U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES

REPORT

ON

FREMONT LAKE

NEWAYGO COUNTY

MICHIGAN

EPA REGION V

WORKING PAPER No. 194

PACIFIC NORTHWEST ENVIRONMENTAL RESEARCH LABORATORY

An Associate Laboratory of the

NATIONAL ENVIRONMENTAL RESEARCH CENTER - CORVALLIS, OREGON

and

NATIONAL ENVIRONMENTAL RESEARCH CENTER - LAS VEGAS, NEVADA

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199

WITH THE COOPERATION OF THE

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

AND THE

MICHIGAN NATIONAL GUARD

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F O R E W O R D

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Michigan Department of Natural Resources for professional involvement and to the Michigan National Guard for conducting the tributary sampling phase of the Survey.

A. Gene Gazlay, former Director, and David H. Jenkins, Acting Director, Michigan Department of Natural Resources; and Carlos Fetterolf, Chief Environmental Scientist, and Dennis Tierney, Aquatic Biologist, Bureau of Water Management, Department of Natural Resources, provided invaluable lake documentation and counsel during the course of the Survey. John Vogt, Chief of the Bureau of Environmental Health, Michigan Department of Public Health, and his staff were most helpful in identifying point sources and soliciting municipal participation in the Survey.

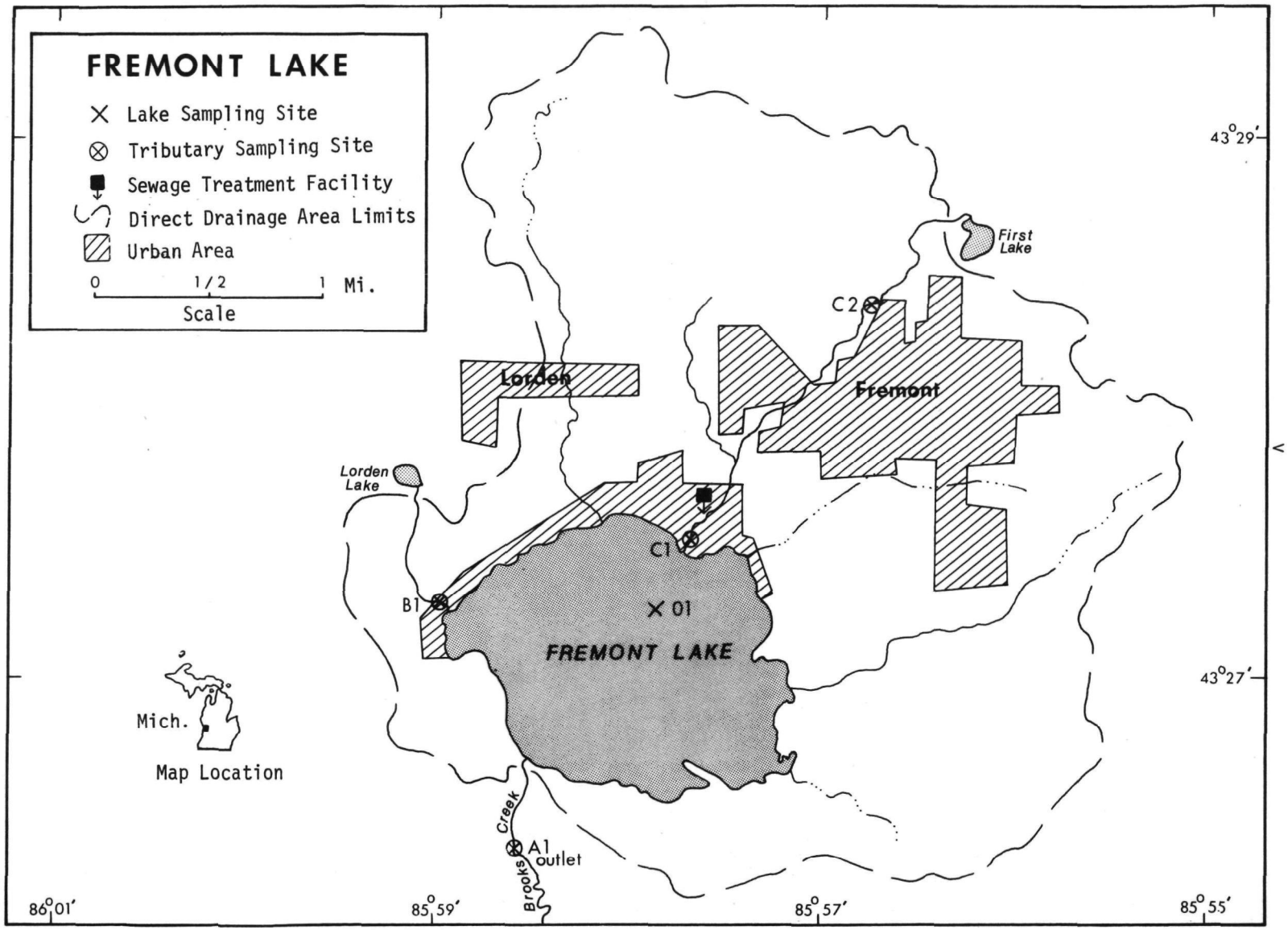
Major General Clarence A. Schnipke (Retired), then the Adjutant General of Michigan, and Project Officer Colonel Albert W. Lesky, who directed the volunteer efforts of the Michigan National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MICHIGAN

