Lyons - Skwarto Associates
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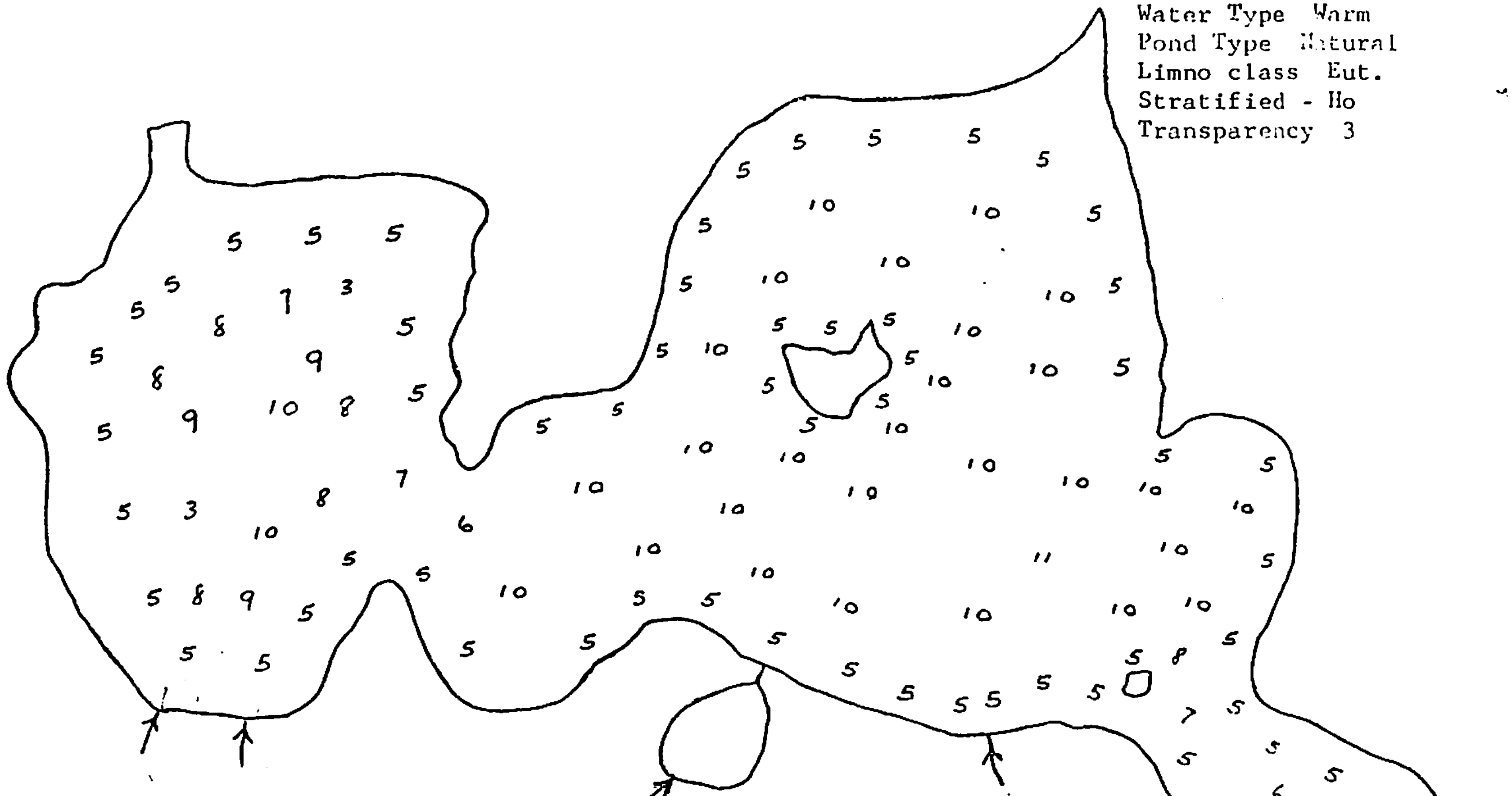
A STUDY OF BILLINGTON SEA, PLYMOUTH, MASSACHUSETTS

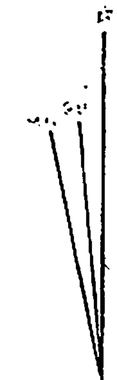
WITH GUIDELINES FOR REHABILITATION

LYONS - SKWARTO ASSOCIATES

BILLINGTON SEA

Plymouth Mass
USGS Map Plymouth
Watershed Coastal
Acres 269
Access Public Ramp
Altitude 0081
Water Type Warm
Pond Type Natural
Limno class Eut.
Stratified - No
Transparency 3





Pond use Irrigation Recreation Fishing Esthetic

Topo sheet up 11.0 R 9.0

Shoreline Distance 7.3 Miles

Retention Time 55 Days

IMPOUNDMENT MAP

BILLINGTON SEA - A Problem Lake

Eutrophication

Nutrient enrichment of waters

Man created - particularly in urban areas

Natural

Indices of eutrophication

Plant Production

Macrophytes - Billington Sea has been having very heavy infestation of aquatic plants. The target species is Elodea (common water weed) and infestation is about 70-80% out to the 5 foot contour line.

Microphytes - Algae blooms common in Billington Sea, in recent years blooms occur in months of July and August.

Nutrient Indicators

Phosphorous - High concentrations well over the accepted minimum promote algae and plant growth. Readings of total phosphorous from .06 to .09 mg/l are not uncommon. Orthophosphate reading is 2-3 times over the accepted .01 mg/l plant limiting level.

Nitrogen - Nitrate and ammonia nitrogen usually well above the bare minimum of .3 mg/l

Transparency - Secchi disc readings generally 4 feet as compared with readings on some Plymouth lakes of up to 18 feet (ex. Micajah, Long)

Oxygen ------ Dissolved oxygen readings average about 7.0 mg/l - this figure is well within current state and federal guidelines for recreational waters.

Depth ------- Shallow average depth is 5.5 feet.

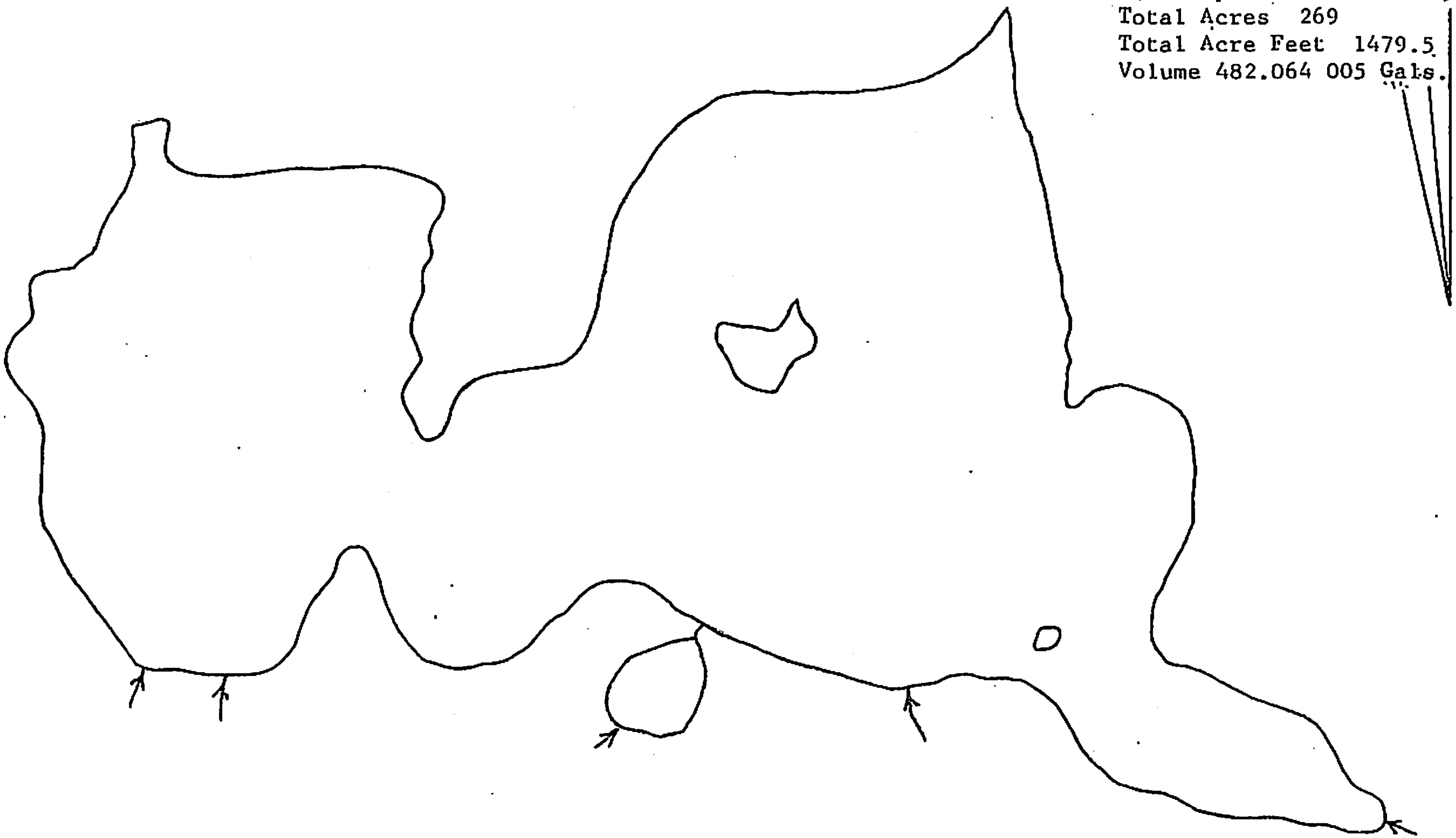
Stratification- Billington Sea is not stratified. Most eutrophic lakes tend to be shallow with a relatively extensive littoral zone.

Heavy Metals -- None to indicate industrial feeding.

Conclusion: Billington Sea is a highly eutrophic lake, with a prospect of generally worsening conditionsunless strong counter measures are instituted. These measures include testing in-lake tributaries and outfall; monitoring all parameters. Reaching conclusions, solutions, and obtaining funding. All these measures aim at offering methods of reducing the effects and rate of eutrophication of Billington Sea.

BILLINGTON SEA

Max Depth 11
Mean Depth 5.5
Total Acres 269
Total Acre Feet 1479.5
Volume 482.064 005 Gals.



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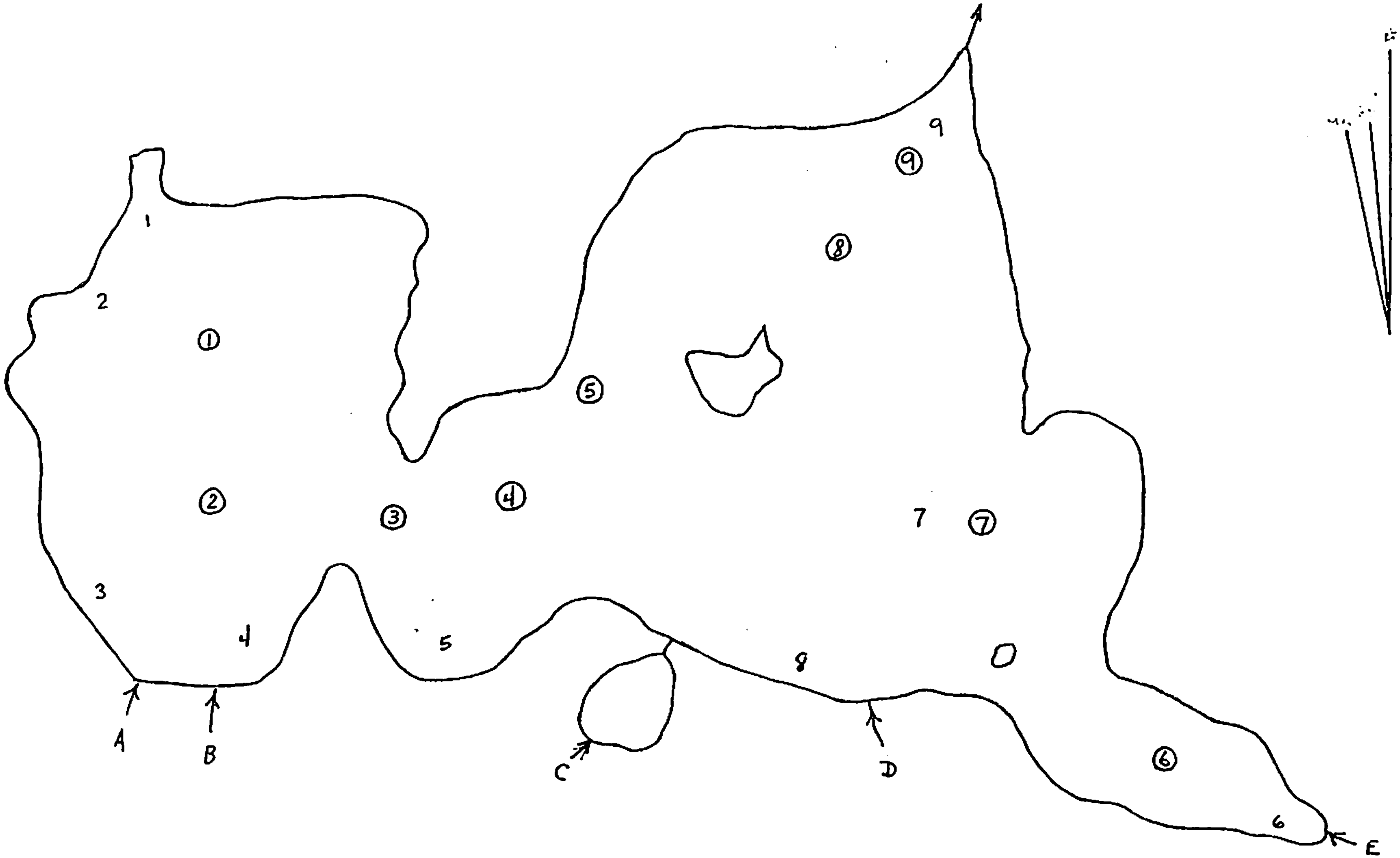
BILLINGTON SEA

Testing Stations



Original Stations 0

Finishing Stations 1-9

SECCHI DISC READINGS

June	3
July	3
August	4
September	4
October	5
November	5
Februray	5
March	5
April	4
May	4

D I S S O L V E D O X Y G E N

In unpolluted water dissolved oxygen is usually present in amounts of 10 mg/l or less.

