTAL NUMBER OF TAXA	19		18		18	
SHANNON-WEAVER INDEX	2.58		2.51		2.43	

77/09/23. 15.54.38.
PROGRAM PHYTO2A

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-DM/GL ANALYZED BY-HEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM MAGICIAN - 4 SEPTEMBER 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM MAGICIAN - 4 SEPTEMBER 1979.

MAGICIAN

	STN. # 36		STN. # 37		STN. # 38		STN. # 39		STN. # 40		STN. # 41	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	150	8.3	243	11.5	243	11.5	150	6.9	281	8.2	262	8.7
CHLAMYDOMONAS SP	0	.0	0	.0	0	.0	0	.0	0	.0	19	.6
COSMARIUM SP	0	.0	0	.0	37	1.8	0	.0	19	.5	37	1.2
CRUCIGENIA IRREGULARIS	0	.0	0	.0	0	.0	19	.9	0	.0	0	.0
CRUCIGENIA TETRAPEDIA	0	.0	19	.9	19	.9	0	.0	56	1.6	0	.0
ELAKATOTHRIX VIRIDIS	0	.0	19	.9	0	.0	0	.0	0	.0	19	.6
LAGERHEIMIA QUADRISETA	112	6.3	0	.0	150	7.1	94	4.3	75	2.2	0	.0
LAGERHEIMIA SUBSALSA	0	.0	75	3.5	0	.0	0	.0	0	.0	56	1.9
OOCYSTIS SP	0	.0	56	2.7	19	.9	0	.0	0	.0	19	.6
SCENEDESMUS BIJUGA	0	.0	56	2.7	19	.9	19	.9	56	1.6	94	3.1
TETRAEDRON CAUDATUM	37	2.1	19	.9	0	.0	0	.0	19	.5	19	.6
TETRASTRUM STAUROGENIAEFORME	0	.0	0	.0	0	.0	19	.9	0	.0	0	.0
UNIDENTIFIED COCCOID GREEN COLONIES	0	.0	0	.0	0	.0	0	.0	56	1.6	0	.0
BACILLARIOPHYTA	599	33.3	487	23.0	561	26.5	861	39.7	2058	60.1	1572	52.2
CYCLOTELLA ANTIQUA	505	28.1	430	20.4	318	15.0	767	35.3	1890	55.2	1404	46.6
CYCLOTELLA BODANICA	0	.0	19	.9	0	.0	0	.0	0	.0	0	.0
FRAGILARIA CROTONENSIS	0	.0	0	.0	37	1.8	0	.0	19	.5	0	.0
NAVICULA SP	0	.0	0	.0	0	.0	19	.9	0	.0	0	.0
RHIZOSOLENIA ERIENSIS	94	5.2	37	1.8	206	9.7	75	3.4	131	3.8	168	5.6
SYNEDRA ULNA	0	.0	0	.0	0	.0	0	.0	19	.5	0	.0
CYANOPHYTA	730	40.6	954	45.1	973	46.0	561	25.9	749	21.9	674	22.4
ANACYSTIS SP	655	36.5	898	42.5	842	39.8	468	21.6	711	20.8	505	16.8
LYNGBYA SP	19	1.0	56	2.7	94	4.4	37	1.7	0	.0	131	4.3
MERISMOPEDIA SP	0	.0	0	.0	0	.0	19	.9	0	.0	37	1.2
OSCILLATORIA SP	56	3.1	0	.0	37	1.8	37	1.7	37	1.1	0	.0
CRYPTOPHYTA	112	6.3	187	8.8	150	7.1	299	13.8	94	2.7	243	8.1
CHROOMONAS ACUTA	75	4.2	75	3.5	37	1.8	75	3.4	19	.5	75	2.5
CRYPTOMONAS EROSA	37	2.1	112	5.3	112	5.3	225	10.3	75	2.2	168	5.6
CHRYSOPHYTA	187	10.4	243	11.5	168	8.0	281	12.9	225	6.6	243	8.1
DINOBRYON SP	56	3.1	112	5.3	94	4.4	150	6.9	187	5.5	168	5.6
HALLOMONAS SP	0	.0	0	.0	37	1.8	0	.0	0	.0	0	.0
HALLOMONAS TONSURATA	19	1.0	0	.0	0	.0	0	.0	37	1.1	37	1.2
OCHROMONAS SP	112	6.3	131	6.2	37	1.8	131	6.0	0	.0	19	.6
SYNURA SP	0	.0	0	.0	0	.0	0	.0	0	.0	19	.6
PYRRHOPHYTA	0	.0	0	.0	0	.0	19	.9	19	.5	0	.0
GLENODINIUM SP	0	.0	0	.0	0	.0	19	.9	19	.5	0	.0
XANTHOPHYTA	19	1.0	0	.0	19	.9	0	.0	0	.0	19	.6
OPHIOCYTIUM CAPITATUM V LONGISPINUM	19	1.0	0	.0	19	.9	0	.0	0	.0	19	.6
TOTAL DENSITY	1796		2114		2114		2170		3424		3012	
TOTAL NUMBER OF TAXA	13		15		17		16		17		19	
SHANNON-WEAVER INDEX	1.88		1.94		2.09		[illegible]					

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-[illegible] ANALYZED BY-NCD

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM MAGICIAN - 4 SEPTEMBER 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM MAGICIAN - 4 SEPTEMBER 1979.

MAGICIAN

	STN. # 42		STN. # 43		STN. # 44		STN. # 45	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	150	3.8	430	8.9	243	5.5	189	9.4
CHLAMYDOMONAS SP	0	.0	19	.4	37	.9	9	.5
COSMARIUM SP	19	.5	19	.4	0	.0	19	.9
CRUCIGENIA IRREGULARIS	0	.0	19	.4	0	.0	9	.5
CRUCIGENIA TETRAPEDIA	0	.0	19	.4	0	.0	0	.0
ELAKATOTHRIX VIRIDIS	0	.0	37	.8	0	.0	9	.5
GOLENKINIA RADIATA	0	.0	0	.0	0	.0	9	.5
KIRCHNERIELLA OBESA	0	.0	37	.8	0	.0	0	.0
LAGERHEIMIA QUADRISETA	37	.9	94	1.9	37	.9	85	4.2
LAGERHEIMIA SUBSALSA	0	.0	0	.0	37	.9	0	.0
OOCYSTIS SP	37	.9	0	.0	0	.0	0	.0
SCENEDESMUS ABUNDANS	19	.5	0	.0	0	.0	0	.0
SCENEDESMUS BIJUGA	37	.9	187	3.9	131	3.0	47	2.3
BACILLARIOPHYTA	2320	58.8	2657	54.8	2770	63.0	1247	62.0
CYCLOTELLA ANTIQUA	1946	49.3	2339	48.3	2208	50.2	1096	54.5
RHIZOSOLENIA ERIENSIS	356	9.0	318	6.6	561	12.8	151	7.5
SYNEDRA ULNA	19	.5	0	.0	0	.0	0	.0
CYANOPHYTA	805	20.4	1048	21.6	767	17.4	274	13.6
ANACYSTIS SP	636	16.1	786	16.2	674	15.3	227	11.3
LYNGBYA SP	37	.9	75	1.5	0	.0	0	.0
MERISMOPEDIA SP	37	.9	56	1.2	19	.4	19	.9
OSCILLATORIA SP	94	2.4	131	2.7	75	1.7	28	1.4
CRYPTOPHYTA	168	4.3	225	4.6	356	8.1	123	6.1
CHROOMONAS ACUTA	0	.0	94	1.9	19	.4	28	1.4
CRYPTOMONAS EROSA	168	4.3	131	2.7	337	7.7	94	4.7
CHRYSOPHYTA	468	11.8	430	8.9	225	5.1	151	7.5
DINOBRYON SP	430	10.9	281	5.8	150	3.4	94	4.7
MALLOMONAS TONSURATA	37	.9	56	1.2	56	1.3	47	2.3
OCHROMONAS SP	0	.0	94	1.9	19	.4	9	.5
EUGLENOPHYTA	0	.0	0	.0	37	.9	0	.0
EUGLENA SP	0	.0	0	.0	19	.4	0	.0
TRACHELOMONAS SP	0	.0	0	.0	19	.4	0	.0
PYRRHOPHYTA	37	.9	19	.4	0	.0	19	.9
GLENODINIUM SP	37	.9	19	.4	0	.0	19	.9
XANTHOPHYTA	0	.0	37	.8	0	.0	9	.5
OPHIOCYTIUM CAPITATUM V LONGISPINUM	0	.0	37	.8	0	.0	9	.5
TOTAL DENSITY	3948		4846		4397		2012	
TOTAL NUMBER OF TAXA	16		21		16		19	
SHANNON-WEAVER INDEX	1.71		1.93		1.68		1.77	

READY.
RUN

79/09/25. 16.09.03.
PROGRAM PHYTO2A

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-DM/GL ANALYZED BY-MEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM KEELER - 5 SEPTEMBER 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM KEELER - 5 SEPTEMBER 1979.