LAKE NAME	COUNTY
Allegan Res.	Allegan
Barton	Kalamazoo
Belleville	Wayne
Betsie	Benzie
Brighton	Livingston
Caro Res.	Tuscola
Charlevoix	Charlevoix
Chemung	Livingston
Constantine Res.	St. Joseph
Crystal	Montcalm
Deer	Marquette
Ford	Washtenaw
Fremont	Newago
Higgins	Roscommon
Holloway Res.	Genesee, Lapeer
Houghton	Roscommon
Jordon	Ionia, Barry
Kent	Oakland
Long	St. Joseph
Macatawa	Ottawa
Manistee	Manistee
Mona	Muskegon
Muskegon	Muskegon
Pentwater	Oceana
Pere Marquette	Mason
Portage	Houghton
Randall	Branch
Rogers Pond	Mecosta
Ross	Gladwin
St. Louis Res.	Gratiot
Sanford	Midland
Strawberry	Livingston
Thompson	Livingston
Thornapple	Barry
Union	Branch
White	Muskegon


FREMONT LAKE
Lake Sampling Site
Tributary Sampling Site
Sewage Treatment Facility
Direct Drainage Area Limits
Urban Area
0
1/2
1 Mi.
Scale
43°29′
43°27′
86°01′
85°59′
85°57′
85°55′
First Lake
C2
Lorden
Fremont
Lorden Lake
C1
B1
X 01
FREMONT LAKE
Mich.
Map Location
Brooks Creek
A1
outlet

FREMONT LAKE

STORET NO. 2631

I. CONCLUSIONS

A. Trophic Condition:

On the basis of Survey data, it is concluded that Fremont Lake is hypereutrophic. Of the 35 Michigan lakes sampled in the fall when essentially all were well-mixed, none had higher mean total and dissolved phosphorus, and only nine had more mean inorganic nitrogen; of the 41 lakes sampled, only three had more mean chlorophyll a, but 22 had less mean Secchi disc transparency*.

Dissolved oxygen was essentially depleted at 50 feet in June and was depleted at 30 feet and deeper in September.

Ketelle and Uttormark (1971) report that Fremont Lake has a long history of algal blooms.

B. Rate-Limiting Nutrient:

The results of the algal assay show that Fremont Lake was nitrogen limited at the time the sample was collected. The lake data indicate nitrogen limitation at the other sampling times as well.

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* See Appendix A.

C. Nutrient Controllability:

1. Point sources--During the sampling year, Fremont Lake received a total phosphorus loading at a rate about six times that proposed by Vollenweider (in press) as "dangerous"; i.e., at a rate far greater than a eutrophic rate (see page 13). Of this load, it is calculated that the City of Fremont contributed over 42%.

In the fall of 1974, the City of Fremont replaced the trickling filter plant with a lagoon-flood irrigation system which does not discharge to Fremont Lake. It is calculated that the elimination of the City of Fremont phosphorus load reduced the loading rate from the 2.97 $g/m^2/yr$ measured during the Survey sampling year to 1.71 $g/m^2/yr$. While the reduced rate is still about four times the eutrophic rate of 0.46 $g/m^2/yr$, the sizable (42%) reduction of the phosphorus input to this hypereutrophic lake should result in some improvement in the trophic condition once a new phosphorus equilibrium is established. However, if the non-point phosphorus loads measured during the Survey sampling year are typical of the Fremont Lake drainage (see below), it appears that a marked improvement in the trophic condition of the lake will require a reduction of non-point loads as well.

2. Non-point sources--Attention is called to what appear to be extremely high mean non-point phosphorus loads in the Fremont

Lake drainage (see page 13). These loads were far greater than those of any of the other Michigan drainages sampled during the Survey year.

For example, the phosphorus export rate of the unnamed creek (B-1; see map, page v) was four times that of the nearby White River (76 $lbs/mi^2/yr$) and was over five times the export rate of the Muskegon River (59 $lbs/mi^2/yr$) just south and southwest of the Fremont Lake drainage area. Further, the export rate of Daisy Creek (C-1) was more than 2½ times that of the unnamed creek and thus was over ten times the White River rate and over 13 times the Muskegon rate.

Now, the cause of these unusual export rates is not known; but there are no known point sources in the drainage, other than the City of Fremont (Tierney, 1974). Whether the extremely high non-point phosphorus loads are really typical of this drainage or resulted from insufficient sampling, unusual weather conditions during the Survey year, or other factors cannot be determined from the data available at this time; and it is concluded that additional, more intensive study is needed in the drainage to determine the magnitude and significance of non-point phosphorus loads.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS:

A. Lake Morphometry†:

1. Surface area: 790 acres.
2. Mean depth: 33.2 feet.
3. Maximum depth: 88 feet.
4. Volume: 26,228 acre-feet.
5. Mean hydraulic retention time: 1.9 years.