About 3-5 mg/l is accepted as the lowest limit for support of fish life over a long period of time.

June ----------------	6.5
July ----------------	6.5
August --------------	7.5
September -----------	10
October -------------	10
November ------------	10
Mid-Winter ----------	9
February ------------	10
March ---------------	10
April ---------------	9
May -----------------	9

Above figures represent average of eight in-lake stations.

TEMPERATURE

(8 stations averaged)

	o F	o C
June	75	23.8
July	76	24.4
August	70	21.1
September	68	20.0
October	58	14.4
November	52	11.1
February	38	3.3
March	42	5.6
April	55	12.8
May	66	18.9

H A R D N E S S

Total Calcium Magnesium Mg/L

Station	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
1	17	19	20	17	17	18				18	19	20
2	22	21	22	20	20	19				19	20	19
3	23	20	20	21	21	20				19	20	20
4	18	17	19	20	20	19				20	20	19
5	20	22	20	20	19	18				19	20	19
6	21	24	23	22	22	23				22	19	20
7	24	17	20	20	23	23				23	21	20
8	22	16	20	19	20	21				21	19	20
OUTLET												
9	17	19	19	18	17	19	19	18	17	17	19	18
A	16	18	19	16	16	18	19	19	17	17	20	18
B	19	20	20	19	19	20	20	19	19	20	19	19
C	20	19	20	20	19	21	20	19	19	19	20	19
D	21	19	20	19	21	21	19	20	20	20	19	20
E	20	18	19	19	20	19	19	19	20	19	19	19

GEOLOGICAL SURVEY CLASSIFICATION

Mgs/L	
0-60	Soft
61-120	Moderatly Hard
121-180	Hard
180 +	Very Hard

I R O N

Station	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
1	.04	.03	.03	.03	.03	.02				.03	.03	.03
2	.03	.03	.02	.03	.03	.02				.02	.02	.03
3	.035	.03	.02	.03	.02	.03				.03	.03	.02
4	.02	.03	.03	.02	.03	.03				.02	.02	.02
5	.01	.02	.02	.02	.03	.02				.02	.03	.02
6	.02	.01	.03	.02	.03	.02				.02	.02	.02
7	.01	.02	.03	.02	.03	.02				.03	.02	.02
8	.02	.03	.02	.02	.02	.02				.03	.02	.02
OUTLET												
9	.02	.02	.02	.03	.02	.02	.03	.02	.03	.02	.03	.02
A	.01	.01	.03	.03	.02	.02	.02	.03	.02	.03	.02	.03
B	.02	.01	.01	.02	.01	.02	.02	.01	.02	.01	.02	.01
C	.03	.02	.02	.02	.02	.03	.02	.03	.02	.03	.03	.03
D	.02	.01	.02	.02	.01	.02	.02	.01	.01	.01	.02	.03
E	.02	.02	.01	.02	.02	.02	.02	.02	.01	.02	.01	.02

NORMAL RANGE USUALLY .02 ± mg/L

BLANKS - ICE COVER

NITROGEN

1. If inorganic nitrogen (ammonia and nitrate nitrogen) is equal to or greater than .3 mg/l, then lake is likely to have excessive crops of algae and other aquatic plants.

2. In general, nitrogen is readily transported in ground waters and, therefore, a significant part of the nitrogen going into septic tank systems will be transported to ground water if it is oxidized to nitrate and does not become denitrified.

3. Nitrate is very poorly absorbed by most aquifer materials and hence it is not uncommon to find nitrate nitrogen in ground waters at a mg/l. Nitrogen, as in the phosphate reading in this report, shows sandy soils retain little if any nitrates.

A M M O N I A

Presence of Ammonia in surface waters usually indicates domestic pollution or agricultural run-off.

FROM ALL TESTING DATA	Avg. in-lake stations	Avg. Tributary	Avg. Outlet
June	.3	.6	.6
July	.1	.1	.1
August	.1	.2	.1
September	.06	.1	.07
October	.05	.05	.05
November	.04	.05	.05
February	.02	.1	.05
March	.03	.05	.04
April	.02	.04	.03
May	.1	.1	.1

N.B. 3 mg/1 total ammonia and nitrate Nitrogen appears to be critical for algae blooms and macrophyte growth (Sawyer, Vollenweider)

NITRITES

Nitrites are not usually found in surface waters to any great extent, the presence of large quantities indicates a source of waste water pollution.

From all testing data (average inlet, outlet and in-lake stations):

MONTH	PPM
June	less than .01
July	" " "
August	" " "
September	" " "
October	" " "
November	" " "
February	" " "
March	" " "
April	" " "
May	" " "

N.B. Although sample data here is averaged, at no time did any given sample contain greater than .01 ppm.

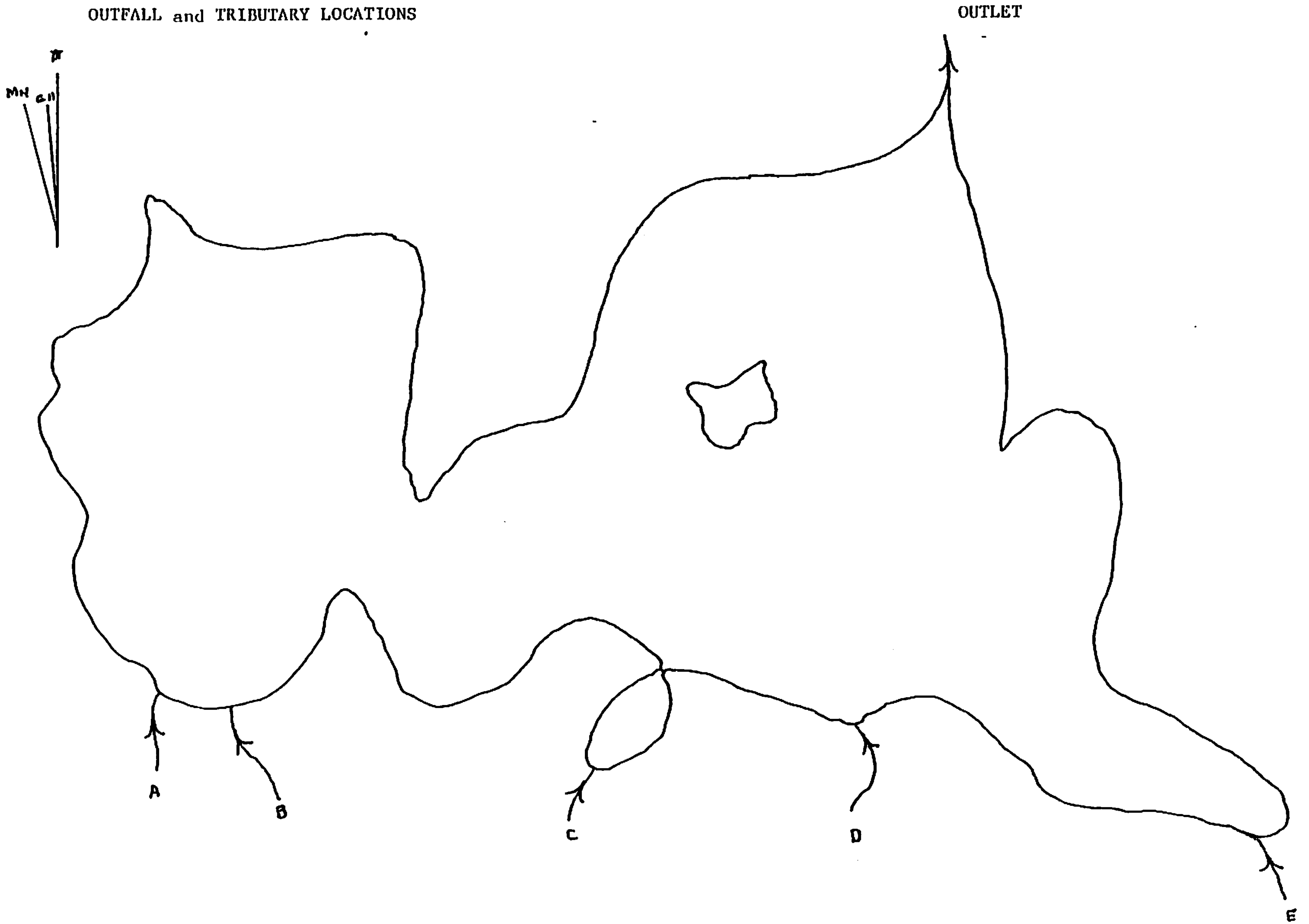
ORTHOPHOSPHATE

MONTH	IN-LAKE (AVG.)	TRIB (AVE.)	OUTFALL (AVE.)
June	.01	.015	.01
July	.02	.016	.025
August	.03	.02	.03
September	.02	.03	.03
October	.02	.05	.03
November	.01	.02	.01
February	.01	.03	.01
March	.02	.03	.02
April	.03	.04	.03
May	.03	.04	.03

N.B. If orthophosphate levels of .01 mg/l or greater occur, then the lake is susceptible to algae blooms and macrophyte growth (Sawyer, Vollenweider)

BILLINGTON SEA

OUTFALL and TRIBUTARY LOCATIONS



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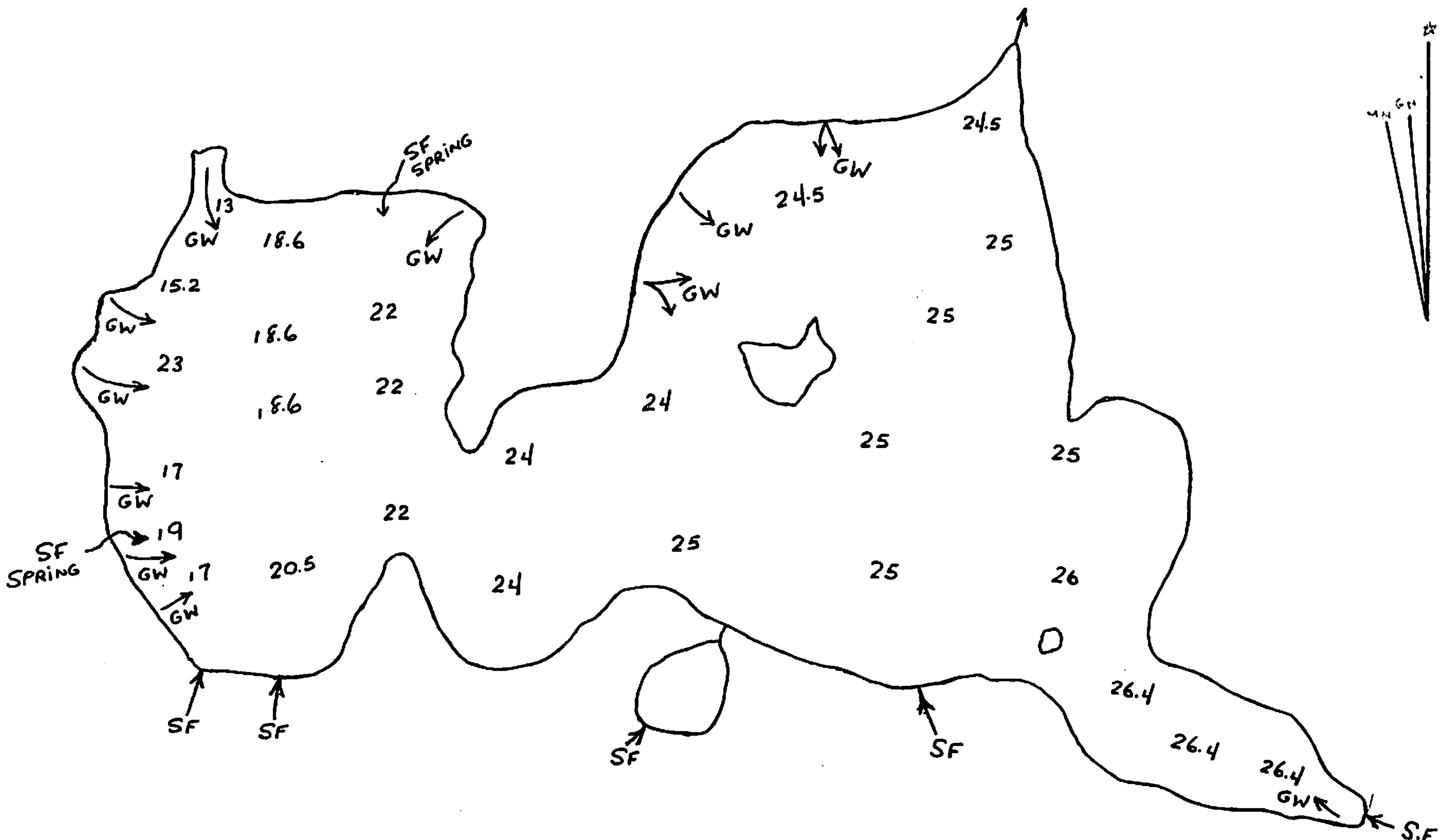
BILLINGTON SEA