KEELER

	STN. # 46		STN. # 47		STN. # 48		STN. # 49		STN. # 50	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	76	27.6	52	32.4	43	9.6	9	5.1	47	19.2
ANKISTRODESMUS FALCATUS	0	.0	14	8.8	0	.0	0	.0	0	.0
CLOSTERIUM SP	5	1.7	14	8.8	0	.0	5	2.6	0	.0
ELAKATOTHRIX VIRIDIS	0	.0	0	.0	0	.0	0	.0	5	1.9
OOCYSTIS SP	5	1.7	0	.0	9	2.1	0	.0	5	1.9
PEDIASTRUM TETRAS	0	.0	0	.0	0	.0	0	.0	5	1.9
QUADRIGULA CLOSTERIOIDES	0	.0	9	5.9	0	.0	0	.0	0	.0
SCENEDESMUS BIJUGA	9	3.4	0	.0	0	.0	0	.0	5	1.9
SELENASTRUM SP	43	15.5	14	8.8	19	4.3	5	2.6	24	9.6
SPONDYLOSIUM SP	0	.0	0	.0	5	1.1	0	.0	0	.0
STAURASTRUM SP	14	5.2	0	.0	9	2.1	0	.0	5	1.9
BACILLARIOPHYTA	0	.0	0	.0	9	2.1	0	.0	19	7.7
CYCLOTELLA ANTIQUA	0	.0	0	.0	9	2.1	0	.0	19	7.7
CYANOPHYTA	113	41.4	43	26.5	52	11.7	38	20.5	76	30.8
ANABAENA SP	57	20.7	24	14.7	28	6.4	24	12.8	38	15.4
ANACYSTIS SP	57	20.7	19	11.8	24	5.3	14	7.7	33	13.5
OSCILLATORIA SP	0	.0	0	.0	0	.0	0	.0	5	1.9
CRYPTOPHYTA	24	8.6	43	26.5	288	64.9	113	61.5	76	30.8
CHROOMONAS ACUTA	0	.0	14	8.8	0	.0	0	.0	5	1.9
CRYPTOMONAS EROSA	24	8.6	28	17.6	288	64.9	113	61.5	71	28.8
CHRYSOPHYTA	33	12.1	5	2.9	38	8.5	19	10.3	9	3.8
MALLOMONAS TONSURATA	0	.0	0	.0	28	6.4	5	2.6	9	3.8
OCHROMONAS SP	33	12.1	5	2.9	9	2.1	14	7.7	0	.0
EUGLENOPHYTA	28	10.3	19	11.8	14	3.2	5	2.6	5	1.9
EUGLENA SP	5	1.7	5	2.9	5	1.1	0	.0	0	.0
TRACHELOMONAS SP	24	8.6	14	8.8	9	2.1	5	2.6	5	1.9
PYRRHOPHYTA	0	.0	0	.0	0	.0	0	.0	14	5.8
GLENODINIUM SP	0	.0	0	.0	0	.0	0	.0	14	5.8
TOTAL DENSITY	273		160		443		184		245	
TOTAL NUMBER OF TAXA	11		11		12		8		15	
SHANNON-WEAVER INDEX	2.10		2.28		1.43		1.33		2.24	

PROJECT 559 SAMPLE TYPE-WW COLLECTED BY-DH/DL ANALYZED BY-HEB

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM INDIAN - 6 SEPTEMBER 1979.

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM INDIAN - 6 SEPTEMBER 1979.

	INDIAN					
	STN. # 57		STN. # 58		STN. # 59	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	198	17.1	337	20.2	139	15.6
CLOSTERIUM SP	9	.8	0	.0	6	.7
COSMARIUM SP	9	.8	0	.0	6	.7
CRUCIGENIA IRREGULARIS	9	.8	0	.0	0	.0
ELAKATOTHRIX GELATINOSA	0	.0	19	1.1	0	.0
ELAKATOTHRIX VIRIDIS	19	1.6	0	.0	0	.0
KIRCHNERIELLA OBESA	0	.0	0	.0	6	.7
LAGERHEIMIA SUBSALSA	0	.0	19	1.1	0	.0
OOCYSTIS SP	66	5.7	206	12.4	88	9.9
PEDIASTRUM BORYANUM	9	.8	0	.0	0	.0
QUADRIGULA CLOSTERIOIDES	9	.8	19	1.1	6	.7
SCENEDESMUS BIJUGA	0	.0	0	.0	6	.7
SCENEDESMUS QUADRICAUDA	19	1.6	0	.0	0	.0
TETRAEDRON CAUDATUM	0	.0	0	.0	13	1.4
TETRASTRUM GLABRUM	47	4.1	75	4.5	6	.7
BACILLARIOPHYTA	38	3.3	75	4.5	13	1.4
CYCLOTELLA ANTIQUA	28	2.4	56	3.4	0	.0
CYCLOTELLA BODANICA	0	.0	0	.0	13	1.4
FRAGILARIA CROTONENSIS	0	.0	19	1.1	0	.0
NITZSCHIA PALEA	9	.8	0	.0	0	.0
CYANOPHYTA	822	70.7	1104	66.3	346	39.0
ANABAENA SP	38	3.3	0	.0	6	.7
ANACYSTIS SP	784	67.5	1104	66.3	340	38.3
CRYPTOPHYTA	66	5.7	112	6.7	233	26.2
CHROOMONAS ACUTA	9	.8	56	3.4	151	17.0
CRYPTOMONAS EROSA	57	4.9	56	3.4	82	9.2
CHRYSOPHYTA	19	1.6	37	2.2	126	14.2
MALLOMONAS TONSURATA	0	.0	19	1.1	13	1.4
OCHROMONAS SP	19	1.6	19	1.1	113	12.8
PYRRHOPHYTA	9	.8	0	.0	19	2.1
CERATIUM SP	9	.8	0	.0	19	2.1
XANTHOPHYTA	9	.8	0	.0	13	1.4
OPHIOCYTIUM CAPITATUM V LONGISPINUM	9	.8	0	.0	13	1.4
TOTAL DENSITY	1161		1665		887	
TOTAL NUMBER OF TAXA	18		12		17	
SHANNON-WEAVER INDEX	1.46		1.32		1.95	

TABLE . DENSITY AND PERCENT OCCURRENCE OF PHYTOPLANKTON IN SAMPLES FROM INDIAN - 6 SEPTEMBER 1979.