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area*	Mean flow*
Daisy Creek	13.0 mi^2	12.4 cfs
Unnamed creek (B-1)	1.6 mi^2	1.5 cfs
Minor tributaries & immediate drainage -	4.5 mi^2	5.4 cfs
Totals	19.1 mi^2	19.3 cfs

2. Outlet -

Brooks Creek	20.3 mi^2**	19.3 cfs

C. Precipitation***:

1. Year of sampling: 32.6 inches.
2. Mean annual: 33.1 inches.

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† MI Dept. Cons. lake inventory map (1952); mean depth by random-dot method.
* Drainage areas are accurate within ±5%; mean daily flows for 74% of the sampling sites are accurate within ±25% and the remaining sites up to ±40%; and mean monthly flows, normalized mean monthly flows, and mean annual flows are slightly more accurate than mean daily flows.
** Includes area of lake.
*** See Working Paper No. 1, "Survey Methods, 1972".

III. LAKE WATER QUALITY SUMMARY

Fremont Lake was sampled three times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from a number of depths at a single station on the lake (see map, page v). During each visit, a single depth-integrated (15 feet to surface) sample was collected for phytoplankton identification and enumeration; and during the second visit, a five-gallon depth-integrated sample was collected for algal assays. Also each time, a depth-integrated sample was collected for chlorophyll a analyses. The maximum depth sampled was 75 feet.

The results obtained are presented in full in Appendix C, and the data for the fall sampling period, when the lake essentially was well-mixed, are summarized below. Note, however, the Secchi disc summary is based on all values.

For differences in the various parameters at the other sampling times, refer to Appendix C.

A. Physical and chemical characteristics:

FALL VALUES

(11/13/72)

Parameter	Minimum	Mean	Median	Maximum
Temperature (Cent.)	7.7	7.7	7.7	7.7
Dissolved oxygen (mg/l)	6.0	6.1	6.2	6.2
Conductivity (μmhos)	515	519	520	520
pH (units)	7.9	7.9	7.9	7.9
Alkalinity (mg/l)	160	161	161	162
Total P (mg/l)	0.368	0.372	0.371	0.378
Dissolved P (mg/l)	0.335	0.342	0.343	0.344
NO_2 + NO_3 (mg/l)	0.070	0.090	0.100	0.100
Ammonia (mg/l)	1.180	1.316	1.340	1.370

ALL VALUES

Secchi disc (inches)	49	58	54	72

B. Biological characteristics:

1. Phytoplankton* -

Sampling Date	Dominant Genera	Number per ml
09/15/72	1. Microcystis	2,080
	2. Anabaena	669
	3. Dinobryon	434
	4. Flagellates	253
	5. Cryptomonas	217
	Other genera	1,139
	Total	4,792
11/13/72	1. Microcystis	296
	2. Stephanodiscus	209
	3. Oocystis	202
	4. Staurastrum	195
	5. Scenedesmus	188
	Other genera	848
	Total	1,938

* The June sample was lost in shipment.

2. Chlorophyll a -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll a (μg/l)
06/13/72	01	50.9
09/15/72	01	26.3
11/13/72	01	8.3

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.400	1.918	44.0
0.010 P	0.410	1.918	50.9
0.020 P	0.420	1.918	48.5
0.050 P	0.450	1.918	52.2
0.050 P + 5.0 N	0.450	6.918	205.7
0.050 P + 10.0 N	0.450	11.918	187.1
10.0 N	0.400	11.918	167.1

2. Discussion -

The control yield of the assay alga, *Selenastrum capricornutum*, indicates that the potential primary productivity of Fremont Lake was very high at the time the sample was collected (09/15/72). Also the lack of significant change in yields with increased levels of orthophosphorus, until nitrogen was also added, shows that the lake was nitrogen limited. Note that the addition of only nitrogen resulted in a yield significantly greater than the control yield.

Nitrogen limitation is also indicated by the lake data; i.e., the nitrogen to phosphorus ratios were less than 6 to 1 at all sampling times.

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Michigan National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of April or May and June when two samples were collected. Sampling was begun in October, 1972, and was completed in September, 1973.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Michigan District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated by using the nutrient loads, in $lbs/mi^2/year$, at station B-1 and multiplying by the ZZ area in mi^2.

The operator of the Fremont wastewater treatment plant provided monthly effluent samples and corresponding flow data. In the following loading tables, the loads attributed to Daisy Creek are those measured at station C-1 minus the Fremont loads.

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* See Working Paper No. 1.