Ground Water and Surface Flow Map



S.F. Surface Flow

G.W. Ground Water

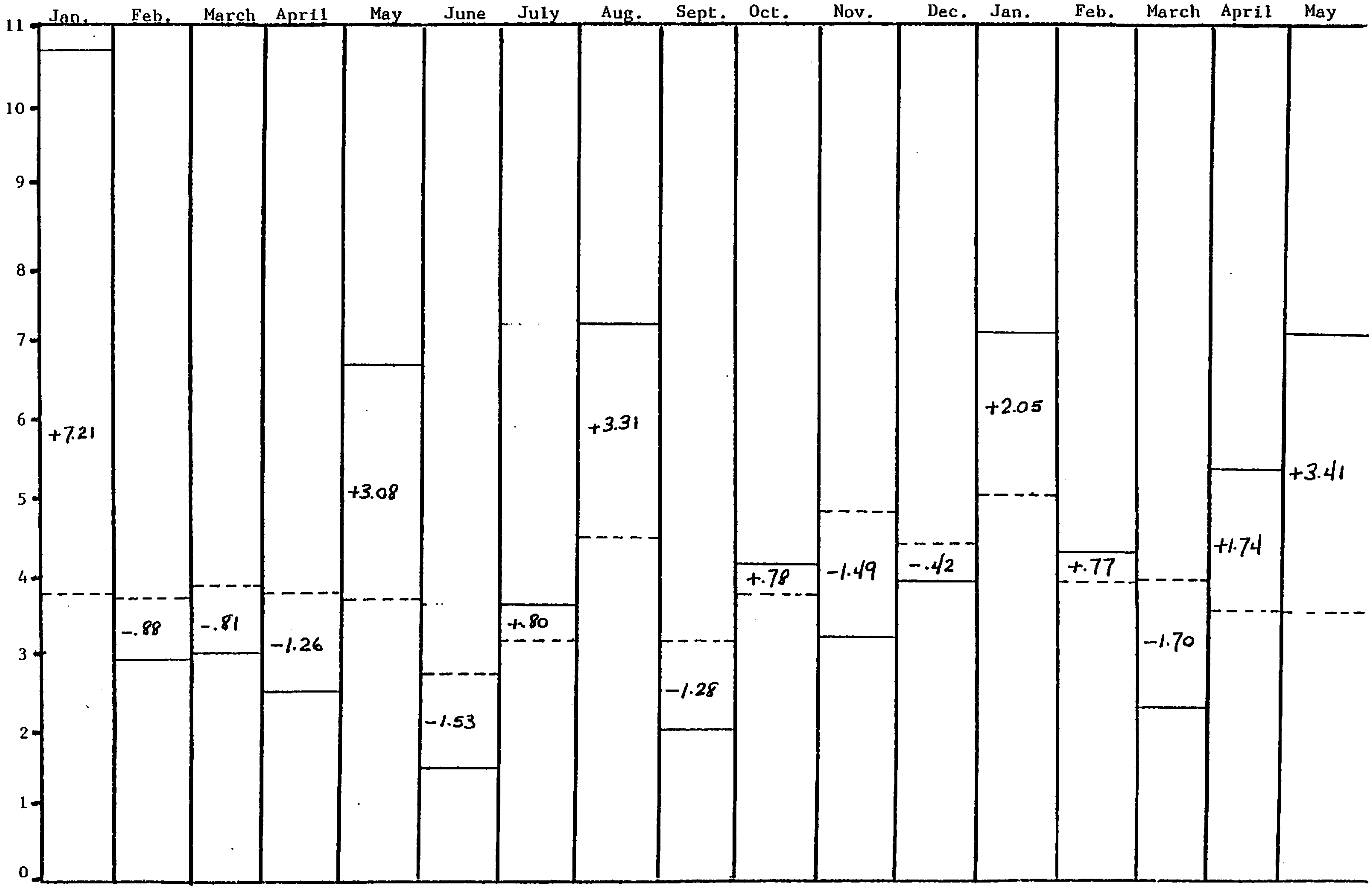
O Temp. at 3' from surface.

Scale 1:788

RAINFALL 1978

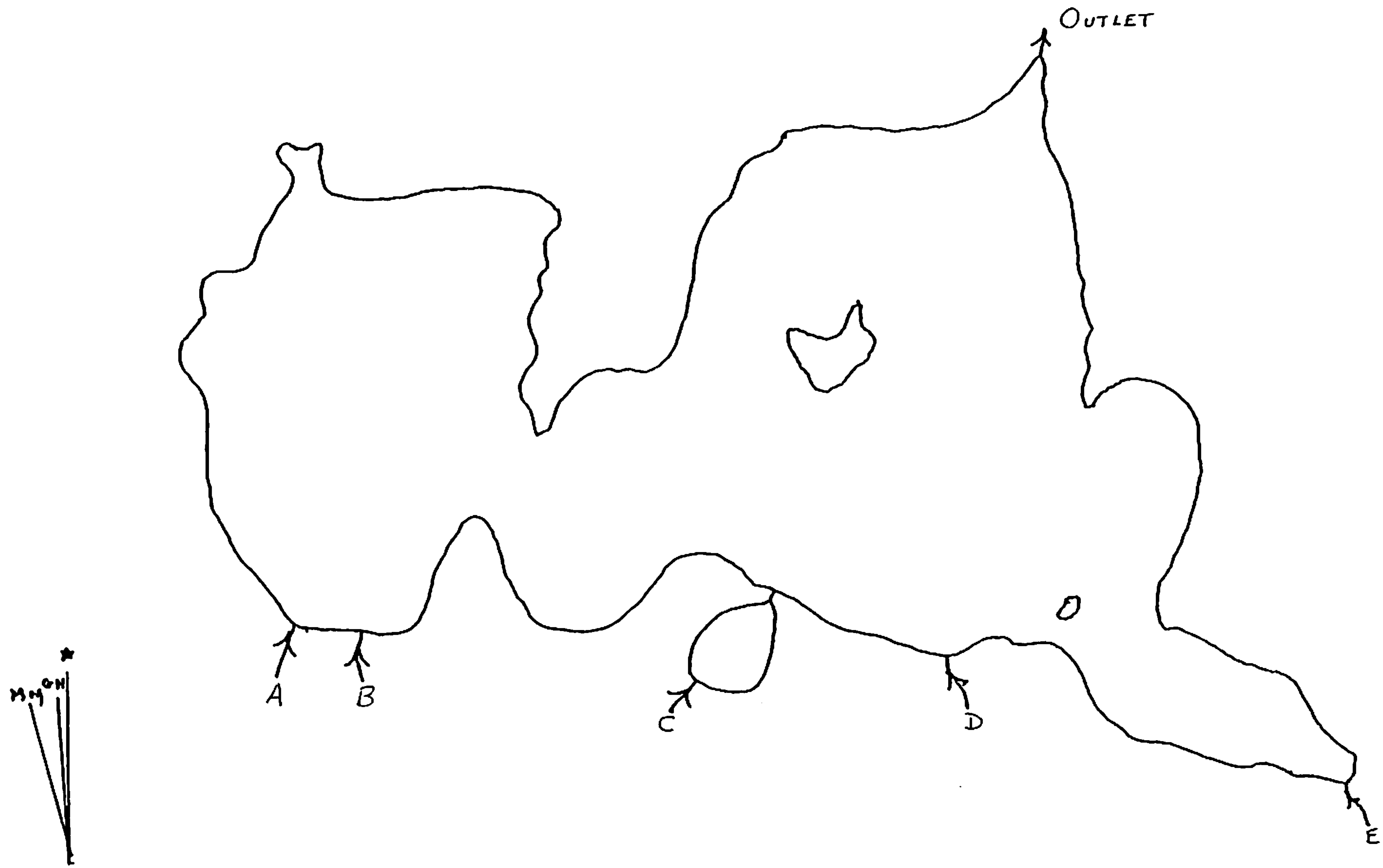
NORMAL - - - - - 44.24

ACTUAL ———— 51.73



BILLINGTON SEA

TRIBUTARY AND OUTLET LOCATION



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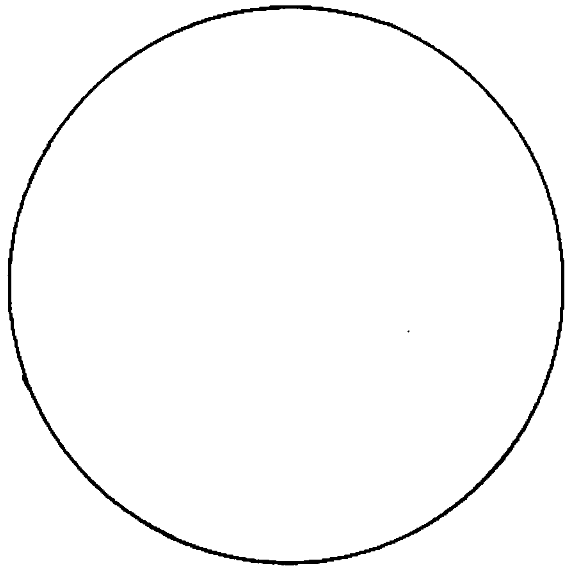
INLET "A"



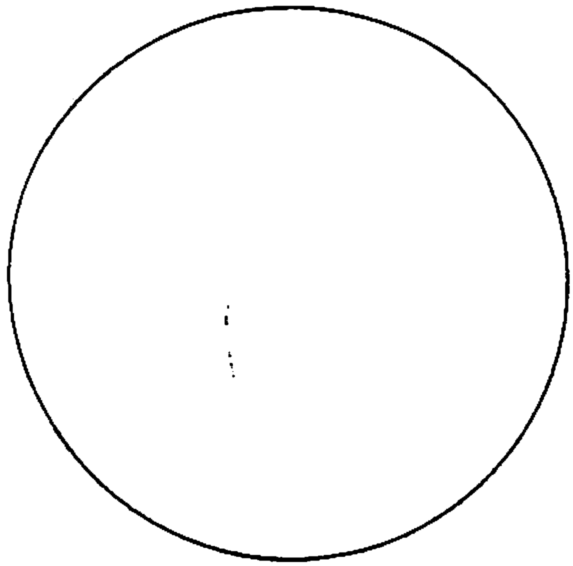
CULVERT

Pipe Size 24"

DELIVERY GALLONS PER MINUTE

June	42
July	36
August	86
September	107
October	131
November	84
December	72
January	128
February	68
March	65
April	64
May	90

INLET "C"