INDIAN

	STN. # 51		STN. # 52		STN. # 53		STN. # 54		STN. # 55		STN. # 56	
	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR	NO/ML	% OCCUR
CHLOROPHYTA	57	11.9	243	14.8	430	23.7	142	11.4	145	20.5	170	17.5
CLOSTERIUM SP	0	.0	19	1.1	37	2.1	19	1.5	19	2.7	9	1.
CRUCIGENIA TETRAPEDIA	0	.0	0	.0	0	.0	0	.0	6	.9	0	.0
DICTYOSPHAERIUM PULCHELLUM	0	.0	0	.0	0	.0	0	.0	6	.9	0	.0
ELAKATOTHRIX GELATINOSA	0	.0	0	.0	0	.0	0	.0	0	.0	19	1.9
ELAKATOTHRIX VIRIDIS	0	.0	0	.0	37	2.1	19	1.5	0	.0	0	.0
KIRCHNERIELLA OBESA	5	1.	0	.0	0	.0	0	.0	0	.0	0	.0
LAGERHEIMIA QUADRISETA	0	.0	0	.0	0	.0	0	.0	0	.0	9	1.
LAGERHEIMIA SUBSALSA	0	.0	19	1.1	0	.0	9	.8	0	.0	0	.0
OOCYSTIS SP	43	8.9	168	10.2	168	9.3	57	4.5	44	6.3	57	5.8
PEDIASTRUM BORYANUM	0	.0	0	.0	0	.0	0	.0	0	.0	19	1.9
SCENEDESMUS ABUNDANS	0	.0	0	.0	0	.0	9	.8	6	.9	9	1.
SCENEDESMUS DIJUGA	0	.0	0	.0	56	3.1	9	.8	25	3.6	19	1.9
SCENEDESMUS QUADRICAUDA	0	.0	19	1.1	19	1.0	0	.0	6	.9	19	1.9
SCHROEDERIA SETIGERA	5	1.	0	.0	0	.0	0	.0	0	.0	0	.0
SELENASTRUM SP	0	.0	0	.0	0	.0	9	.8	0	.0	9	1.
TETRAEDRON SP	0	.0	0	.0	19	1.0	0	.0	0	.0	0	.0
TETRAEDRON CAUDATUM	0	.0	0	.0	19	1.0	0	.0	0	.0	0	.0
TETRAEDRON MINIMUM	5	1.	0	.0	19	1.0	0	.0	0	.0	0	.0
TETRASTRUM GLABRUM	0	.0	19	1.1	0	.0	0	.0	25	3.6	0	.0
TETRASTRUM STAURODENIAEFORME	0	.0	0	.0	56	3.1	9	.8	0	.0	0	.0
TREUBARIA SP	0	.0	0	.0	0	.0	0	.0	6	.9	0	.0
BACILLARIOPHYTA	47	9.9	75	4.5	37	2.1	85	6.8	101	14.3	142	14.6
CYCLOTELLA ANTIQUA	28	5.9	37	2.3	37	2.1	47	3.8	50	7.1	104	10.7
CYCLOTELLA BODANICA	5	1.	0	.0	0	.0	28	2.3	44	6.3	9	1.
FRAGILARIA SP	0	.0	0	.0	0	.0	0	.0	0	.0	9	1.
FRAGILARIA CROTONENSIS	0	.0	37	2.3	0	.0	9	.8	0	.0	9	1.
MELOSIRA ISLANDICA	9	2.0	0	.0	0	.0	0	.0	0	.0	0	.0
NITZSCHIA PALEA	5	1.	0	.0	0	.0	0	.0	0	.0	0	.0
SYNEDRA ULNA	0	.0	0	.0	0	.0	0	.0	6	.9	9	1.
CYANOPHYTA	274	57.4	861	52.3	1123	61.9	822	65.9	277	39.3	397	40.8
ANABAENA SP	0	.0	0	.0	0	.0	28	2.3	6	.9	19	1.9
ANACYSTIS SP	274	57.4	861	52.3	1085	59.8	794	63.6	271	38.4	378	38.8
OSCILLATORIA SP	0	.0	0	.0	37	2.1	0	.0	0	.0	0	.0
CRYPTOPHYTA	66	13.9	393	23.9	131	7.2	94	7.6	94	13.4	142	14.6
CHROOMONAS ACUTA	14	3.0	206	12.5	37	2.1	66	5.3	50	7.1	38	3.9
CRYPTOMONAS EROSA	52	10.9	187	11.4	94	5.2	28	2.3	44	6.3	104	10.7
CHRYSOPHYTA	19	4.0	75	4.5	94	5.2	104	8.3	63	8.9	94	9.7
DINOBRYON SP	0	.0	0	.0	19	1.0	0	.0	0	.0	0	.0
HALLOMONAS SP	0	.0	0	.0	0	.0	9	.8	6	.9	9	1.
HALLOMONAS TONSURATA	9	2.0	0	.0	19	1.0	0	.0	19	2.7	9	1.
OCHROMONAS SP	9	2.0	75	4.5	56	3.1	94	7.6	38	5.4	76	7.8
EUGLENOPHYTA	5	1.	0	.0	0	.0	0	.0	6	.9	0	.0
EUGLENA SP	5	1.	0	.0	0	.0	0	.0	6	.9	0	.0
PYRRHOPHYTA	9	2.0	0	.0	0	.0	0	.0	0	.0	19	1.9
CERATIUM SP	5	1.	0	.0	0	.0	0	.0	0	.0	0	.0
GLENODINIUM SP	0	.0	0	.0	0	.0	0	.0	0	.0	19	1.9
PERIDINIUM SP	5	1.	0	.0	0	.0	0	.0	0	.0	0	.0
XANTHOPHYTA	0	.0	0	.0	0	.0	0	.0	19	2.7	9	1.
OPHIOCYTIUM CAPITATUM V LONGISPINUM	0	.0	0	.0	0	.0	0	.0	19	2.7	9	1.
TOTAL DENSITY	477		1646		1815		1246		705		972	
TOTAL NUMBER OF TAXA	16		11		17		17		21		23	
SHANNON-WEAVER INDEX	1.65		1.60		1.69		1.55		2.33		2.29	

APPENDIX J

TERRESTRIAL BIOTA DATA

Table J-1. Endangered and threatened species of plants, Berrien County, Michigan (Beaman u.p.).

Scientific Name	Common Name	Status[a] MI	Status[a] Fed.	Plant[b] Characteristics
Aristolochia serpentaria	Virginia snakeroot	T		PNF
Baptisia leucantha	Prairie false indigo	T		PNF
Carex crus-corui	Raven's-foot sedge	T		PNGl
Carex seorsa	Weak stellate sedge	T		PNGl
Castanea dentata	American chestnut	E		Ntr
Cirsium pitcheri	Pitcher's thistle	T	T	BNF
Coreopsis palmata	Stiff tickseed	T		PNF
Cypripedium candidum	White lady slipper	T	T	PNF
Diarrhena americana	No common name	T		PNG
Eryngium yuccifolium	Rattlesnake master	T		PNF
Gentiana saponaria	Soapwort gentian	E		PNF
Gymnocladus dioica	Kentucky coffee tree	T		Ntr
Habenaria ciliaris	Orange finged orchid	T		PNF
Hibiscus palustris	Swamp rose mallow	T		PNF
Isotria medeoloides	Smaller whorled pogonia	E	E	PNF
Ludwigia alternifolia	Seedbox	T		PNEF
Lycopodium adpressum	Club-moss	T		PNC
Lycopodium habereri	Club-moss	T		PNC
Polemonium reptans	Jacob's ladder	T		PNF
Populus heterophylla	Swamp cottonwood	T		NTr
Sabatia angularis	Rose-pink	T		ANF
Silphium integrifolium	Rosinweed	T	E	PNF
Silphium laciniatum	Compass plant	T		PNF

Table J-1. Endangered and threatened species of plants, Berrien County (concluded).

Scientific Name	Common Name	Status[a] MI	Status[a] Fed.	Plant[b] Characteristics
Silphium perfoliatum	Cup plant	T		PNF
Tipularia discolor	Cranefly orchid	T		PNF
Trillium recurvatum	Prairie trillium	T		PNF
Trillium sessile	Toadshade	T		PNF
Trillium undulatum	Painted trillium	T		PNF
Triplasis purpurea	Sand grass	T		ANG
Uniola latifolia	Wild oats	T		PNG
Valerianella chenopodifolia	Corn salad	T		ANF
Zizania aquatica	Wild rice	T		ANG

a Key:

E = endangered
T = threatened

b Key:

A = annual
B = biennial
C = clubmoss
F = forb
E = emergent
G = grass
Gl = grass-like
N = native
P = perennial
Tr = tree

Table J-2. Endangered and threatened species of plants, Cass County, Michigan (Beaman, u.p.).