A. Waste Sources:

1. Known municipal* -

Name	Pop. Served	Treatment	Mean Flow (mgd)	Receiving Water
Fremont	3,465**	trickling filter	0.471	Daisy Creek

2. Known industrial - None

* Wetzel, 1973.
** 1970 Census.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
Daisy Creek	10,020	47.8
Unnamed creek (B-1)	490	2.3
b. Minor tributaries & immediate drainage (non-point load) -	1,380	6.6
c. Known municipal STP's -		
Fremont	8,870	42.4
d. Septic tanks* -	60	0.3
e. Known industrial - None	-	-
f. Direct precipitation** -	120	0.6
Total	20,940	100.0

2. Outputs -

Lake outlet - Brooks Creek 11,070

3. Net annual P accumulation - 9,870 pounds

* Estimate based on 100 lakeshore dwellings; see Working Paper No. 1.
** See Working Paper No. 1.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	lbs N/ yr	% of total
a. Tributaries (non-point load) -		
Daisy Creek	59,210	51.1
Unnamed creek (B-1)	5,730	4.9
b. Minor tributaries & immediate drainage (non-point load) -	16,110	13.9
c. Known municipal STP's -		
Fremont	24,780	21.4
d. Septic tanks* -	2,350	2.0
e. Known industrial - None	-	-
f. Direct precipitation** -	7,610	6.7
Total	115,790	100.0

2. Outputs -

Lake outlet - Brooks Creek 84,130

3. Net annual N accumulation - 31,660 pounds

* Estimate based on 100 lakeshore dwellings; see Working Paper No. 1.
** See Working Paper No. 1.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	lbs P/mi^2/yr	lbs N/mi^2/yr	N/P Ratio
Daisy Creek	771	4,555	6/1
Unnamed creek (B-1)	306	3,581	12/1

E. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (in press). Essentially, his "dangerous" rate is the rate at which the receiving waters would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with very short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
Units	Total	Accumulated	Total	Accumulated
lbs/acre/yr	26.5	12.5	146.6	40.1
grams/m^2/yr	2.97	1.40	16.4	4.5

Vollenweider loading rates for phosphorus (g/m^2/yr) based on mean depth and mean hydraulic retention time of Fremont Lake:

"Dangerous" (eutrophic rate)	0.46
"Permissible" (oligotrophic rate)	0.23

V. LITERATURE REVIEWED

Carbine, Robert, 1974. Personal communication (status of Fremont STP conversion). Fremont Wastewater Treatment Plant, Fremont.

Fetterolf, Carlos, 1973. Personal communication (mean depth of Fremont Lake). MI Dept. Nat. Resources, Lansing.

Ketelle, Martha J., and Paul D. Uttormark, 1971. Problem lakes of the United States. EPA Water Poll. Contr. Res. Ser., Proj. 16010 EHR.

Tierney, Dennis, 1974. Personal communication (point sources in the Fremont Lake drainage). MI Dept. Nat. Resources, Lansing.

Vollenweider, Richard A. (in press). Input-output models. Schweiz. Z. Hydrol.

Wetzel, Michael C., 1973. Treatment plant questionnaire (Fremont STP). MI Dept. Public Health, Lansing.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	FALL VALUES MEAN TOTAL P	FALL VALUES MEAN DISS P	FALL VALUES MEAN INORG N	ALL VALUES 500-MEAN SEC	ALL VALUES MEAN CHLORA	ALL VALUES 15-MIN DO
26A0	HOLLOWAY RESERVOIR	0.062	0.043	1.461	439.375	10.678	9.200
26A1	CARO RESERVOIR	0.117	0.022	3.835	473.000	11.967	9.500
26A2	BOARDMAN HYDRO POND	0.006	0.005	0.358	363.500	1.267	6.600
2603	ALLEGAN LAKE	0.123	0.057	1.168	470.222	20.311	12.600
2606	BARTON LAKE	0.121	0.086	1.489	456.167	27.800	14.850
2609	BELLEVILLE LAKE	0.118	0.048	1.420	465.250	28.262	8.200
2610	BETSIE LAKE	0.025	0.008	0.273	461.667	4.567	7.400
2613	BRIGHTON LAKE	0.109	0.073	1.015	456.000	44.233	7.500
2617	LAKE CHARLEVOIX	0.007	0.006	0.230	351.250	3.008	9.240
2618	LAKE CHEMUNG	0.044	0.014	0.132	404.333	13.483	14.800
2621	CONSTANTINE RESERVOIR	0.027	0.008	0.910	456.167	39.317	7.500
2629	FORD LAKE	0.105	0.058	1.536	456.167	14.733	14.000
2631	FREMONT LAKE	0.372	0.342	1.406	441.667	28.500	14.800
2640	JORDAN LAKE	0.180	0.144	1.998	427.667	20.517	14.900
2643	KENT LAKE	0.040	0.015	0.417	455.000	33.944	13.000
2648	LAKE MACATAWA	0.197	0.120	2.358	477.600	25.600	12.200
2649	MANISTEE LAKE	0.018	0.010	0.304	451.333	6.317	11.380
2659	MUSKEGON LAKE	0.087	0.043	0.469	436.444	9.511	14.800
2665	PENTWATER LAKE	0.027	0.017	0.496	430.667	16.083	14.800
2671	RANDALL LAKE	0.246	0.183	0.818	457.333	27.217	8.020
2672	ROGERS POND	0.026	0.015	0.183	435.500	8.133	9.600
2673	ROSS RESERVOIR	0.034	0.021	0.460	465.333	10.383	8.200
2674	SANFORD LAKE	0.016	0.008	0.307	458.750	13.791	8.300
2683	THORNAPPLE LAKE	0.042	0.032	1.737	442.833	14.650	10.800
2685	UNION LAKE	0.083	0.064	1.252	455.500	15.667	8.200
2688	WHITE LAKE	0.027	0.019	0.367	417.778	9.211	13.400
2691	MONA LAKE	0.307	0.241	0.963	451.667	27.783	14.100
2692	LONG LAKE	0.163	0.148	0.749	418.400	10.067	13.600