CULVERT

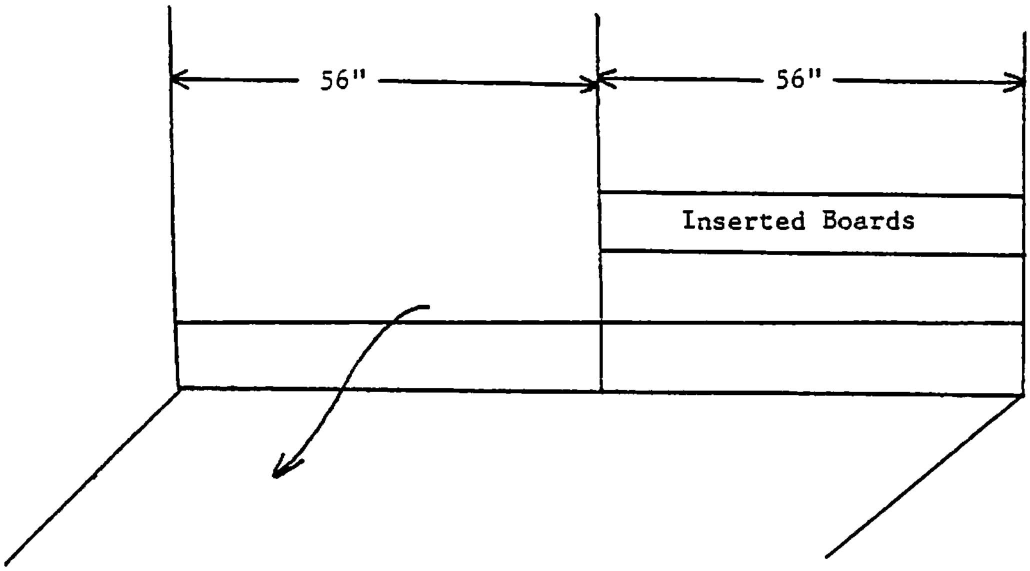
Pipe Size 24"

DELIVERY IN GALLONS PER MINUTE

June	237
July	256
August	261
September	302
October	411
November	385
December	315
January	320
February	375
March	380
April	370
May	365

INLET "D"

CRANBERRY BOARD TYPE DAM

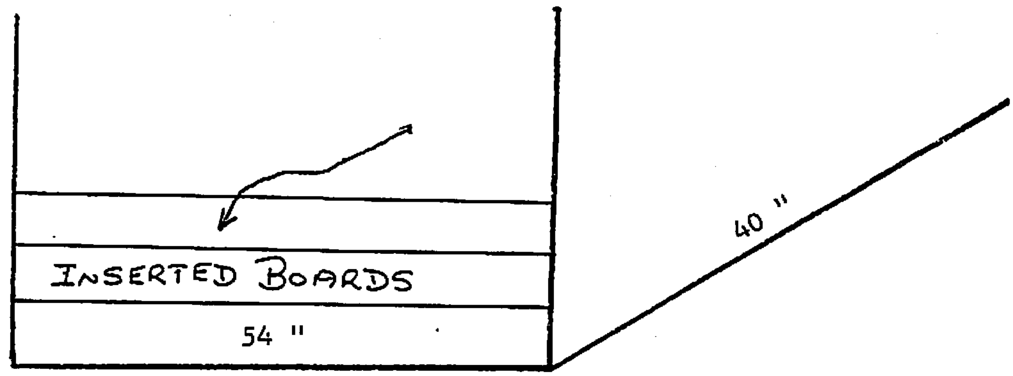


June	65	Gallons per Minute	1 Gate Partially Open
July	60	" " "	" " "
August	10	" " "	Both Closed, 1 Leaking
September	72	" " "	1 Gate Partially Open
October	750	" " "	Both Open (*1)
November	127	" " "	1 Gate Partially Open
December	110	" " "	" " "
January	140	" " "	" " "
February	70	" " "	" " "
March	98	" " "	" " "
April	72	" " "	" " "
May	130	" " "	" " "

(*1) ANNUAL FLOODING FOR HARVESTING.

INLET E

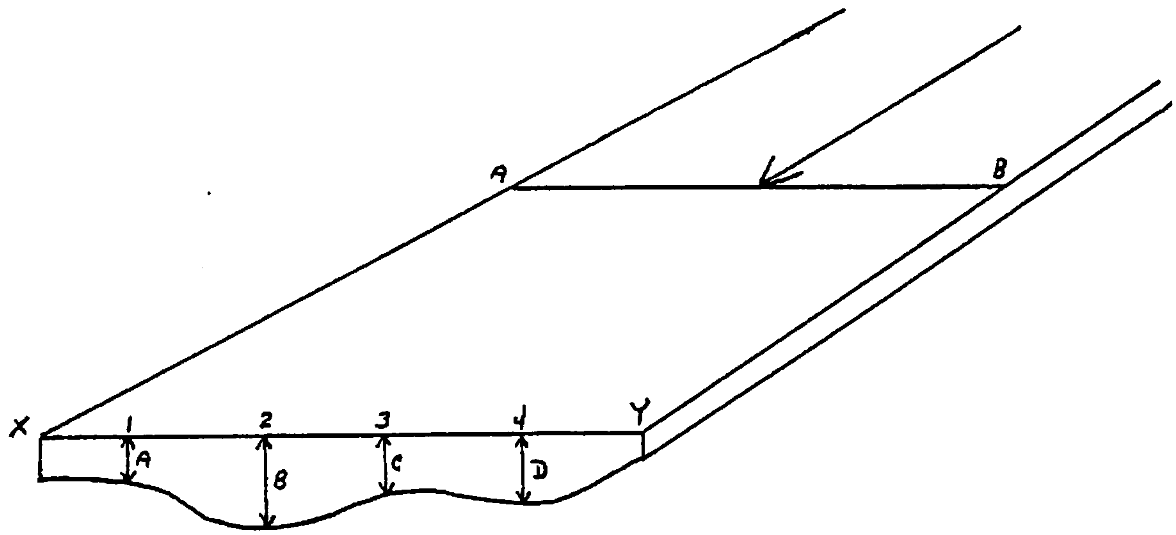
TYPICAL CRANBERRY BOG DAM



June	36	Gallons	per	minute	Gate	Open
July	34	"	"	"	"	"
August	41	"	"	"	"	"
September	40	"	"	"	"	"
October	215	"	"	"	"	" *
November	70	"	"	"	"	"
December	62	"	"	"	"	"
January	80	"	"	"	"	"
February	40	"	"	"	"	"
March	55	"	"	"	"	"
April	40	"	"	"	"	"
May	73	"	"	"	"	"

* Flooding for Harvesting.

OUTLET



X - 1 - 2 - 3 - 4 - 4 Equidistant

$\frac{A + B + C + D}{4}$ Av. Depth W.

X ⟶ Y Width

Speed of Flow 4 Feet in Seconds.

Area X ⟶ Y X AX XW = Cubic Feet X 7.48 Gallons H_2O per C.F.

DISCHARGE GALLONS PER MINUTE

June	6230	
July	7690	
August	8684	
September	6672	
October	5433	(*1)
November	8023	
December	8320	
January	8420	
February	7528	
March	8727	
April	8036	
May	8520	

(*1) Annual Bog Flooding for Harvesting.

HYDROLOGIC AND PHOSPHOROUS AND NITRATE (N) BUDGET

FEBRUARY 1978

INLET (GPM)		GAL./MONTH	tP (PPM)	LBS./MONTH	N (PPM)	LBS. /MONTH
A	68	2,741,760	.08	1.83	.35	8.0
B	150	6,048,000	.04	2.01	.20	27.7
C	375	15,120,000	.05	6.31	.55	69.4
D	70	3,124,800	.11	2.86	.10	2.60
F	40	1,612,800	.08	1.07	.60	8.08
OUTLET	7528	303,528,960	.05	126.69	.45	1140.2

TOTAL A+B+C+D+F = 14,087 115.78

DISCHARGE = 126.69 1140.2

IN LAKE LOADING 112.603 1024.42

TOTAL PHOSPHOROUS IN LAKE

			2012.8
482,226,920	.02	.5	100.64

FLUSH RATE 44.5 days

HYDROLOGIC AND PHOSPHOROUS AND NITRATE (N) BUDGET

MARCH 1978

INLET (GPM)		GAL./MONTH	tP (PPM)	LBS./MONTH	N (PPM)	LBS./MONTH
A	65	2,901,600	.04	.968	.28	6.78
B	134	5,981,760	.04	1.99	.03	1.50
C	380	16,963,200	.04	5.66	.71	100.5
D	98	4,374,726	.04	1.46	.03	1.1
F	50	2,455,220	.06	1.30	.07	.85
OUTLET	7528	303,528,960	.05	126.69	.12	304.06

TOTAL A+B+C+D+F = 11.376 110.73

DISCHARGE 126.69 304.06

IN LAKE LOADING 115.314 193.33

TOTAL PHOSPHOROUS IN LAKE

482,226,920 .02 .58 95.406

2334.85

FLUSH RATE 49 Days

HYDROLOGIC AND PHOSPHOROUS AND NITRATE (N) BUDGET

APRIL 1978

INLET (GPM)		GAL./MONTH	tP (PPM)	LBS./MONTH	N(PPM)	LBS. /MONTH
A	64	2,764,800	.09	2.07	.30	6.92
B	143	6,177,600	.09	4.64	.25	12.89
C	390	16,848,000	.05	7.03	.50	70.3
D	72	3,214,680	.07	1.88	.25	6.70
F	40	1,728,800	.09	1.30	.10	1.44
OUTLET	8036	347,155,200	.02	57.96	.30	869

TOTAL A+B+C+D+F	=	16.92	98.25
DISCHARGE	=	57.96	869
IN LAKE LOADING		41.04	770.75

TOTAL PHOSPHOROUS IN LAKE

482,226,920	.02	90.57
	.52	2113.44

FLUSH RATE 41.67 Days

HYDROLOGIC AND PHOSPHOROUS AND NITRATE (N) BUDGET

MAY 1978

INLET	(GPM)	GAL./MONTH	tP (PPM)	LBS./MONTH	N (PPM)	LBS./MONTH
A	90	4,017,600	.08	2.68	.30	10.0
B	157	7,008,480	.06	3.51	.30	17.55
C	365	16,293,600	.04	5.44	.40	54.4
D	130	5,803,200	.05	2.42	.25	12.11
F	73	3,258,720	.04	1.08	.08	2.17
OUTLET	8520	380,332,800	.02	63.49	.30	952.5

TOTAL A+B+C+D+F =	15.133	96.23
DISCHARGE =	63.49	952.5
IN LAKE LOADING	48.36	856.27

TOTAL PHOSPHOROUS IN LAKE

482,226,920	.02	90.57
	.525	2113.4

FLUSH RATE 39 DAYS

HYDROLOGIC AND PHOSPHOROUS AND NITRATE (N) BUDGET

JUNE 1978

INLET (GPM)		GAL./MONTH	tP (PPM)	LBS. P/MONTH	N(PPM)	LBS./MONTH
A	42	1,814,400	.03	.45	.2	3.02
B	120	5,184,000	.02	.86	.2	8.66
C	237	10,238,400	.02	1.70	.6	51.28
D	64	2,808,000	.03	.70	.3	7.03
F	36	1,555,200	.03	.389 4.104		
OUTLET	6230	269,136,000	.03	67.40	.25	561.68
GROUND WATER		247,000,536				

TOTAL PHOSPHOROUS	A+B+C+D+F	4.104	LBS.	69.69
	DISCHARGE	67.40	LBS.	561.68
	In-Lake Loading	63.30	LBS.	491.99

TOTAL PHOSPHOROUS IN LAKE	8 Station Av.	.0255	102.65 In-Lake
Gals. 482,326,920		0.19	754.80

LAKE FLUSH RATE: 53.75 DAYS

HYDROLOGIC AND PHOSPHOROUS AND NITRATE (N) BUDGET

JULY 1978

INLET	(GPM)	GAL./MONTH	tP (PPM)	LBS. P/MONTH	N(PPM)	LBS./MONTH
A	36	1,607,040	.04	.53	.2	2.68
B	112	4,999,680	.03	1.25	.1	4.17
C	256	11,427,840	.03	2.86	.8	76.32
D	60	2,678,400	.03	.67	.3	6.7
F	34					
TOTAL OUTLET	7690	343,281,600	.05	143.38	.3	859.7

TOTAL PHOSPHOROUS	A+B+C+D+F	=	5.31	89.87
	DISCHARGE		143.28	859.7
TOTAL IN-LAKE			137.97	769.83

Gals. in·lake	8 Station Av.	
482,226,920	.03	120.77
	.22	905.76

FLUSH RATE 43.5

HYDROLOGIC AND PHOSPHOROUS AND NITRATE (N) BUDGET

AUGUST 1978

INLET	(GPM)	GAL./MONTH	tP (PPM)	LBS./MONTH	N(PPM)	LBS./MONTH
A	86	3,839,040	.04	1.28	.2	6.40
B		5,580,000	.03	1.39	.1	4.66
C	261	11,251,040	.03	2.92	.9	28.18
D	10	446,400	.03	.11	.3	1.11
F						
TOTAL	8684	387,653,760	.07	226.52	.3	970.8

TOTAL PHOSPHOROUS A+B+C+D+F = 5.75 LBS. 40.35

DISCHARGE = 226.52 LBS. 970.8

TOTAL IN LAKE 230.77 LBS. 930.45

Gals. In Lake 8 Station av. .03 120.76
.2 805.12
482,226,920

FLUSH RATE 38.5 DAYS

HYDROLOGIC AND PHOSPHOROUS AND NITRATE (N) BUDGET

SEPTEMBER 1978

INLET (GPM)		GAL./MONTH	tP (PPM)	LBS. P/MONTH	N (PPM)	LBS./MONTH
A	53	2,289,600	.06	1.14	.3	5.73
B	106	4,579,200	.02	.76	.35	13.38
C	302	13,046,400	.02	2.17	.63	68.61
D	72	3,110,400	.03	.73	.05	1.30
F	40	1,728,000	.02	.29	___	___
TOTAL INLETS	573	24,753,600		5.13		
OUTLET	5905	255,096,000	.05	106.47	.29	617.56
GROUND WATER		230,342,400	.04	76.91	.05	96.14

TOTAL PHOSPHOROUS A+B+C+D+F = /Month 5.128 89.02

DISCHARGE = /Month 106.47 617.56

IN-LAKE LOADING = /Month 101.34 (76.9 Aquifers)
(24.44 From In-Lake)
528.54

TOTAL PHOSPHOROUS IN-LAKE (FIGURE DOES NOT INCLUDE BENTHOS, MACROPHYTES OR MICROPHYTES)

Gals. IN-LAKE 482,226,920 8 station av. .05 211.26 IN-LAKE
.48 1952.4

At 25.3 Mg Allowable per year = 4.6 lbs. per month av.