Scientific Name	Common Name	Status[a] MI	Status[a] Fed.	Plant[b] Characteristics
Baptisia leucantha	Prairie false indigo	T		PNF
Berula pusilla	Water parsnip	T		PIF
Cirsium hillii	Hill's thistle	T		PNF
Commelina erecta	Dayflower	Pr-ext		PNF
Coreopsis palmata	Stiff tickweed	T		PNF
Cuscuta glomerata	Dodder	T		PNP2F
Digitaria filiformis	Slender crabgrass	Pr-ext		PNG
Dryopteris celsa	Log fern	T		PNF3
Eleocharis melanocarpa	Black-fruited spike-rush	T		PNG1
Eryngium yuccifolium	Rattlesnake master	T		PNF
Fimbristylis puberula	No common name	T		PNG1
Fuirena squarrosa	Umbrella-grass	T		PNG1
Habenaria ciliaris	Orange fringed orchid	T		PNF
Habenaria flava	Tubercled orchid	R	T	PNF
Hemicarpha micrantha	No common name	T		ANG1
Ludwigia alternifolia	Seedbox	T		PNEF
Panax quinquefolius	Ginseng	T	T	PNF
Panicum verrucosum	Warty panic-grass	T		ANG
Phlox maculata	Wild sweet william	T		PNF
Polemonium reptans	Jacob's ladder	T		PNF
Polygonum careyi	No common name	T		ANF
Potamogeton pulcher	Spotted pondweed	T		PNS3F
Silphium integrifolium	Rosinweed	T	E	PNF

Table J-2. Endangered and threatened species of plants, Cass County (concluded).

Scientific Name	Common Name	Status[a] MI	Status[a] Fed.	Plant[b] Characteristics
Solidago remota	Goldenrod	T		PNF
Triphora trianthophora	Nodding pogonia	T		PNF

a Key:
Pr-ext = probably extinct
R = rare
T = threatened

b Key:

A = annual	G1 = grass-like
E = emergent	I = introduced
F = forb	N = native
F3 = fern	P = perennial
G = grass	P2 = parasitic
	S3 = submerged

Table J-3. Endangered and threatened species of plants, Van Buren County, Michigan (Beaman u.p.).

Scientific Name	Common Name	Status[a] MI	Fed.	Plant[b] Characteristi
Aristida tuberculosa	Triple-awned grass	Pr-ext		ANG
Aristolochia serpentaria	Virginia snakeroot	T		PNF
Aster sericeus	Silky aster	T		PNF
Baptisia leucantha	Prairie false indigo	T		PNF
Carex seorsa	Weak stellate sedge	T		PNG1
Castanea dentata	American chestnut	E		NTr
Cirsium pitcheri	Pitcher's thistle	T	T	BNF
Eleocharis melanocarpa	Black-fruited spike rush	T		PNG1
Eryngium yuccifolium	Rattlesnake master	T		PNF
Fuirena squarrosa	Umbrella-grass	Pr-ext		PNG1
Gymnocladus dioica	Kentucky coffee tree	T		NTr
Habenaria ciliaris	Orange fringed orchid	T		PNF
Habenaria flava	Tubercled orchid	R	T	PNF
Helianthus microcephalus	Small wood sunflower	T		PNF
Hemicarpha micrantha	No common name	T		ANG1
Juncus scirpoides	No common name	T		PNG1
Lycopodium sp. nov.	Club-moss	E		PNC
Panax quinquefolius	Ginseng	T	T	PNF
Petalostemum purpureum	Red prairie clover	E		PNF
Potamogeton lateralis	Opposite leaved pondweed	Pr-ext		PNS3F
Psilocarya scirpoides	Bald rush	T		ANG1
Sabatia angularis	Rose-pink	T		ANF
Scleria pauciflora	Papillose nut-rush	T		PNG1

Table J-3. Endangered and threatened species of plants, Van Buren County (concluded).

Scientific Name	Common Name	Status[a] MI	Status[a] Fed.	Plant[b] Characteristics
Silphium integrifolium	Rosinweed	T	E	PNF
Triphora trianthophora	Nodding pogonia	T		PNF
Woodwardia areolata	Netted chain fern	E		PNF3

a Key:

E = endangered
Pr-ext = probably extinct
R = rare
T = threatened

b Key:

A = annual
B = biennial
C = clubmoss
F = forb
F3 = Fern
G = grass
Gl = grass-like
N = native
P = perennial
S3 = submerged
Tr = tree

APPENDIX K

RECREATION PARTICIPATION DATA

Table K-1. Participation rates in recreational activities of residents in Berrien County, Cass County, and Van Buren County, and the State of Michigan (MDNR 1978).

Recreational Activity	Three-county Area Rank	Three-county Area Participations (1,000)	Three-county Area Participations Per Person	State of Michigan Rank	State of Michigan Participations (1,000)	State of Michigan Participations Per Person
Competitive sports	1	5,658	20.6	1	197,845	21.8
Land-mobile	2	5,193	18.9	2	155,679	17.2
Miscellaneous	3	3,051	11.1	4	100,346	11.1
Swimming	4	2,563	9.3	3	105,127	11.6
Fishing	5	1,947	7.1	7	45,162	5.0
Foot-related	6	1,939	7.0	5	90,425	10.0
Other games	7	1,573	5.7	13	29,346	3.2
On-foot activities	8	1,099	4.0	6	52,283	5.8
Winter-related	9	907	3.3	10	36,283	4.0
Viewing competitive events	10	907	3.2	14	28,345	3.1
Visiting sites	11	788	2.9	9	38,409	4.2
Attending meetings	12	746	2.7	11	33,092	3.7
Shooting sports	13	717	2.6	15	27,508	2.8
Viewing non-competitive sports	14	616	2.4	8	39,914	4.4
Camping	15	644	2.3	16	22,949	2.5
Watercraft	16	508	1.8	12	30,223	3.3
Nature-related	17	391	1.4	17	17,025	1.9
Arts and crafts	18	107	0.4	18	6,046	0.7

APPENDIX L

METHODOLOGY FOR THE

COUNTY DEBT TO PER CAPITA INCOME RATIOS

Table L-1. Methodology for the calculation of county debt to per capita income ratios.

County	Debt ($1000)	÷	Population	=	Debt per Capita ($)	÷	Per Capita Personal Income ($)	=	Debt/Per Capita Personal Income
Berrien	57,920		171,276		338		9,156		3.7%
Cass	1,335		49,499		27		7,169		0.4%
Van Buren	2,045		66,814		31		8,316		0.4%

APPENDIX M

RESIDENTIAL FUEL REQUIREMENTS IN MICHIGAN

Table M-1. Average energy consumption for single-family homes in Michigan (Michigan Department of Commerce 1978).

Fuel Type (Unit)	Btu Content Per Unit	Amount Used Per Home Per Year	Price Per Unit (1977 $)	Cost Per Home Per Year ($)	Cost Per Million Btu ($)
Fuel oil (gallons)	138,800/gal	1,441 gal	0.4681	674.50	3.37
Natural gas (million cubic feet)	1.021 X 10^6/mcf	195.9 mcf	1.98	387.90	1.94
Electricity (kilowatt-hours)	3,412/kwh	38,101 kwh	0.365	1,390.70	10.70
Propane/butane (gallons)	95,500/gal	2,095 gal	0.41	859.00	4.29
Coal (tons)	23.65 X 10^6/ton	8.46 tons	25.00	211.50	1.05

APPENDIX N

ANALYSIS OF GRANT ELIGIBILITY

Table N-1. Governmental grants and local shares of costs for Alternative 2 (costs are stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Components (eligible)	Total Capital	Total O&M (Local Cost)	USEPA Grant		USEPA Grant + 5% State Grant		
			Federal	Local	Federal	State	Local
Collection	18,913.9	186.2	16,076.8 (85%)	2,837.1 (15%)	16,076.8 (85%)	945.7 (5%)	1,891.4 (10%)
Conveyance	1,962.8	10.6	1,472.1 (75%)	490.7 (25%)	1,472.1 (75%)	98.1 (5%)	392.6 (20%)
Treatment plant	3,229.5	64.8	2,422.1 (75%)	807.4 (25%)	2,422.1 (75%)	161.5 (5%)	645.9 (20%)
Total	24,106.2	261.6	19,971.0	4,135.2	19,971.0	1,205.3	2,929.9