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	---------FALL VALUES--------- MEAN TOTAL P	MEAN DISS P	MEAN INORG N	----------ALL VALUES---------- 500- MEAN SEC	MEAN CHLORA	15- MIN DO
2693	ST LOUIS RESERVOIR	0.134	0.093	1.227	462.667	5.583	8.420
2694	CRYSTAL LAKE	0.009	0.006	0.164	380.000	2.986	13.000
2695	HIGGINS LAKE	0.007	0.005	0.058	268.500	1.043	9.400
2696	HOUGHTON LAKE	0.018	0.008	0.136	420.833	9.217	8.200
2697	THOMPSON LAKE	0.043	0.029	0.436	407.889	11.967	14.800
2698	PERE MARQUETTE LAKE	0.032	0.024	0.346	448.667	11.833	8.600
2699	STRAWBERRY LAKE	0.069	0.050	0.567	419.800	11.117	13.600

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	FALL VALUES: MEAN TOTAL P	FALL VALUES: MEAN DISS P	FALL VALUES: MEAN INORG N	ALL VALUES: 500- MEAN SEC	ALL VALUES: MEAN CHLORA	ALL VALUES: 15- MIN DO	INDEX NO
26A0	HOLLOWAY RESERVOIR	46 (16)	43 (15)	17 (6)	57 (20)	60 (21)	63 (22)	286
26A1	CARO RESERVOIR	29 (10)	54 (19)	0 (0)	3 (1)	49 (17)	54 (19)	189
26A2	BOARDMAN HYDRO POND	97 (34)	97 (34)	69 (24)	91 (32)	94 (33)	97 (34)	545
2603	ALLEGAN LAKE	20 (7)	31 (11)	31 (11)	6 (2)	29 (10)	40 (14)	157
2606	BARTON LAKE	23 (8)	20 (7)	14 (5)	29 (9)	14 (5)	3 (1)	103
2609	BELLEVILLE LAKE	26 (9)	37 (13)	20 (7)	11 (4)	11 (4)	79 (26)	184
2610	BETSIE LAKE	77 (27)	77 (27)	80 (28)	17 (6)	86 (30)	94 (33)	431
2613	BRIGHTON LAKE	31 (11)	23 (8)	34 (12)	34 (12)	0 (0)	90 (31)	212
2617	LAKE CHARLEVOIX	91 (32)	91 (32)	83 (29)	94 (33)	89 (31)	60 (21)	508
2618	LAKE CHEMUNG	49 (17)	71 (25)	94 (33)	86 (30)	46 (16)	11 (2)	357
2621	CONSTANTINE RESERVOIR	71 (25)	83 (29)	40 (14)	29 (9)	3 (1)	90 (31)	316
2629	FORD LAKE	34 (12)	29 (10)	11 (4)	29 (9)	37 (13)	23 (8)	163
2631	FREMONT LAKE	0 (0)	0 (0)	23 (8)	54 (19)	9 (3)	11 (2)	97
2640	JORDAN LAKE	11 (4)	11 (4)	6 (2)	69 (24)	26 (9)	0 (0)	123
2643	KENT LAKE	57 (20)	69 (24)	63 (22)	40 (14)	6 (2)	36 (12)	271
2648	LAKE MACATAWA	9 (3)	14 (5)	3 (1)	0 (0)	23 (8)	43 (15)	92
2649	MANISTEE LAKE	80 (28)	74 (26)	77 (27)	46 (16)	80 (28)	46 (16)	403
2659	MUSKEGON LAKE	37 (13)	40 (14)	54 (19)	60 (21)	69 (24)	11 (2)	271
2665	PENTWATER LAKE	69 (24)	63 (22)	51 (18)	66 (23)	31 (11)	11 (2)	291
2671	RANDALL LAKE	6 (2)	6 (2)	43 (15)	23 (8)	20 (7)	86 (30)	184
2672	ROGERS POND	74 (26)	66 (23)	86 (30)	63 (22)	77 (27)	51 (18)	417
2673	ROSS RESERVOIR	60 (21)	57 (20)	57 (20)	9 (3)	63 (22)	79 (26)	325
2674	SANFORD LAKE	86 (30)	80 (28)	74 (26)	20 (7)	43 (15)	71 (25)	374
2683	THORNAPPLE LAKE	54 (19)	46 (16)	9 (3)	51 (18)	40 (14)	49 (17)	249
2685	UNION LAKE	40 (14)	26 (9)	26 (9)	37 (13)	34 (12)	79 (26)	242
2688	WHITE LAKE	66 (23)	60 (21)	66 (23)	80 (28)	74 (26)	31 (11)	377
2691	MONA LAKE	3 (1)	3 (1)	37 (13)	43 (15)	17 (6)	20 (7)	123
2692	LONG LAKE	14 (5)	9 (3)	46 (16)	77 (27)	66 (23)	27 (9)	239