LAKE FLUSH RATE: 56.71 DAYS

HYDROLOGIC AND PHOSPHOROUS AND NITRATE (N) BUDGET

OCTOBER 1978

INLET	(GPM)	GAL./MONTH	tP (PPM)	LBS./MONTH	N (PPM)	LBS./MONTH
A	131	5,847,846	.07	3.41	.22	10.74
B	141	6,294,240	.04	2.10	.24	12.61
C	411	18,347,040	.01	1.53	.64	98
D	215	9,597,600	.07	3.20	.33	26.4
F						
TOTAL OUTLET	5,433	242,529,120	.04	80.98	156	1133.8

TOTAL PHOSPHOROUS A+B+C+D+F = 10.24 LBS. 147.7

DISCHARGE = 80.98 LBS. 1133.8

TOTAL IN LAKE 70.74 LBS. 986.1

Gal.in lake	8 Station av..	.02	100.64 LBS.
482,226,920		.67	2721.3

FLUSH RATE 61.6 Days

HYDROLOGIC AND PHOSPHOROUS AND NITRATE (N) BUDGET

NOVEMBER 1978

INLET (GPM)		GAL./MONTH	tP (PPM)	LBS./MONTH	N(PPM)	LBS./MONTH
A	84	3,628,800	.06	1.81	.15	4.54
B	157	6,782,400			.12	6.79
C	385	16,632,000	.06	8.23	.09	12.5
D	127	5,669,280	.05	2.36	.02	.94
F						
TOTAL						
OUTLET	8,023	346,593,600	.04	115.7	.05	144.7

TOTAL PHOSPHOROUS A+B+C+D+F = 12.4 LBS. 24.76
DISCHARGE = 115.7 LBS. 144.7

TOTAL IN LAKE 103.3 LBS. 119.94

Gal. in lake 8 Station av.. .02
.27 1107.0
482,226,920

FLUSH RATE 41.73

CRANBERRY BOGS

(Background Information)

For every acre of cranberry bogs 1/40 - 1/50 is ditches.

Crop production approximately 100 barrels/acre.

Total nitrogen applied 30 lbs. per year per acre.

Total phosphorous applied 30 lbs. per year per acre.

Balanced fertilizer (usually 16-16-16 or 20-20-20) is applied by hand cyclone application.

New evidence shows that cranberries apparently do not use nitrate nitrogen, some growers are switching to ammonium sulfate or urea base to give ammonium nitrogen and eliminate nitrate nitrogen.

Fertilizer application occurs in early May, June and July and 2-3 weeks before flooding.

Flooding occurs twice yearly - once in the fall for picking and once in the winter for protection.

Flooding height is 1-1.½ feet per acre.

Irrigation is used for frost control (hence, only 2 floodings for past ten years.)

Irrigation rate is 50 gals. per minute per acre (usually from 1 A.M. to 8 P.M.) or 1/10 inch per hour.

Chemicals used:

Fertilizer: 16-16-16

20-20-20

Weed Killers:

Dow Pon

Casciron

Piquat

Fungicide: Ferbam

Insecticides:

Parathion 3/4 pint per acre 8 lb. flowable - 2 times per year.

Sevin 4 lb./A.I. - 2 qts. per acre per year.

No diazinone is used on bogs around Billington Sea.

Additional Fertilizer Information: 100 barrels of cranberries per acre depletes 23 pounds of nitrogen per year and 20 pounds of phosphorous per year. Applied rates of fertilizer are 30 pounds of nitrogen and 30 pounds of phosphorous per year. The difference, theoretically, is for plant growth (roots, leaves, stems).

HYDROLOGY

The Plymouth aquifer occupies nearly all of Plymouth and parts of Carver, Wareham and Bourne. This aquifer is naturally recharged by precipitation and an unknown amount of ground water that moves in from nearby sources.

The water table in the Gloucester - Carver soil series varies, sometimes as deep as 80 - 90 feet, and near ponds and lakes as shallow as 10 feet or less. Generally, this is an excellent source of large supplies of water in areas having more than 50 feet of saturated thickness.

Generally, surface run-off is very low and infiltration capacity is very high in the Carver - Gloucester soil associations.

The water quality is generally good with the following chemical characteristics: ground and surface waters are soft, low in dissolved mineral content, slightly acid, with some iron, and usually well within recommended limits of U.S. Public Health Service for drinking water.

G E O L O G Y

Billington Sea is located in the Carver-Gloucester Soil Association. The Carver-Gloucester Soil Association extends southward from the Town of Plymouth and covers much of the southeastern part of the county. Carver soils occupy about 50% of the association and Gloucester soils 40% with the balance filled by secondary soil associations.

"Carver series soils consist of excessively drained, nearly level to steep sandy soils that formed in thick deposits of coarse, pebbly quartz sand. These soils are the coarsest textured in the county and occupy much of the pitted and dissected outwash plain in the southeastern part of the county."

"Gloucester series soils are nearly level to steep, well drained,and somewhat excessively drained soils that formed in glacial till derived chiefly from granite.

Gloucester soils are extremely stony except where they have been cleared for tillage."

In most places Carver soils are coarse sand, but in some places the surface layer and the upper part of the subsoil are loamy coarse sand.

Water moves rapidly downward through the solum and the under lying substratum, these soils do not retain sufficient moisture for good plant growth, and are extremely acid.

Carver soils are excessively drained; the permeability of Carver soils is a rapid 6.3 inches per hour - this was the most rapid classification listed in the soil survey of Plymouth County.

The coarseness and permeability causes applied fertilizer to be rapidly leached and lost.

The characteristics of the Carver soils make the whole ecosystem susceptable to groundwater contamination. Many of the lakes, ponds, and kettle holes in Plymouth are fed by aquifers, and any nutrients transferred by this means aids in the eutrophication of these systems. Long-range safeguards must be implemented to protect this valuable natural resource.

SOIL MAP KEY

CcD - Carver Gloucester Soils 8-35% Slopes

CaB - Carver Course Sand 3-8% Slopes

Sb - Sanded Muck

Pe - Peat

HaE - Hinckley Gravelly Loamy Sand 15-35% Slopes

CaE - Carver Coarse Sand 15-35% Slopes

CbB - Carver Loamy Coarse Sand 3-8% Slopes

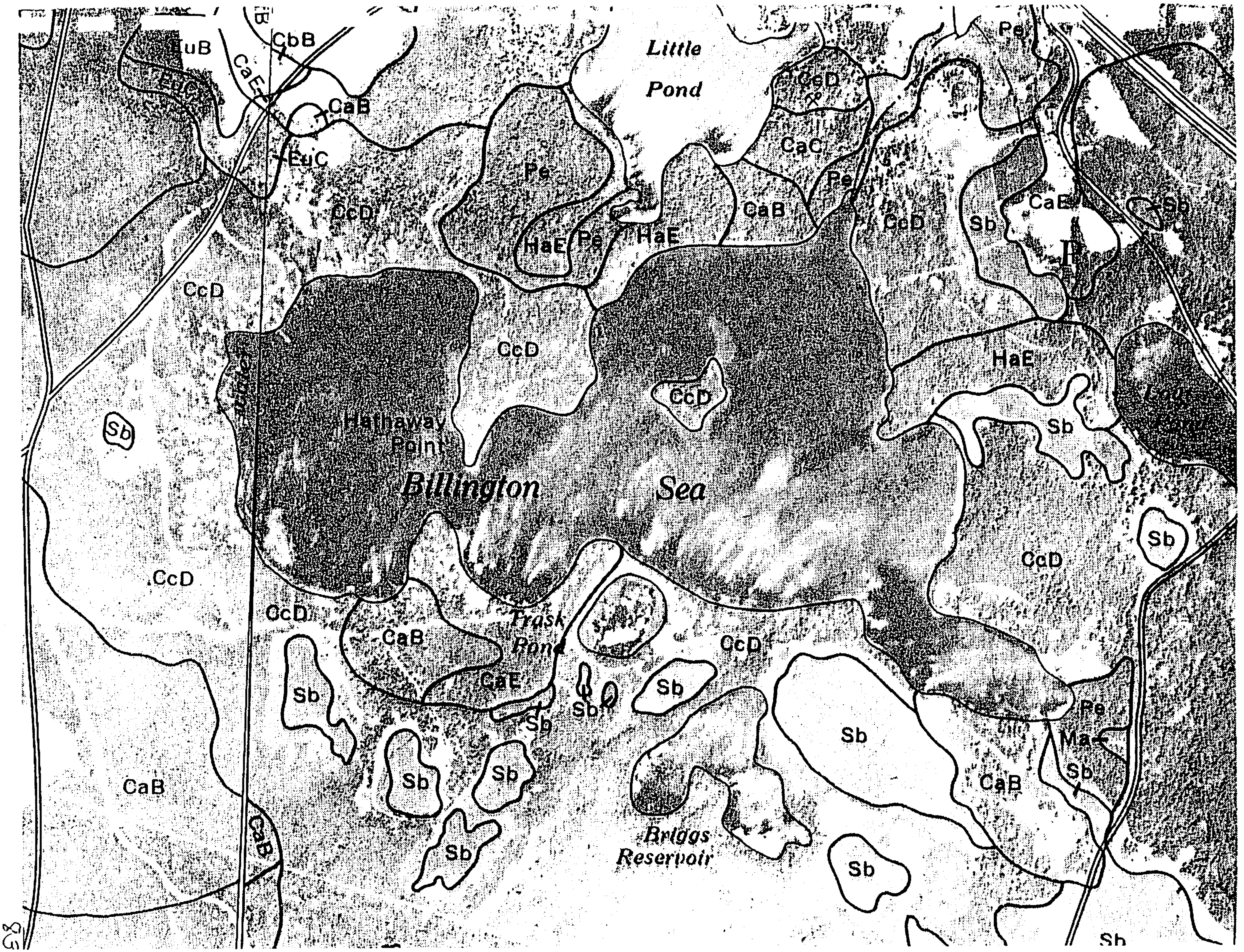
CaC - Carver Coarse Sand 8-15% Slopes

CbC - Carver Loamy Coarse Sand 8-15% Slopes

MfB - Merrimac Sandy Loam 3-8% Slopes

Ma - Made Land

HaC - Hinckley Gravelly Loamy Sand 8-15% Slopes


Little
Pond
Billington
Sea
Hathaway
Point
Trask
Pond
Briggs
Reservoir
CaB
CaC
CaE
CbB
CcD
EuB
EuC
HaE
Pe
Ma
Sb

GUIDELINES FOR REHABILITATION

OF

BILLINGTON SEA

LONG RANGE CONTROL TECHNIQUES

IN-LAKE MANAGEMENT METHODS

LONG RANGE CONTROL TECHNIQUES.

1. Controlling Nutrient and Sediment Influx

2. Watershed Management

    A. Non-Structural

    B. Structural

VOLUNTARY PHOSPHATE BAN

Though few studies have been made in depth, reports by Sawyer (32) and Vollenweider (17) pertaining to Wisconsin and Swiss lakes respectively indicate that when inorganic nitrogen (ammonia plus nitrate nitrgen) is equal to or greater than .3 mg/1 and the orthophosphate is equal to or greater than .01 mg/1, then the lake is likely to have excessive crops of algae and other aquatic plants.

A recent study make in Vermont showed that all the lakes so tested were found to be phosphorous limited.

A Cornell research team conducted a study of 13 lakes in central New York - this study led to a quantitative expression of the relation between phosphorous loading and concentrations of algae.