Table N-2. Governmental grants and local shares of costs for Alternative 3 (costs are stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Components (eligible)	Total Capital	Total O&M (Local Cost)	USEPA Grant		USEPA Grant + 5% State Grant		
			Federal	Local	Federal	State	Local
Collection	18,913.9	186.2	16,076.8 (85%)	2,837.1 (15%)	16,076.8 (85%)	945.7 (5%)	1,891.4 (10%)
Conveyance	1,687.7	11.4	1,265.8 (75%)	421.9 (25%)	1,265.8 (75%)	84.4 (5%)	337.5 (20%)
Treatment plant	3,218.0	88.3	2,735.3 (85%)	482.7 (15%)	2,735.3 (85%)	160.9 (5%)	321.8 (10%)
Total	23,819.6	285.9	20,077.9	3,741.7	20,077.9	1,191.0	2,550.7

Table N-3. Governmental grants and local shares of costs for Alternative 4 (costs are stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Components (eligible)	Total Capital	Total O&M (Local Cost)	USEPA Grant		USEPA Grant + 5% State Grant		
			Federal	Local	Federal	State	Local
Collection	18,913.9	186.2	16,076.8 (85%)	2,837.1 (15%)	16,076.8 (85%)	945.7 (5%)	1,891.4 (10%)
Conveyance	3,041.9	16.7	2,281.4 (75%)	760.5 (25%)	2,281.4 (75%)	152.1 (5%)	608.4 (20%)
Treatment plant	2,618.0	49.5	1,963.5 (75%)	654.5 (25%)	1,963.5 (75%)	130.9 (5%)	523.6 (20%)
Total	24,573.8	252.4	20,321.7	4,252.1	20,321.7	1,228.7	3,023.4

Table N-4. Governmental grants and local shares of costs for Alternative 5A (costs are stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Components (eligible)	Total Capital	Total O&M (Local Cost)	USEPA Grant		USEPA Grant + 5% State Grant		
			Federal	Local	Federal	State	Local
Collection	18,913.9	186.2	16,076.8 (85%)	2,837.1 (15%)	16,076.8 (85%)	945.7 (5%)	1,891.4 (10%)
Conveyance	2,082.3	11.3	1,561.7 (75%)	520.6 (25%)	1,561.7 (75%)	104.1 (5%)	416.5 (20%)
Treatment plant	2,618.0	49.5	1,963.5 (75%)	654.5 (75%)	1,963.5 (75%)	130.9 (5%)	523.6 (20%)
Total	23,614.2	247.0	19,602.0	4,012.2	19,602.0	1,180.7	2,831.5

Table N-5. Governmental grants and local shares of costs for Alternative 5B (costs are stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Components	Total Capital	Total O&M (Local Cost)	USEPA Grant		USEPA Grant + 5% State Grant		
			Federal	Local	Federal	State	Local
Collection -		217.4					
eligible	18,043.2		13,532.4 (75%)	4,510.8 (25%)	13,532.4 (75%)	902.2 (5%)	3,608.6 (25%)
ineligible	2,304.6		--	2,304.6 (100%)	--	--	2,304.6 (100%)
homeowner-ineligible	4,550.6		--	4,550.6 (100%)	--	--	4,550.6 (100%)
Conveyance -		11.3					
eligible	2,082.3		1,561.7 (75%)	520.6 (25%)	1,561.7 (75%)	104.1 (5%)	416.5 (20%)
Treatment plant -		49.5					
eligible	2,618.0		1,963.5 (75%)	654.5 (25%)	1,963.5 (75%)	130.9 (5%)	523.6 (20%)
Total	25,598.7	278.2	17,057.6	12,541.1	17,057.6	1,137.2	11,403.9

Table N-6. Governmental grants and local shares of costs for Alternative 6 (costs are stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Components (eligible)	Total Capital	Total O&M (Local Cost)	USEPA Grant		USEPA Grant + 5% State Grant		
			Federal	Local	Federal	State	Local
Collection	18,913.9	186.2	16,076.8 (85%)	2,837.1 (15%)	16,076.8 (85%)	945.7 (5%)	1,891.4 (10%
Conveyance	2,360.9	10.5	1,770.7 (75%)	590.2 (25%)	1,770.7 (75%)	118.0 (5%)	472.2 (20%)
Treatment plant	2,212.6	97.6	1,659.5 (75%)	553.1 (25%)	1,659.5 (75%)	110.6 (5%)	442.5 (20%)
Total	23,487.4	294.3	19,507.0	3,980.4	19,507.0	1,174.3	2,806.1

Table N-7. Governmental grants and local shares of costs for Alternative 7 (costs are stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Components (eligible)	Total Capital	Total O&M (Local Cost)	USEPA Grant		USEPA Grant & 5% State Grant		
			Federal	Local	Federal	State	Local
Collection	18,913.9	186.2	16,076.8 (85%)	2,837.1 (15%)	16,076.8 (85%)	945.7 (5%)	1,891.4 (10%)
Conveyance	3,543.3	14.9	2,657.5 (75%)	885.8 (25%)	2,657.5 (75%)	177.2 (5%)	708.6 (20%)
Treatment plant	--	265.0	--	--	--	--	--
Total	22,457.2	466.1	18,734.3	3,722.9	18,734.3	1,122.9	2,600.0

Table N-8. Governmental grants and local shares of costs for Alternative 8A (costs are stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Components (eligible)	Total Capital	Total O&M (Local Cost)	USEPA Grant		USEPA Grant + 5% State Grant		
			Federal	Local	Federal	State	Local
Cluster systems	7,675.6	129.3	6,524.3 (85%)	1,151.3 (15%)	6,524.3 (85%)	383.7 (5%)	767.6 (10%)
On-site systems	2,008.2	56.9	1,707.0 (85%)	301.2 (15%)	1,707.0 (85%)	100.4 (5%)	200.8 (10%)
Administration	134.6	94.0	100.9 (75%)	33.7 (25%)	100.9 (75%)	6.8 (5%)	26.9 (20%)
Total	9,818.4	280.2	8,332.2	1,486.2	8,332.2	490.9	995.3

Table N-9. Governmental grants and local shares of costs for Alternative 8B (costs are stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Components (eligible)	Total Capital	Total O&M (Local Cost)	USEPA Grant		USEPA Grant + 5% State Grant		
			Federal	Local	Federal	State	Local
Cluster systems	7,636.0	114.8	6,490.6 (85%)	1,145.4 (15%)	6,490.6 (85%)	381.8 (5%)	763.6 (10%)
On-site systems	2,008.1	56.9	1,706.9 (85%)	301.2 (15%)	1,706.9 (85%)	100.4 (5%)	200.8 (10%)
Administration	134.6	94.0	100.9 (75%)	33.7 (25%)	100.9 (75%)	6.8 (5%)	26.9 (20%)
Total	9,778.7	265.7	8,298.4	1,480.3	8,298.4	489.0	991.3

Table N-10. Governmental grants and local shares of costs for Alternative 9 (costs are stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Components	Total Capital	Total O&M (Local Cost)	USEPA Grant		USEPA Grant + 5% State Grant		
			Federal	Local	Federal	State	Local
On-site - eligible	3,226.0	130.0	2,742.1 (85%)	483.9 (15%)	2,742.1 (85%)	161.3 (5%)	322.6 (10%)
Homeowner - ineligible	484.6	--	--	484.6 (100%)	--	--	484.6 (100%)
Administration - eligible	134.6	94.0	100.9 (75%)	33.7 (25%)	100.9 (75%)	6.8 (5%)	26.9 (20%)
Total	3,845.2	224.0	2,843.0	1,002.2	2,843.0	168.1	834.1

Table N-11. Annual residential user costs for USEPA and local distribution of costs.