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	FALL VALUES: MEAN TOTAL P	FALL VALUES: MEAN DISS P	FALL VALUES: MEAN INORG N	ALL VALUES: 500-MEAN SEC	ALL VALUES: MEAN CHLORA	ALL VALUES: 15-MIN DO	INDEX NO
2693	ST LOUIS RESERVOIR	17 (6)	17 (6)	29 (10)	14 (5)	83 (29)	69 (24)	229
2694	CRYSTAL LAKE	89 (31)	89 (31)	89 (31)	89 (31)	91 (32)	36 (12)	483
2695	HIGGINS LAKE	94 (33)	94 (33)	97 (34)	97 (34)	97 (34)	57 (20)	536
2696	HOUGHTON LAKE	83 (29)	86 (30)	91 (32)	71 (25)	71 (25)	79 (26)	481
2697	THOMPSON LAKE	51 (18)	49 (17)	60 (21)	83 (29)	51 (18)	11 (2)	305
2698	PERE MARQUETTE LAKE	63 (22)	51 (18)	71 (25)	49 (17)	54 (19)	66 (23)	354
2699	STRAWBERRY LAKE	43 (15)	34 (12)	49 (17)	74 (26)	57 (20)	27 (9)	284

APPENDIX B

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MICHIGAN 2/3/75

LAKE CODE 2631 FREMONT LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ MI) 20.30

TRIBUTARY	SUB-DRAINAGE AREA(SQ MI)	NORMALIZED FLOWS(CFS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
2631A1	20.30	18.90	20.20	27.80	32.40	22.40	17.50	12.90	11.80	12.60	15.20	19.00	20.80	19.27
2631B1	1.59	1.50	1.60	2.20	2.50	1.70	1.40	1.00	0.90	1.00	1.20	1.50	1.60	1.51
2631C1	13.00	12.10	12.90	17.80	20.80	14.40	11.20	8.30	7.60	8.10	9.70	12.20	13.40	12.36
2631ZZ	5.71	5.30	5.70	7.80	9.10	6.30	4.90	3.60	3.30	3.50	4.30	5.30	5.80	5.40

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 20.30 TOTAL FLOW IN = 231.50
SUM OF SUB-DRAINAGE AREAS = 20.30 TOTAL FLOW OUT = 231.50

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2631A1	10	72	14.00	29	20.00				
	11	72	14.00						
	12	72	14.00	3	14.00				
	1	73	26.00	7	20.00				
	2	73	19.00	4	24.00				
	3	73	26.00	4	28.00				
	4	73	22.00	6	23.00	25	26.00		
	5	73	23.00	12	29.00				
	6	73	11.00	2	23.00	6	22.00	23	10.00
	7	73	7.70	7	8.00	11	7.50	27	7.30
	8	73	6.70	25	6.80				
	9	73	6.10	29	6.60				
2631B1	10	72	0.40	29	0.60				
	11	72	0.40						
	12	72	0.40	3	0.40				
	1	73	0.70	7	0.60				
	2	73	0.50	4	0.60				
	3	73	0.70	4	0.80				
	4	73	0.60	6	0.60	25	0.60		
	5	73	0.60	12	0.80				
	6	73	0.40	2	0.60	6	0.60	23	0.40
	7	73	0.30	7	0.30	11	0.30	27	0.30
	8	73	0.30	25	0.30				
	9	73	0.30	29	0.30				

TRIBUTARY FLOW INFORMATION FOR MICHIGAN 2/3/75

LAKE CODE 2631 FREMONT LAKE

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2631C1	10	72	9.80	29	14.00				
	11	72	10.00						
	12	72	10.00	3	9.60				
	1	73	18.00	7	14.00				
	2	73	13.00	4	17.00				
	3	73	18.00	4	19.00				
	4	73	15.00	6	16.00	25	18.00		
	5	73	16.00	12	20.00				
	6	73	12.00	2	16.00	6	15.00	23	9.90
	7	73	8.30	7	8.60	11	8.00	27	7.80
	8	73	7.40	25	7.20				
	9	73	6.80	29	7.00				
2631ZZ	10	72	4.00						
	11	72	4.00						
	12	72	4.00						
	1	73	7.00						
	2	73	5.00						
	3	73	7.00						
	4	73	6.00						
	5	73	6.00						
	6	73	0.0						
	7	73	0.0						
	8	73	0.0						
	9	73	0.0						