Phosphorous in runoff occurs in 3 general forms:

1. Dissolved organic
2. Dissolved inorganic
3. Particulated

The dissolved phosphorous in both forms has a far more important influence on algal growth than has phosphorous which is attached to soil particles.

Sources of Dissolved Phosphorous:

Sewage - 55%

Agricultural runoff - 18%

Forest runoff - 15%

Residential runoff - 6%

Atmospheric fall-out - 6%

Studies have shown that approximately 50% of the phosphorous present in domestic waste water is derived from the phosphorous that is used in various cleaning compounds such as detergents.

Phosphate is usually strongly absorbed by aquifer materials except in sandy areas. Quartz and other sands that have low iron, carbonates, aluminum, clay mineral, and organic content will readily transport phosphate in ground water.

In sandy soil such as those contacted in southern Massachusetts, it is found that the sorption capacity of the sandy soil is exceedingly small with the results that septic tank disposal systems located in the watershed area with sandy soil rarely have problems with plugging. Those systems readily transmit the nutrients from the household to a nearby water course via ground water. High phosphorous readings in aquifer and springs feeding Billington Sea are evidence of this phenomenon.

According to a Cornell study, the phosphorous content of domestic sewage ranges from 1-2 kilograms (2.2 - 4.4 lbs.) per capita per year depending primarily on whether laundry detergents containing phosphates are being used by householders.

Various researchers have recorded the annual per capita contribution of phosphorous in pounds from domestic sewage as 2-4 (Bush - Mulford 1954); 2.3 (Metzler et al 1958); 1.9 (Owen 1953); and 3.5 (Sawyer 1965).

The eutrophication of a lake can be controlled or its effects on water minimized by reducing the nutrient input into the lake, increasing nutrient output from the lake, immobilizing nutrients within the lake and controlling excessive growths of algae and macrophytes within the lake.

Most lakes, so studies indicate, are phosphorous limited, any reduction in their phosphorous loading may slow their eutrophication. One sure method of reducing phosphorous loading is to reduce the amount of phosphorous entering water treatment facilities and domestic waste water facilities (septic systems).
As phosphate detergents may contribute over 50% of the phosphorous in domestic wastewaters, eliminating this source can have a significant impact. The solution is simple: stop using detergents with phosphates and use phosphate-free detergents.

A voluntary local ban or even a state-wide ban of household laundry detergents and cleaning fluids containing more than .5% phosphorous.

Advantages:

1. Better water quality
2. Algae free lakes and ponds
3. No cost to state or town

Disadvantages:

1. There may be a slight added cost to consumer
2. Ring around the collar

How:

1. Newspaper articles
2. Local radio
3. Town government

This is classified as a long-range control technique but an immediate execution will initiate an in-lake comeback.

LOCATING FAULY SEPTIC SYSTEMS AROUND BILLINGTON

DYE METHOD

A. Long Time For Results

B. Access Problem

C. Many Small But Complex Problems

D. High Cost

SEPTIC SNOOPER

A. Minimal Time

B. No Access Problem

C. Very Simple In Application

D. Low Cost

E. Data Is More Special And Discriminating

   1. This factor allows for far superior planning techniques and can represent substantial savings.

This is a very useful tool in pinpointing nutrient influx by tracing septic leachate. Gives exact location of septic plumes by surveying perimeter of lake where homes are located.

Estimated cost for 2 miles of shoreline on Billington Sear about $2,000.

Time: 2 days.

NON-STRUCTURAL CONTROL TECHNIQUES

1. ZONING REGULATION

   A. MINIMUM LOT SIZES

   B. BUILDING SET BACKS

   C. DISCOURAGE DEVELOPMENT OF PORTIONS OF SHORELINE

   D. RESTRICT HIGH POLLUTION GENERATING SOURCES

      1. NEAR SHORE

      2. NEAR TRIBUTARIES

      3. IN FLOOD PLAINS

2. DEVELOPMENT CONTROL

   A. RESTRICT DIVISION OF LAND FOR BUILDING OR SETTLING

   B. LIMIT DEVELOPMENT IN EROSION AREAS

   C. LIMIT DEVELOPMENT IN AREAS WHERE SOIL CHARACTERISTICS PREVENT ADEQUATE ON-SITE WASTE DISPOSAL.

   D. ENCOURAGE FORMS OF DEVELOPMENT WHICH FACILITATE EFFECTIVE AND ECONOMIC WASTE DISPOSAL PRACTICES AND PRESERVATION OF NATURAL SPACES.

ZONING REGULATION

Lot sizes should depend on:

1. Soil conditions

   The state of Maine uses an in-depth soil percolation method called site evaluation for subsurface waste water disposal - it includes guidelines for monitoring high ground water levels.

2. Environmental conditions

   Such considerations include size of developments, if ground water water can become contaminated with large numbers of dwellings and/or businesses.

Building set-backs:

State of Maine has established a minimum distance of 100 feet from leaching field to any river, stream, lake, pond, ocean or drinking-water supply.

Discourage development of shoreline:

Use these areas as non-polluting recreation areas.

Restrict high pollution generating sources:

Especially in areas that could possibly contaminate groundwater.

It is possible that one of the best methods to control nutrient in-flux for a given lake is to control land use within the watershed.

NON-STRUCTURAL DEVELOPMENT CONTROL

DEVELOPMENT CONTROL

Lot size should be determined by actual soil type with particular interest devoted to:

1. The soil's hydraulic capabilities
2. The soil's purification capabilities
3. Any physical constraints

Some soils like the Carver series pecolate water rapidly but such soils are inadequate in terms of removing wastewater impurities such as bacteria, phosphorous and nitrogen. It is these impurities that can cause ground and surface water pollution.

To best determine the above 3 factors a soil evaluation program should be established (the state of Maine guidelines are recommended). The site evaluation would determine whether a specific parcel of land would be considered suitable for the proposed disposal system.

Slope should be another limiting factor on lot sizes; the difficulty of designing and building adequate absorption fields on steep slopes, as well as erosion problems associated with steep slopes call for further adjustment of lot sizes according to the capability of the natural slope.

Other factors to be considered are ground water flow, watersheds, nearby wells and streams, topography, vegetation and ground cover.

Where soil characteristics prevent adequate on-site waste disposal or if an area is heavily developed, closed system sewage disposal is recommended. Included in closed systems are:

1. recirculating toilets
2. gas incinerating toilets
3. electric incinerating toilets
4. composting toilets
5. chemical toilets
6. low water flush toilets
7. vacuum toilets
8. sewerless toilets

A list of manufacturers is included in the Addenda.

Investigations (Childs 1972A, Childs 1972B, Dudley and Stephensen, 1973) indicate that problem areas occur:

1. Where coarse sands and gravel are the principal subsoil materials.
2. Very impermeable materials where effluent may become ponded above horizons at short distances from point of release.
3. In poorly drained soils with high water table.

DEVELOPMENT CONTROL

C. Limit development in areas where soil characteristics prevent adequate on-site waste disposal, or if developed use closed system sewage disposal.

1. Recirculating toilets
2. Gas incinerating toilets
3. Electric incinerating toilets
4. Composting toilets
   (used in EPA grant - Sturgridge, Mass.)
5. Chemical toilets
6. Low water flush toilets
7. Vacuum toilets
8. Sewerless toilets

Manufacturers listed in the report.

Soil characteristics can best be determined by using the state of Maine guidelines, e.g. soil evaluation for subsurface wastewater disposal in Maine.

Site evaluation combines on-site soil evaluation along with consideration and review of site conditions such as ground water flow, watersheds, nearby wells and streams, topography, vegetation, and so on.

STRUCTURAL CONTROL TECHNIQUES

A. DIVERSION

B. CATCH BASINS

C. SOIL EROSION CONTROL

D. SANITARY LANDFILL LEACHATE

E. SEWERING

DIVERSION

The most frequently used method to reduce lake eutrophication is to divert waste waters around or away from the lake. The various tributaries feeding Billington Sea are contributing 10-11% of the annual nutrient influx. When bogs are flooded and then released into the ecosystem, excess nutrients and foreign organic matter are fed into the system. Billington Sea's hydrologic and nutrient budgets have no need of these superfluous "feeders".

Diversion of nutrient rich water away from eutrophying lakes and ponds will be encouraged by the State when:

1. Sewage treatment plant effluent or storm sewer outflow enters a lake or pond by its tributaries or direct outfall.
2. Rerouting of the inflow does not have a significant negative impact on the biota or hydrologic cycle of the system, adjacent wetlands or any other riparian habitats within the course of diversion.
3. Further treatment of wastewater or storm water cannot render it nutrient-impoverished, or is not cost-effective.

If all other procedures were to be implemented the above method would not be needed based on a percentage contribution of nutrients, however, it is recommended that the town engineers look into the possibility and feasibility of diversion, especially of waters released by flooding. As stated previously, Billington Sea has no need of these nutrient rich tributaries to maintain its water level or to add further nutrients to an already overburdened nutrient budget.

CATCH BASINS, RECHARGE BASINS, SETTLING PONDS, SEDIMENT BASINS.

1. Many of various means to intercept nutrients before entering the lake system. Storm water runoff is discharged directly into the lake at present.

2. Sediment and nutrient loading of tributaries by storm water is significant.

A sediment basin is a small impoundment which retains storm water runoff long enough to allow heavier sediment particles to settle to the bottom of the basin. They can be constructed in various ways, such as a dam forming a basin with runoff provided by a perforated vertical riser pipe ringed by a collar to collect trash. Periodically the basins must be attended as they fill with sediments. Construction of basins of this type would be an effective means of capturing sediments eroded from developed areas and unpaved roads. On paved areas they are aimed at catching runoff contaminated with oils and heavy metals.

Basins should be located in natural depressions to reduce construction cost and diversion methods should be applied to direct runoff to these basins. (The water table at Billington Sea will not be affected by any diversion methods as it's water budget is supplied by underground aquifers.)

Sediment basins will not have a great effect on phosphorous loading, however, following major storms and thaws they will substantially affect lake visibility, turbidity, and prevent sediment and oil residues. Their relatively low cost and easy maintenance (most town D.P.W.'s have equipment that can easily do this type of work.) make them a very useful tool in watershed management.

STORM WATER RUN-OFF

Storm water run-off has the potential of picking up and carrying high levels of pollutants to lakes and streams. This is expecially true where a long period without rain is followed by intensive rainfall, under these circumstances, the initial

///

surge of run-off carries oils, fertilizers, organic matter and eroded soil as well as other forms of pollution to the aquatic system. This initial surge can be more highly polluted than the sewage being treated at the municipal treatment plant.

Surface pollution can be reduced and in some areas stormwater is treated to remove suspended material.

SEWERING

The ultimate aim of the Town of Plymouth or in fact any town should be a sewage system. The Cornell study recommends; firstly, a ban on phosphate detergents, then tertiary treatment of sewage plant effluent; however, sewage systems beyond tertiary are being used for mineral stripping with the end result being nearly pure water. This report deals with phosphorous removal, hence this position is only secondary, however, with all factors being considered sewering should be considered as an ultimate goal.

The State of Massachusetts would encourage sewering:

1. If septic system leachate is or will become a significant contributor to the overall nutrient flux of the lake or pond.
2. If alternate methods of waste disposal (i.e. no-discharge waste disposal methods) are not available.
3. If the construction of a sewer system does not encourage growth in the watershed which could lead to a significant degradation of the environmental quality of the watershed and lake ecosystem.

The physical characteristics of the Plymouth soils; the number of ponds, lakes and kettleholes being fed by deep aquifers and ground water, lead to the conclusion that the ultimate goal should be a sewage system encompassing the whole town with a tertiary treatment system that would eliminate any future danger of contamination. Eastern Massachusetts is presently plagued with outbreaks of even artesian well contamination. Human waste and industrial contamination must be contained. The cost of such systems is great - but the destruction and pollution of clean water systems will be of far greater cost to everyone. To clean contaminated water is costly and perhaps some waters will not be able to be cleaned. Preventative methods are tantamount.

ALTERNATIVE SEPTIC WASTE SYSTEMS

In areas where soil characteristics prevent adequate on-site waste disposal, the following alternatives should be considered:

Non water-using toilets

The single most important non-point source of pollution in surface waters may well be nutrient loading from shoreline subsurface sewage disposal systems. The results of the Billington Sea groundwater sampling point directly to this conclusion. The prevalence of the Carver - Gloucester soil association makes not only the shoreline a target of non-point source nutrient loading, but possibly the entire watershed.

Eliminating toilet discharge as a contributing factor to subsurface disposal systems would significantly reduce both the problem of malfunctioning systems and the problem of nutrient migration into ground and surface waters.

It is recommended that non water using toilets be used in the following geographic areas:

1. Islands
2. Existing development adjacent to surface waters.
3. On marginal soils where groundwater pollution would be a danger.