Alternative	Cost ($1,000x) Capital Cost	Federal Share	Local Share	Annual Equivalent of Local Share (0.09903)[a]	Annual Operation and Maintenance	Annual Cost to Local Residents	Number of Residents (1981)	Monthly Cost per Residence	Annual Cost per Residence
2	24,106.2	19,971.0	4,135.2	409.5	261.7	671.2	2,535	22.06	264.77
3	23,819.6	20,077.9	3,741.7	370.5	285.9	656.4	2,535	21.58	258.95
4	24,573.7	20,321.7	4,252.0	421.1	252.5	673.6	2,535	22.14	265.69
5A	23,614.2	19,602.0	4,012.2	397.3	247.0	644.3	2,535	21.18	254.18
5B	29,598.6	17,057.6	12,541.0	1,241.9	278.2	1,520.1	2,535	49.97	599.66
6	23,487.4	19,506.9	3,980.5	394.2	294.4	688.6	2,535	22.63	271.62
7	22,457.2	18,734.3	3,722.9	368.7	466.1	834.8	2,535	27.44	329.30
8A	9,683.8	8,231.2	1,452.6	143.8	280.2	424.0	2,535	13.94	167.29
8B	9,644.2	8,197.6	1,446.6	143.3	265.7	409.0	2,535	13.45	161.34
9	3,710.6	2,742.1	968.4	95.9	224.0	319.9	2,535	10.52	126.21

[a]Local share is amortized at 7-5/8% interest at 20 years.

Table N-12. Annual residential user costs without any governmental grants.

Alternative	Cost ($1,000x) Capital Cost (local cost)	Annual Equivalent of Local Cost (0.09903)[a]	Annual Operation and Maintenance	Annual Cost to Local Residents	Number of Residences (1981)	Monthly Cost per Residence	Annual Cost per Residence
2	24,106.2	2,387.2	261.7	2,648.9	2,535	87.8	1,044.93
3	23,819.6	2,358.9	285.9	2,644.8	2,535	86.94	1,043.29
4	24,573.7	2,433.5	252.5	2,686.0	2,535	88.30	1,059.58
5A	23,614.2	2,338.6	247.0	2,585.6	2,535	85.00	1,020.00
5B	29,598.6	2,931.1	278.2	3,209.3	2,535	105.50	1,266.02
6	23,487.4	2,326.0	294.4	2,620.4	2,535	86.14	1,033.69
7	22,457.2	2,223.9	466.1	2,690.0	2,535	88.43	1,061.16
8A	9,683.8	959.0	280.2	1,239.2	2,535	40.74	488.83
8B	9,644.2	955.1	265.7	1,220.8	2,535	40.13	481.56
9	3,710.6	367.5	224.0	591.5	2,535	19.44	233.32

[a]Local cost is amortized at 7-5/8% interest over 20 years.

APPENDIX O

PERTINENT CORRESPONDENCE

City of Dowagiac

(Doe-Wah-Jack)

241 South Front Street P. O. Box 430 Dowagiac, Michigan 49047 616-782-2195

January 19, 1982

RECEIVED JAN 25 1982

J. P. Singh
Wapora, Inc.
35 East Wacker Drive, Suite #490
Chicago, IL 60601

RE: Water/Sewer Rates

Dear Mr. Singh:

Enclosed is a copy of the City's latest Water and Sewer Rates ordinance. Section 2.124 provides you with definitions concerning the various charges made; however, those charges which would be applicable to customers outside the corporate limits of Dowagiac are indicated in Section 2.125 which shows a consumption charge of $.11 per 100 gallons.

At the present time, the City's Sewer Fund is operating in the red which indicates that at some time in the future, a rate increase is very likely. At this time there are no figures available for such an increase. This rate increase, as well as future rates, would be dependent upon a large area such as the Indian Lake/Sister Lakes Area hooking into our current Wastewater Treatment Plant System.

If you should have any questions concerning this matter, please do not hesitate to contact my office.

Sincerely yours,

David A. Pilot

David A. Pilot
Director of Finance

DAP/fv

Enclosures

c: City Manager

CHAPTER 24 WATER AND SEWER RATES

2.121. Definitions. Unless the context indicates otherwise, the meanings of terms used in this Chapter shall be as follows:

(1) "Premises" shall mean each lot or parcel of land, building or premises having any connection to the Water Distribution System of the City, or the Sewage Disposal System of the City.

(2) "Person" shall mean any individual, firm, association, public or private corporation or public agency or instrumentality.

(3) "Department" shall mean the City Department of Engineering.

2.122. Fixing Rates. The rates to be charged for water and sewage disposal service furnished by the System shall be as prescribed by the City Council, and until otherwise provided, shall be at the rates and shall be collected as prescribed in this Chapter.

2.123. Water Rates. Charges for water service to each premises connected to the water system of the City of Dowagiac shall be measured by a meter. All metered water shall be charged at a two-part rate consisting of a "Readiness to Serve Charge" plus a "Commodity Charge".

(1) Readiness to Serve Charge. There shall be charged for water service within the City of Dowagiac a "Readiness to Serve" charge in the following amounts:

Meter Size	Residential Monthly Charge	Commercial, Industrial Gov't. Monthly Charge
5/8	$ 3.04	$ 4.39
3/4	4.39	5.74
1	5.74	7.09
1-1/2	9.65	11.00
2	16.20	17.55

Section 2.123 amended by Ordinance adopted 9/19/1977.
Section 2.123 amended, Ord. No. 79-4, 7/2/1979.

Meter Size	Residential Monthly Charge	Commercial, Industrial Gov't. Monthly Charge
3	$29.02	$30.37
4	42.52	43.87
6	64.46	65.81
8	86.73	88.08

Outside the corporate limits of the City of Dowagiac the "Readiness to Serve" charge shall be 200% of the rate as established for use within the corporate limits of the City.

When more than one meter is used, the "Readiness to Serve" charge shall be a total of the charges for each meter times the number of meters.

When a single large meter is used to serve Apartment Houses or Multiple Dwellings, a charge in addition to the charge for the meter size shall be applied and the charge shall be one unit plus 20% of one unit for all units over 4. Any self-contained living quarters for a single family is a Unit.

The "Readiness to Serve" charge covers the cost necessary to keep the water system in good operating condition and other overhead costs and is the amount of the minimum bill.

(2) Commodity Charge. There shall be levied a commodity charge inside the corporate limits of the City of Dowagiac in the following amounts:

Gallon Limits	Residential	Comm. -Ind. -Gov't.
0 to 10,000 gallons	.094¢ per 100 gal.	.135¢ per 100 gal.
10,001 to 40,000 gallons	.078¢ per 100 gal.	.078¢ per 100 gal.
40,001 to 55,000 gallons	.057¢ per 100 gal.	.061¢ per 100 gal.
55,001 to 75,000 gallons	.050¢ per 100 gal.	.050¢ per 100 gal.
All over 75,000 gallons	.043¢ per 100 gal.	.043¢ per 100 gal.

Outside the corporate limits of the City of Dowagiac, the "Commodity Charge" shall be 200% of the rate as established for the use within the corporate limits of the City.

(3) Fire Protection Rates. The charges for automatic sprinkler services or hose connections for fire protection purposes only shall be:

4 inch Meter	$ 8.50 per month
6 inch Meter	11.00 per month
8 inch Meter	13.50 per month

(4) Rates Covering Water Main Tapping. All service taps to water mains shall be made by the Water Department for which the following charges will be made:

3/4 inch tap	$325.00
1 inch tap	375.00

The connection charge shall include the cost of material and labor required to install the connection from the main to the property line but no further than sixty-six (66) feet. Any extension beyond sixty-six (66) feet shall be at the rate of the actual cost of material and labor plus thirty-five (35%) per cent.

Larger services shall be charged on the basis of actual cost of labor and materials, plus thirty-five (35%) per cent.

The water meter shall be the property of the City of Dowagiac.

(5) Turn-on Charge. If service is disconnected, payment plus a reconnection charge of $10.00 must be received by 3:00 p.m. in order for such service to be restored that same day. For payments received after 3:00 p.m. on any City working day, such utility services disconnected will remain so until the following working day. If service is to be restored after 3:00 p.m. on a working day, or during a holiday or weekend, the reconnection charge will be $25.00 in addition to past due utility account charges.

(6) HYDRANT RENTAL

For water used through fire hydrants and for the availability of water for fire protection, the City shall pay from its General Funds or from the proceeds of taxes which the City may levy, the sum of $8.00 per hydrant per year.