APPENDIX C

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 75/02/04

263101
43 27 00.0 085 58 00.0
FREMONT LAKE
26 MICHIGAN

11EPALES 2111202
5 0060 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/13	10 20	0000	18.4	13.8	54	510	9.20	162	0.020	0.030	0.233	0.210
	10 20	0015	17.9									
	10 20	0030	8.8			500	7.80	169	0.030	2.000	0.540	0.480
	10 20	0050	5.8	0.2		550	7.55	168	0.020	2.000	0.560	0.560
72/09/15	17 45	0000			72	445	8.90	155	0.050	0.080	0.161	0.118
	17 45	0004	19.6	6.9		450	8.90	154	0.050	0.090	0.195	0.125
	17 45	0015	19.7	8.8		430	8.90	155	0.050	0.100	0.172	0.131
	17 45	0022	19.6	7.6		440	8.87	155	0.050	0.240	0.293	0.166
	17 45	0030	14.4	0.0		470	7.65	182	0.120	3.340	0.620	0.610
	17 45	0037	8.8	0.0		480	7.50	183	0.130	3.380	0.645	0.625
	17 45	0043	8.0	0.0		470	7.40	182	0.110	3.560	0.700	0.630
	17 45	0050	6.8	0.0		460	7.35	184	0.120	4.040	0.730	0.680
	17 45	0057	6.6	0.0		480	7.32	185	0.080	4.340	0.760	0.725
	17 45	0064	6.3	0.0		480	7.27	194	0.050	4.270	0.820	0.775
	17 45	0071	6.3	0.0		480	7.25	193	0.090	5.050	0.860	0.830
72/11/13	14 05	0000			49	520	7.90	161	0.100	1.180	0.375	0.344
	14 05	0004	7.7	6.2		520	7.90	160	0.100	1.360	0.371	0.343
	14 05	0015	7.7	6.0		520	7.90	160	0.100	1.330	0.368	0.344
	14 05	0025	7.7									
	14 05	0035	7.7									
	14 05	0045	7.7	6.2		515	7.90	161	0.070	1.340	0.378	0.342
	14 05	0055	7.7									
	14 05	0065	7.7									
	14 05	0075	7.7	6.2		520	7.90	162	0.080	1.370	0.370	0.335

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/13	10 20	0000	50.9J
72/09/15	17 45	0000	26.3J
72/11/13	14 05	0000	8.3J

J VALUE KNOWN TO BE IN ERROR

APPENDIX D

TRIBUTARY and WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 75/02/04

2631A1 LS2631A1
43 26 30.0 085 58 30.0
BROOKS CREEK
26 15 FREMONT
O/FREMONT LAKE
CO RD BRDG 1.5 MI S & 1.75 MI W FREMONT
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	09 30		0.126	2.650	0.700	0.250	0.315
72/12/03	08 15		0.410	2.400	0.190	0.008	0.370
73/01/07	08 15		0.147	2.600	1.230	0.345	0.390
73/02/04	09 00		0.220	2.200	1.020	0.330	0.360
73/03/04	09 25		0.273	2.700	1.100	0.330	0.375
73/04/06	08 50		0.290	2.800	0.870	0.290	0.360
73/04/25	11 15		0.210	2.100	0.022	0.200	0.450
73/05/12	11 15		0.220	1.890	0.115	0.210	0.340
73/06/02	09 13		0.210	2.200	0.300	0.220	0.300
73/06/23	10 45		0.154	1.500	0.065	0.126	0.240
73/07/11	14 30		0.105	1.100	0.016	0.060	0.160
73/07/27	17 10		0.110	1.050	0.015	0.018	0.065
73/09/29	11 30		0.260	1.400	0.027	0.095	0.195

STORET RETRIEVAL DATE 75/02/04

2531B1 LS2631B1
43 27 30.0 085 59 00.0
UNNAMED OUTLET OF LORDEN LAKE
26 15 FREMONT
T/FREMONT LAKE
CO RD XING W FREMONT LK 1.5MI SW FREMONT
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	09 40		0.410	1.700	0.220	0.091	0.160
72/12/03	08 35		0.220	0.630	0.168	0.037	0.110
73/01/07	08 45		1.400	2.100	0.200	0.074	0.120
73/02/04	09 20		1.080	1.150	0.168	0.062	0.105
73/03/04	09 20		1.000	2.967	0.620	0.154	0.345
73/04/06	08 40		0.126	1.300	0.050	0.018	0.085
73/05/12	11 00		0.085	1.260	0.032	0.029	0.085
73/06/06	09 50		0.380	2.200	0.231	0.120	0.210
73/06/23	10 30		0.430	1.680	0.198	0.168	0.210
73/07/07	10 15		0.390	1.470	0.310	0.200	0.330
73/07/27	17 30		0.630	1.680	0.240	0.180	0.220
73/08/25	08 45		0.260	0.800	0.018	0.088	0.095
73/09/29	11 25		0.660	1.150	0.530	0.357	0.410