Two recommended systems are: composting toilets and incinerating toilets; there are many other types such as vacuum toilets, chemical toilets, etc. but composting and incinerating toilets are the most popular.

Composting Toilets

There are a number of composting toilets on the market (see Addenda) but most consist of a tough plastic container in which compostable wastes are placed. In some units the decomposition of the waste is accelerated by a heating coil at the base of the unit and aeration from a fan, which draws air through the compost and out a vent pipe. The fan runs continuously and removes all odors whereas the heating coil functions intermittently depending on room temperature.

Buildings using a self-contained sewage disposal system, instead of a sub-surface disposal system could reduce the amount of nutrient pollution 30-50% depending on the nutrient loading of the gray water discharge. (Uttormark et al 1974)

A system for a family of 5-6, can be purchased for about $700 and has an operating cost of $6.00 - $7.00 per month.

Incinerating Toilets

These toilets consist of a cabinet similar to a conventional toilet which uses propane or natural gas to incinerate the waste and an exhaust fan to blow the gases out the exhaust vent. The incinerating cycle is controlled by a preset timer and lasts 15 - 20 minutes. Periodically the mineral ash in the firebox must be cleaned by a vacuum cleaner. One unit can service up to 12 people on a full-time basis. The unit is easily installed, requiring only gas and electrical connections and the attachment of a vent pipe to the outside.

The price for an incinerating toilet is about $600.00 plus delivery and installation charges. Operating costs using bottled gas would be about 6 cents per incineration cycle or about $45.00 a month for a family of 5.

Another system which uses air instead of water for the transport of sewage from the toilet is recommended for further study. The vacuum system uses only 3 pints of water per flush rather than the conventional 4-6 gallons per flush. Because of the reduced volume of liquid, the sewage is collected in a holding tank and transported to an existing treatment plant.

IN-LAKE MANAGEMENT METHODES

A. CONTROL OF MACROPHYTES AND MICROPHYTES BY HARVESTING

B. REDUCTION OF MOTOR BOAT USE

C. CHEMICAL INACTIVATION OF NUTRIENTS

D. CHEMICAL CONTROL VIA ALGICIDES AND HERBICIDES

E. LAKE BOTTOM SEALING

F. DRAWDOWN

G. BIOLOGICAL METHODS

H. DILUTION

I. AERATION AND MIXING OF WATER

J. DREDGING

MACROPHYTE HARVESTING

Aquatic plant harvesting is a widely used technique for in-lake management in lakes or bays with excessive local plant growths. It involves three stages to be at maximum efficiency.

1. Cutting
2. Collecting
   - A. Harvesting machines effective out to the 5 foot contour line both harvest and collect plants together with a portion of the rooted mass.
3. Disposal
   - A. Front-end loader and dump truck handle the disposal process. Disposal can become difficult, however, when submersed aquatic plants approach 7 tons/acre wet weight and contain 3.2 lbs./acre phosphorous. (MacKenthun and Ingram) Large areas are needed for disposal and Plymouth has ample sand dunes and sand bank erosion areas which could benefit from spreading of the harvested material.

ADVANTAGES

1. The primary advantage is that it is an ecologically elegant solution to nuisance plant control. Nutrients are removed from the aquatic ecosystem and are not recycled through bacterial decomposition of dead matter. Further growth may become impaired or even limited by the removal of macro-nutrients (phosphates, nitrates, carbon, etc.)
2. No chemicals are added to the aquatic environment.
3. No"closing" of the lake.
   - A. Intervals of up to 2 weeks are necessary with chemical application.
4. No lowering of dissolved oxygen.
5. Controls all species
   - A. Chemicals have resistant species problem.
6. No build-up of detritus.

DISADVANTAGES

1. Cost: $225.00 per acre was average cost in State '79 program. Towns must also assume cost of disposal.

2. Effective only to depth of 5 feet.

3. Does not harvest all roots.

   A. Many aquatic plants reproduce by rhizome as well as seed and root.

The aquatic plant harvesting program is recommended for Billington Sea not only for the above advantages but also because most disadvantages are overcome by the physical characteristics of Billington itself:

<u>Short flush time</u>

A. Suspended material would be flushed out of the aquatic system.

<u>Depth</u>

A. With a 5.5 foot average depth much of the lake area is available to the harvester.

<u>Relatively smooth bottom</u>

A. There are no stumps or debris such as is prevalent in an artificial system.

<u>Elodea</u>

A. The target species is susceptible to efficient harvesting

<u>Disposal</u>

A. Dune stabilization
B. Erosion control

<u>Recreation</u>

A. Lake is immediately available for recreation.

RENTAL COST:

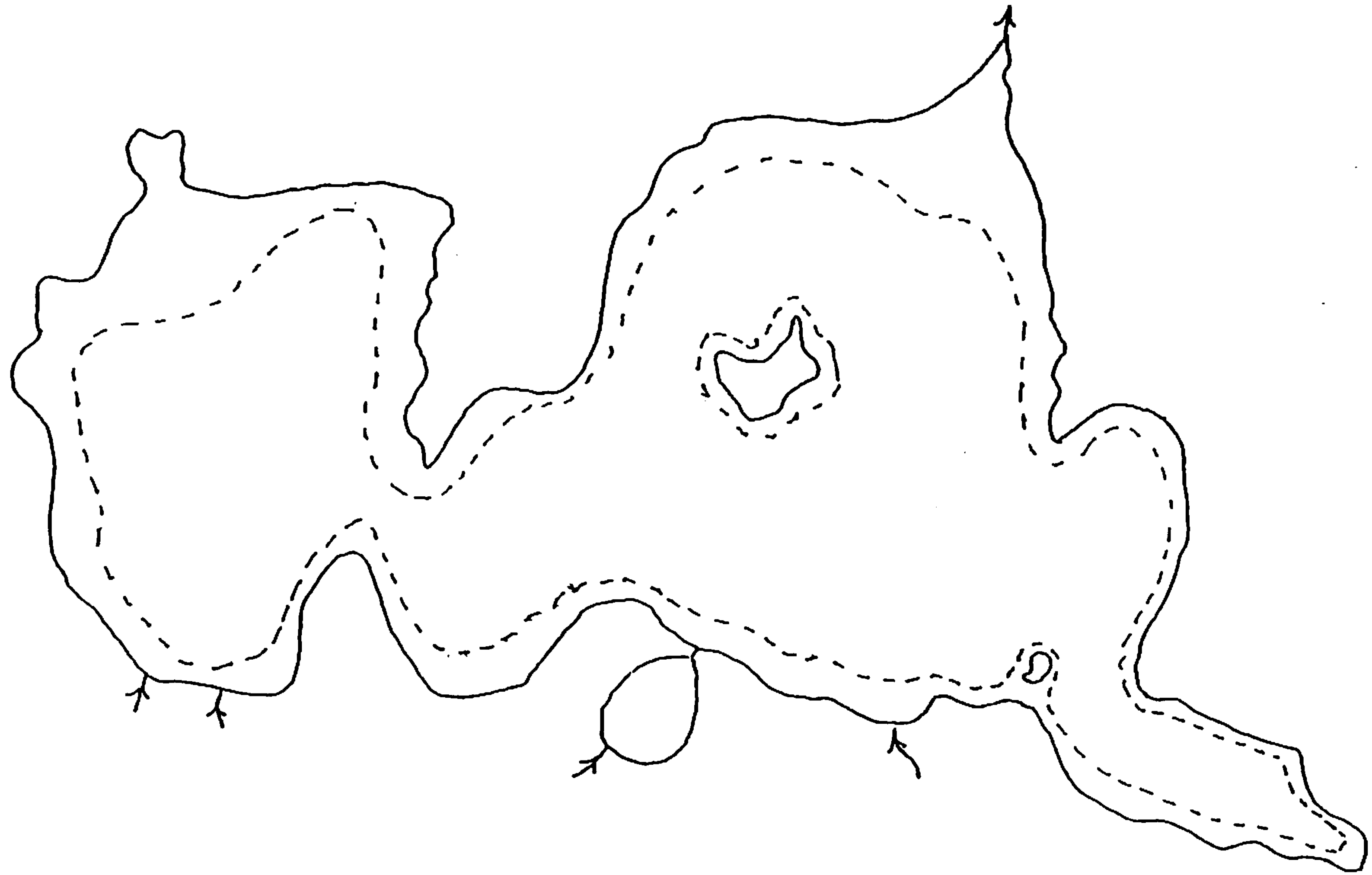
1979 State bid average cost $225.00/acre

A. Town attends to disposal

DEQE Eutrophication and Aquatic Begetation Control Program

MACROPHYTE HARVESTING MAP

Five-Foot Harvest Line Is Noted



FLOATING AQUATIC PLANTS ATTACHED

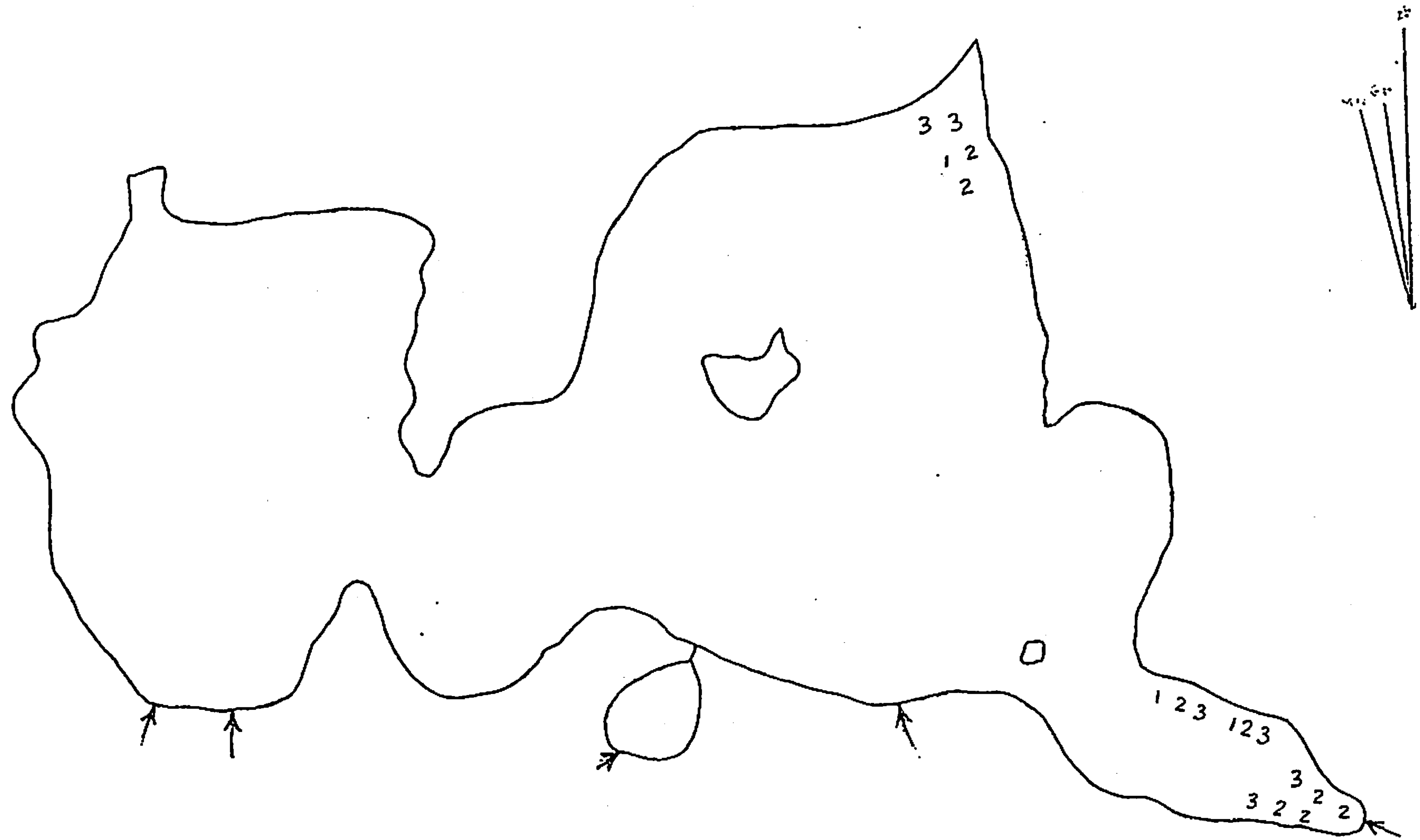
LATIN	COMMON	MAP NUMBER
Nuphar	Cow Lily, Yellow Water Lily, Spatterdock	1
Nymphaea	Water Lily, White Water Lily	2
Brasenia	Watershield	3
	Addenda	

FLOATING AQUATIC PLANTS - UNATTACHED

LATIN	COMMON	MAP NUMBER
Lemna	Duckweed	
Spirodelia	Big Duckweed	
Wolffia	Watermeal	
	Addenda	