(7) CAPITAL CHARGE (Water Connection)

There is hereby imposed a capital charge of two hundred seventy-five ($275.00) dollars per unit. The capital charge shall not be applicable to residences, businesses and buildings connected to existing municipally-owned and operated water systems.

A unit shall be regarded as a normal house service connection for a single family residence.

Based upon this unit charge, charges for other types of new connections are as follows, and in no instance shall be less than two hundred seventy-five ($275.00) dollars.

USAGE	UNIT FACTOR
Auto Dealers - New Cars	1 Unit plus 15% of a Unit per stall
Bars	1½¢ per sq. foot plus 5% of a Unit per seat
Barber Shops	1 Unit plus 15% of a Unit per chair
Bowling Alleys, with bar & lunch	1 Unit plus 20% of a Unit per lane
Bowling Alleys only	1 Unit plus 8% of a Unit per lane
Beauty Shops	1 Unit plus 15% of a Unit per booth
Car Wash	1 Unit plus 15¢ per square foot
Churches	1½¢ per square foot plus 8% of a Unit per seat
Clinics	1 Unit plus 50% of a Unit per examining room
Factories (Office and Production)	1½¢ per square foot plus 4% of a Unit per person
Groceries & Supermarkets	1½¢ per square foot plus 50% of a Unit per employee
Hospital	1 Unit plus 75% of a Unit per bed
Hospital (Convalescent Homes)	1 Unit plus 20% of a Unit per bed
Hotels, Motels & Dormitories	1 Unit plus 20% of a Unit per bed
Two-Family Residences	1 Unit plus 50% of a Unit
Multiple Family Residences	1 Unit plus 50% of a Unit
Office Buildings	1½¢ per sq. foot plus 25% of a Unit per employee
Restaurants (Food only)	1½¢ per sq. foot plus 8% of a Unit per seat
Restaurants (with food and drink)	1½¢ per sq. foot plus 16% of a Unit per seat
Schools	1 Unit plus 1 Unit for each additional classroom
Service Stations	1 Unit plus 15% of a Unit per pump
Drive-ins (Snack Bars, etc.)	1 Unit plus 4% of a Unit per seat or stall
Theatres (Drive-Ins)	1 Unit plus 4% of a Unit per car space
Trailer Parks	1 Unit plus 50% of a Unit per trailer

(Section 2.124 follows)

2.124. Definitions.

(1) "Service Charge" shall mean a fixed monthly charge of $4.65 which will be assessed each discharger of wastewater into the wastewater system.

(2) "User Charge" shall mean a volume charge of $.084/100 gallons which will be assessed monthly to each discharger. This charge will be based on metered water use.

(3) "Debt Service" shall mean a volume charge of $.013/100 gallons which will be assessed monthly to each discharger. This charge will be based on metered water use.

(4) "Surcharge Rate" shall mean a charge which will be made for discharges in excess of normal strength domestic sewage, as defined herein. The following formula shall be used to compute the surcharge:

$C_s = (S_c (S) + B_c (B)) \times 8.34 \times V_u \times N_d$, Where

C_s = Surcharge Cost, dollars

S_c = Unit cost of treatment of BOD, $.083/ pound BOD

S = Average concentration of SS above the specified base level, mg/l

B_c = Unit cost of treatment of SS, $.039/pound SS

B = Average concentration of BOD above the specified base level, mg/l

8.34 = A constant

V_u = User Flow, MGD

N_d = Number of days of excess discharge during the period, days.

2.125. Special Rates for Service.

(1) RATE A - Users of Sewer Only Inside City Limits: A charge of seven dollars and seventy cents ($7.70) per month shall be assessed to all residential, commercial and industrial properties inside the City limits using sewer service only. Any multiple residential users or commercial and industrial users of sewer and not water

Sections 2.124 - 2.132 amended, Ordinance adopted 9/6/1977.
Sections 2.124, 2.125 amended, Ord. No. 79-4, 7/2/1979.

under Rate "A" shall be reported to the City Council on October 1st of each year. The City Council shall determine a Special Sewer Rate under the provisions of section 2.125(4) on said properties, but, in no event shall the rate be less than would be charged under this section.

(2) RATE B - Rates for Sewer Service Outside the Corporate Limits of Dowagiac Where Customer is Served by City Water: Rates for sewer service outside the corporate limits of Dowagiac where customer is served by City water shall be the sum of $4.65 service charge, the $.084 per 100 gallons user charge, and a debt service charge of $.026 per 100 gallons. The surcharge rate identified above shall also apply.

(3) RATE C - Users of Sewer Only Outside City Limits: A charge of eleven dollars and fifty-five cents ($11.55) per month shall be assessed to all residential, commercial and industrial properties outside the City limits, using sewer service only. Any multiple residential users or commercial and industrial users of sewer and not water under Rate "C" shall be reported to the City Council on October 1st of each year. The City Council shall determine a Special Sewer Rate under the provisions of section 2.125(5) on said properties, but, in no event, shall the rate be less than would be charged under this section.

(4) RATE D - Special Rates: Special rates may be determined by the City Council after recommendation by the City Manager and, on adoption, shall be published in the Dowagiac Daily News, at once, and thereafter so long as the rate is in effect once each year in October. All special rates shall be reviewed by the City Council at the first meeting in October in each year. Special rates shall be based upon the rates as set forth in this Chapter; and, insofar as possible, shall be in relation to the use of the water on the premises, if any.

2.126. Capital Charge. (Sewer Connection). There is hereby imposed a capital charge of three hundred ($300.00) dollars per unit. The capital charge shall not be applicable to residences, businesses, and buildings connected to existing municipally-owned and operated sewer systems.

A unit shall be regarded as a normal house service connection for a single family residence.

Based upon this unit charge, charges for other types of new connections are as follows, and in no instance shall be less than three hundred ($300.00) dollars.

USAGE	UNIT FACTOR
Auto Dealers - New Cars	1 Unit plus 15% of a Unit per stall
Bars	$.015 per square foot plus 5% of a Unit per seat
Barber Shops	1 Unit plus 10% of a Unit per chair
Bowling Alleys, with bar and lunch	1 Unit plus 20% of a Unit per lane
Bowling Alleys only	1 Unit plus 8% of a Unit per lane
Beauty Shops	1 Unit plus 15% of a Unit per booth
Car Wash	1 Unit plus $.10 per square foot
Churches	$.015 per square foot plus 8.8% of a Unit per seat
Clinics	1 Unit plus 50% of a Unit per examining room
Factories (Office and Production)	$.015 per square foot plus 4% of a Unit per person
Groceries & Supermarkets	$.015 per square foot plus 50% of a Unit per employee
Hospital	1 Unit plus 75% of a Unit per bed
Hospital (Convalescent Homes)	1 Unit plus 20% of a Unit per bed

USAGE	UNIT FACTOR
Hotels, Motels and Dormitories	1 Unit plus 20% of a Unit per bed
Two-Family Residences	1 Unit plus 50% of a Unit
Multiple Family Residences	1 Unit plus 20% of a Unit after 4 Units
Office Buildings	$.015 per square foot plus 25% of a Unit per employee
Restaurants (Food Only)	$.015 per square foot plus 8% of a Unit per seat
Restaurants (with food & drink)	$.015 per square foot plus 16% of a Unit per seat
Schools	1 Unit plus 1 Unit for each additional classroom
Service Stations -	1 Unit plus 15% of a Unit per pump
Drive-Ins (Snack Bars, etc.)	1 Unit plus 4% of a Unit per seat or stall
Theaters (Drive-Ins)	1 Unit plus 4% of a Unit per car space
Trailer Parks	1 Unit plus 50% of a Unit per trailer

2.127. Special Meters. Lawn sprinkling may be provided without wastewater costs being added if the customer installs a separate water meter at his own cost, and provided the Water Department makes the proper inspections. The water meter will be provided by the Water Department at no cost to the customer and the customer will pay the readiness-to-serve charge during the months when the meter is being used, or a minimum of six months.