STORET RETRIEVAL DATE 75/02/04

2631C1 LS2631C1
43 27 30.0 085 57 30.0
DAISY CREEK
26 15 FREMONT
T/FREMONT LAKE
CITY ST BRDG NEAREST LAKE BELO FREMT STP
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	10 50		0.280	2.550	0.700	0.357	0.580
72/12/03	08 55		0.360	2.940	0.500	0.350	0.610
73/01/07	09 05		0.590	2.600	0.400	0.190	0.340
73/02/04	09 40		0.730	2.600	0.880	0.270	0.440
73/03/04	09 00		0.810	2.700	0.930	0.220	0.570
73/04/06	08 30		0.520	2.600	0.490	0.380	0.680
73/04/25	10 45		0.336	3.990	1.600	0.420	0.720
73/05/12	10 40		0.450	1.200	0.180	0.220	0.420
73/06/06	08 30		0.770	5.900	0.810	0.420	1.650
73/06/23	10 15		0.350	2.310	0.180	0.520	0.820
73/07/07	09 50		0.300	2.000	0.231	0.580	0.800
73/07/27	17 50		1.420	4.700	2.400	1.500	1.720
73/08/25	08 20		0.294	3.000	0.650	0.490	0.980
73/09/29	13 15		0.290	1.890	0.270	0.350	0.630

STORET RETRIEVAL DATE 75/02/04

2631C2 LS2631C2
43 28 30.0 085 57 00.0
DAISY CREEK
26 15 FREMONT
T/FREMONT LAKE
AT DIVISION ST BRDG N FREMONT ABOV STP
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	11 05		0.137	0.750	0.164	0.012	0.035
72/12/03	09 20		0.150	1.780	0.126	0.005K	0.023
73/01/07	09 20		0.378	1.400	0.120	0.012	0.036
73/02/04	10 00		0.560	0.815	0.110	0.021	0.055
73/03/04	08 30		0.620	1.000	0.210	0.036	
73/04/06	08 00		0.357	0.770	0.037	0.019	0.047
73/04/25	12 30		0.230	0.580	0.008	0.013	0.020
73/05/12	10 00		0.240	0.610	0.016	0.008	0.025
73/06/06	09 40		0.260	1.890	0.170	0.038	0.075
73/06/23	10 00		0.198	1.050	0.072	0.032	0.045
73/07/07	09 30		0.084	1.380	0.069	0.033	0.040
73/07/27	18 15		0.147	0.950	0.056	0.026	0.040
73/08/25	08 00		0.075	0.750	0.054	0.020	0.030
73/09/29	11 05		0.077	1.380	0.075	0.016	0.030

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

263150 TF263150 P003760
43 27 30.0 085 57 30.0
FREMONT
26 15 FREMONT
T/FREMONT LAKE
FIRST LAKE OUTLET
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/01/29 08 00 CP(T)- 73/01/29 17 00			0.060	21.000	5.100	4.700	6.150	0.543	0.527
73/02/22 08 00 CP(T)- 73/02/22 17 00			0.040	26.000	8.900	4.200	8.000	0.415	0.468
73/03/20 08 00 CP(T)- 73/03/20 17 00			6.400	15.000	0.060	4.600	5.600	0.618	0.558
73/04/27 08 00 CP(T)- 73/04/27 17 00			0.009	26.000	8.150	4.000	6.800	0.499	0.472
73/05/30 08 00 CP(T)- 73/05/30 17 00			0.214	11.000	0.420	2.570	4.700	0.602	0.574
73/06/18 08 00 CP(T)- 73/06/18 17 00			0.110	27.750	4.200	7.300	8.200	0.532	0.547
73/07/26 08 00 CP(T)- 73/07/26 17 00			0.130	10.500	0.240	4.400	6.300	0.465	0.435
73/08/21 08 00 CP(T)- 73/08/21 17 00			0.039	12.600	0.210	3.600	6.000	0.475	0.437
73/09/21 08 00 CP(T)- 73/09/21 17 00			0.050	11.500	0.970	5.300	6.600	0.437	0.405
73/10/24 08 00 CP(T)- 73/10/24 17 00			0.054	11.000	0.390	3.600	5.800	0.465	0.390
73/11/19 08 00 CP(T)- 73/11/19 17 00			0.060	21.500	5.000	4.600	7.200	0.424	0.432
73/12/06 08 00 CP(T)- 73/12/06 17 00			0.120	11.500	2.730	2.400	4.750	0.580	0.438

STORET RETRIEVAL DATE 75/02/04

263150 TF263150 P003760
43 27 30.0 085 57 30.0
FREMONT
26 15 FREMONT
T/FREMONT LAKE
FIRST LAKE OUTLET
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
74/01/17 08 00 CP(T)- 74/01/17 17 00			0.080	21.000	7.200	4.700	6.800	0.417	0.435