2.128. Service to City. The City shall pay the same water and sewer rates for service to it as would be payable by a private customer for the same service. The City shall pay a charge of eight ($8.00) dollars per year per fire hydrant. All such charges for service and fire hydrants shall be payable quarterly from the

current funds of the City, or from the proceeds of taxes which the City, within constitutional limits, is hereby authorized and required to levy in amounts sufficient for that purpose.

2.129. Billing. Billing for water and sewer service charges shall be made monthly and bills shall be sent to consumers monthly. Bills for water and sewer service shall be due on the 15th day after the date rendered. For bills not paid when due, a penalty charge of six (6%) per cent of such bill shall be added.

2.130. Collection. The charges for water services which are under the provisions of Section 21, Act 94, Public Acts of Michigan, 1933, as amended, made a lien on all premises served thereby, unless notice is given that a tenant is responsible, are hereby recognized to constitute such lien and whenever any such charge against any piece of property shall be delinquent for three (3) months, the City official or officials in charge of collection thereof, shall certify annually, on April 1 of each year, to the Tax Assessing Officer of the City, the fact of such delinquency, whereupon such charge shall be by him entered upon the next Tax Roll as a charge against such premises and shall be collected and the lien thereof enforced in the same manner as general City Taxes against such premises as collected, and the lien thereof enforced: Provided, however, where notice is given that a tenant is responsible for such charges and service as provided by said Section 21, no further service shall be rendered such premises until a cash deposit of not less than fifteen dollars ($15.00) shall have been made as security for payment of such charges and service.

In addition to other remedies provided, the City shall have the right to shut off and discontinue the supply of water to any premises for the nonpayment of water rates when due. If such charges are not paid within thirty (30) days after the due date thereof, then water service to such premises shall be discontinued. Water services so discontinued shall not be restored until all sums due and owing shall be paid, plus a turn-on charge of the amount indicated in section 2.123.

Section 2.130 amended, Ord. No. 79-4, 7/2/1979.

2.131. Review and Update of Rates. The City Administration shall conduct an annual review of the sewer charge schedule to assure its equitability. Recommendations shall be made to the Mayor and Council by the City Manager prior to May 1 of each year so as to be able to make changes prior to adoption of budget.

2.132. Billing Adjustments. No rates other than the rates as set forth or determined pursuant to this Chapter shall be charged. Adjustments of billings may be allowed only in case of unusual usage, error in metering, broken water lines, and other such extraordinary situations by the City Manager, and a list of all adjustments shall be sent to each Councilman at least monthly.

STATE OF MICHIGAN

NATURAL RESOURCES COMMISSION
[illegible]
E M LAFLER
HILARY F SNELL
HARRY H WHITELEY
JOAN L WOLFE
CHARLES G YOUNGLOVE

WILLIAM G. MILLIKEN, Governor

DEPARTMENT OF NATURAL RESOURCES

HOWARD A TANNER Director

STEVENS T MASON BLDG
BOX 30028
LANSING MI 48909

February 26, 1980

Mr. Gene Lempert
Gove Associates
1601 Portage Street
Kalamazoo, Michigan 49001

RE: Effluent Limits for the Indian Lake/Sister Lake Plan of Study Area C26-3048-01

Dear Mr. Lempert:

This is in response to your request for effluent limits for the Indian Lake/Sister Lake Plan of Study Area in Cass County. The Engineering and Technical Services Section of the Department of Natural Resources has determined effluent limits for a municipal wastewater treatment plant with the design flow of 0.7 MGD at two of the discharge points considered. They are Indian Lake outlet in the W½ of Section 32, Silver Creek Township; and Silver Creek in Section 2 of Silver Creek Township.

The Engineering and Technical Services Section recommends that no discharge be allowed at the following locations because of the non-degredation policy of not allowing new discharges to cold water streams: the Dowagiac River in the NE¼ of Section 4 of Pokagan Township; the Indian Lake outlet in Section 33 of Silver Creek Township; the Dowagiac River in Sections 24, 26, & 27 of Silver Creek Township; and Pipestone Creek in Section 35 of Bainbridge Township. For the other two proposed discharge points, the first recommendation of the Engineering and Technical Services Section is land applications. If this is not feasible, they recommend the following:

For Indian Lake outlet in the W½ of Section 32, T5S, R16W, an annual discharge from March 1st to May 15th which will meet the following effluent limits:

carbonaceous BOD_5	30 mg/l as a 30 day average 45 mg/l as a 7 day average
total suspended solids	70 mg/l as a 30 day average 100 mg/l as a 7 day average
pH	6.0 to 9.0
dissolved oxygen	5.0 mg/l daily minimum

MICHIGAN THE GREAT LAKES STATE

at such time that technology provides an economically feasible means of removing phosphorus from stabilization lagoons, it shall be required at this facility

During discharge the ratio of wastewater flow to upstream flow shall be as follows: 1.0 from March 1 to March 31; 0.4 from April 1 to April 30; and 0.1 from May 1 to May 15.

The Indian Lake outlet in W½ Section 32, T5S, R16W is protected for agricultural and industrial water supply, navigation, partial body contact recreation, warmwater fish, and domestic water supplies at the point of intake.

The other acceptable discharge point is:

Silver Creek in Section 2 of Silver Creek Township. Again, an annual discharge from March 1st to May 15th is recommended with the following limits:

carbonaceous BOD_5	30 mg/l as a 30 day average 45 mg/l as a 7 day average
total suspended solids	70 mg/l as a 30 day average 100 mg/l as a 7 day average
pH	6.0 to 9.0
dissolved oxygen	5.0 daily minimum
total phosphorus as P	at such time that technology provides an economically feasible means of removing phosphorus stabilization lagoons, it shall be required at this facility

During discharge, the ratio of wastewater flow to upstream flow shall be as follows: 1.0 from March 1 to March 31; 0.4 from April 1 to April 30; and 0.1 from May 1 to May 15.

All previous recommendations are no longer valid and only the two locations for which effluent limits were determined are now acceptable for discharge from the proposed wastewater treatment facility at Indian Lake/Sister Lake Plan of Study Area.

If you have any questions regarding these limits, please contact Catherine Breidt at (517) 373-3710.

Very truly yours,

WATER QUALITY DIVISION

Richard Hinshon, Chief
Grants Administration Section

RH/CB:amk

CC: Cass Co. DPW
Wastewater Operations Section
Municipal Design Review Section
Engineering & Technical Services Section

...D M. AUSTIN SECRETARY OF STATE

LANSING
MICHIGAN 489...

MICHIGAN HISTORY DIVISION
ADMINISTRATION, ARCHIVES, HISTORIC SITES, AND PUBLICATI...
3423 N Logan Street
517-373-0510
STATE MUSEUM
505 N Washington Avenue
517-373-0515

...uary 8, 1979

Mr. George P. Bartnik
MAPORA, Inc.
...S. Wacker Drive
Suite 2380
Chicago, Illinois 60601

Ref: ER-1665

Dear Mr. Bartnik:

Please excuse the extended delay in responding to your letter of November 9, 1978. We are aware of a considerable amount of information on the prehistory of Cass County, but unfortunately it is in an unprocessed form not readily accessible to us at this time. No cultural resource surveys conducted in the area may be considered sufficient in scope to adequately inventory the study area's potentially impacted areas. A brief, "broad brush" survey done in the summer of 1977 produced information which suggests that these sites may be of architectural or historical value: a round barn on 60th Avenue, south of Sister Lakes; a house on County Road 681, between 71st Street and 77th Avenue in Keeler Township; a house on County Road 352, west of the intersection of County Roads 352 and 681 in Keeler Township. At this time these structures appear to be significant. No research has been done to document this apparent significance. Final routings and primary impact sites should be forwarded to us so the need for mitigative measures, such as archaeological survey, may be assessed.

You may wish to contact the Cass County Historical Society, Route #2, Cassopolis, Michigan 49031 for local information.

Any questions you may have should be addressed to Dr. John R. Halsey, Environmental Review Coordinator for the Michigan History Division.

Thank you for this opportunity to comment.

Sincerely,

Martha M. Bigelow
Director, Michigan History Division
and
State Historic Preservation Officer

By: Michael J. Washo
Deputy State Historic Preservation Officer

0-17

MMB/JRH:++