BILLINGTON SEA

Floating Aquatic Plant Map With Key

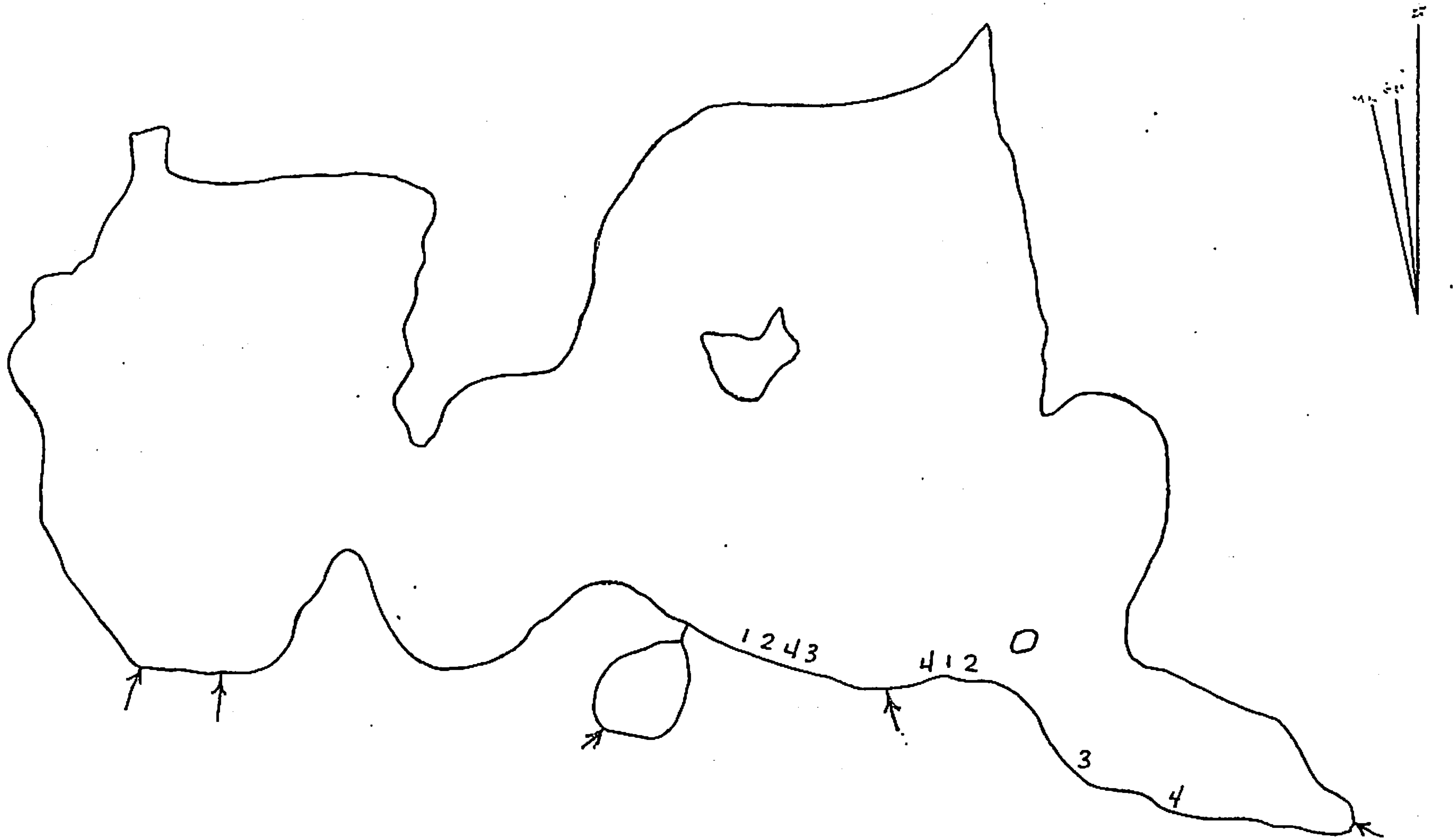


EMERSED AQUATIC PLANTS

LATIN	COMMON	MAP NUMBER
Peltandra	Arrow Arum	
Pontederia	Pickerel Weed	1
Sagittaria	Arrowhead; Duck Potatoe	
Polygonum	Watersmart Weed	
Typha	Cattail	
Eleocharis	Spike Rush Sedge	2
Scirpus	Bulrush Sedge	3
Juncaceae	Juncus Rush	4
	Addenda	

BILLINGTON SEA

Emersed Aquatic Plant Map With Key



SCALE 1:788

SUBMERSED AQUATIC PLANTS

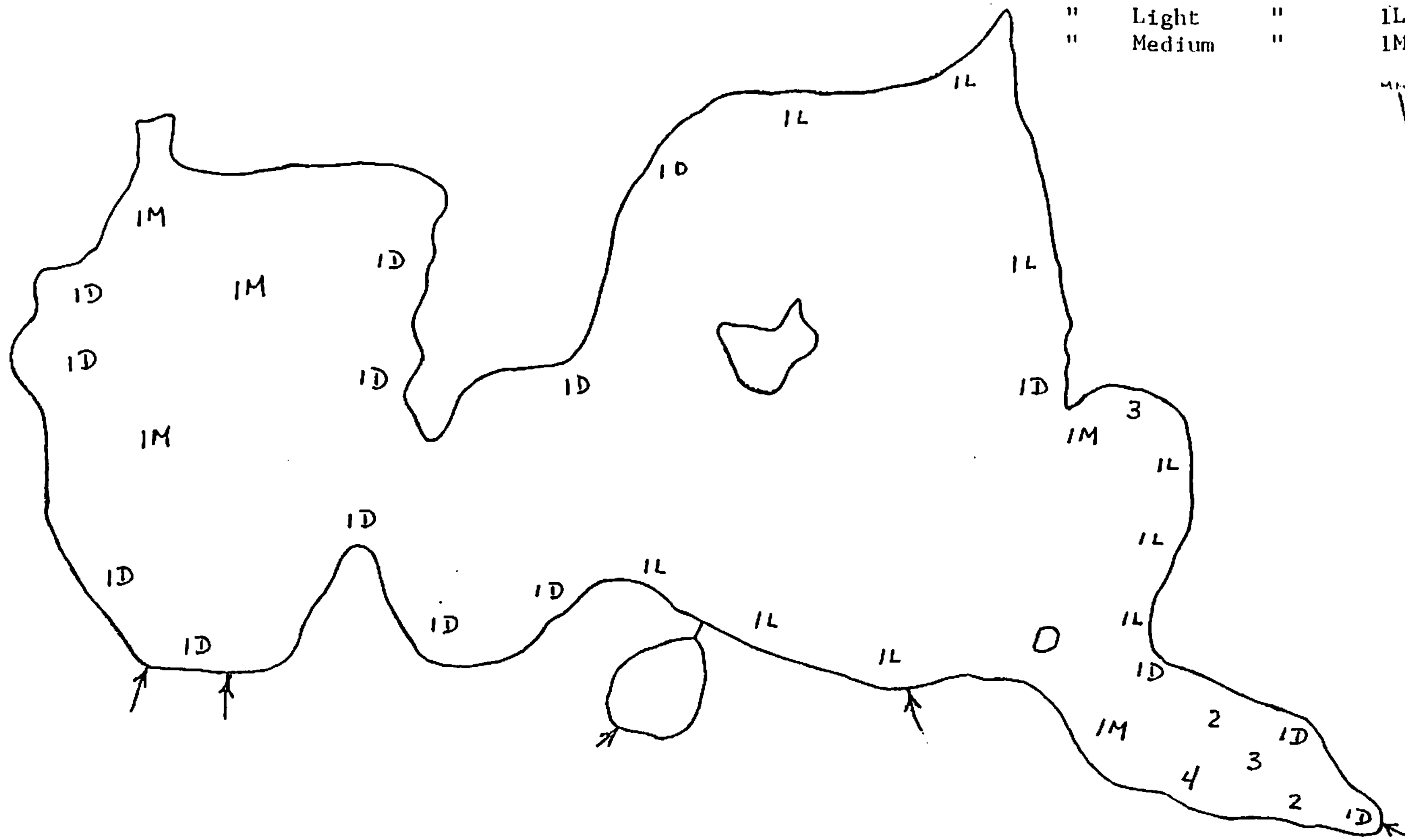
LATIN	COMMON	MAP NUMBER
Potamogeton	Pondweed	
Potamogeton Americanus		
Potamogeton Ampl. Folius	Large Leaf Pondweed	
Potamogeton Crispus	Curly Leaf Pondweed	
Potamogeton Diversifolius	Waterthread Pondweed	
Potamogeton Filiformus		
Potamogeton Filiosus	Leafy Pondweed	3
Potamogeton Gramineus	Variable Pondweed	4
Potamogeton Natans	Floating Brown Leaf	
Potamogeton Nodosus	American Pondweed	
Potamogeton Pectinatus	Sago Pondweed	
Potamogeton Praelongus	White Stem Pondweed	
Potamogeton Richardsonii	Richardson Pondweed	
Potamogeton Robinsii		
Potamogeton Vaginatus	Giant Pondweed	
Najas	Bushy Pondweed	
Zannichellia	Horned Pondweed	
Elodea	Waterweed	1
Ranunculus	Water Buttercup	
Ceratophyllum D.	Coontail	2
Myriophyllum	Water Milfoil	
Alisma	Waterplantain	
Heteranthera D.	Water Star Grass; Mud Plantain	
Nasturtium	Water, Cress	
Utricularia	Bladderwort	
Vallisneria	Wild Celery	
	Addenda	

BILLINGTON SEA

Submersed Aquatic Plant Map with Key

Note

Elodea Dense Infestation 1D
" Light " 1L
" Medium " 1M



Primary Aquatic Plant Infestation: Common Elodea

Elodea Cahadensis Waterweed

1:788

MACHINE PURCHASE:

Small Chub	-	$12,900
Trailer		1,250

Capable of 1 - 2 acres/day, 2 man crew, manual operation

H-400	$28,000

2 - 4 acres per day, 1 man crew, hydraulic operation

Aquamarine Corp. Waukesha, Wisc.

AERATION

Aeration and circulation can be used to improve water quality for a wide array of beneficial uses including domestic water supply, downstream releases, industrial use, fish management, and algae bloom control. Maintenance of aerobic conditions may also affect nutrient exchange within the lake.

Total aeration would not be encouraged by the State if aeration techniques would de-stratify a lake.

Hypolimnetic aeration increases the oxygen content of a lake without de-stratifying the lake.

Positive Effects:

1. Reduction in sediment/water nutrient exchange.
2. Increased habitat for fish, zooplankton, and benthic fauna.

Hypolimnetic aeration would be encouraged by the State when:

1. Nutrient loading from watershed is not sufficient to promote eutrophic conditions in the lake without the addition of internal nutrient loading.

   (Billington Sea has a high enough nutrient level without addition by aeration.)

2. Where concentrations of DO in the hypolimnion are less than 3.0 mg/l and are not the result of natural springs or ground water seepage.

   (Dissolved oxygen in Billington is never this low; Dissolved oxygen in aquifers leading into Billington is relatively high.)

3. When an increase in hypolimnetic oxygen will significantly decrease the loss of nutrients from sediments in the water column and internal nutrient loading is an important factor contributing to the occurrence of planktonic algal blooms.

Billington Sea with it's physical characteristics, i.e. shallow depth (5.5 ft. average); large surface area (269 acres); and high flush rate (55 days) make it an unsuitable candidate for any long range benefits from any aeration or circulation techniques. Wind, sun, and flow would be enough to maintain high DO rates if the nutrient influx problem was solved or even curbed.

RESTRICTION OF MOTOR BOAT USE

The Environmental Protection Agency and Massachusetts Resources Commission have conducted recent investigations focusing on biological effects of oil and gasoline discharges, specifically; raw fuel, phenols, lead, volatile and non-volatile oil discharged by two-stroke outboard motors.

A. Since 1972 outboard manufacturers have included a recycling device to reduce discharge of unused gasoline and oil.

B. Older engines manufactured before 1972 release as high as 50% unburned fuel mixtures.

However, results of the E.P.A. and state studies conclude:

1. There is no significant adverse aquatic life impact.
2. Most volatile aromatic constituents of gasoline and oil evaporate.
3. Some non-volatiles persist but are decomposed by bacteria.

Most of the data gathered by these studies indicates no firm support for either complete restriction, or size restriction. Billington Sea is a recreational lake and hence, widely used for fishing, water-skiing, and boating. To use restrictive measures might put an unnecessary burden on both the Town and lake inhabitants. New engine designs coupled with looming petroleum shortages might solve the problem without added procedures. As new data becomesavailable, perhaps then a new approach may develop. Other eutrophic causes are major, this at present is minor.

NUTRIENT INACTIVATION

This method can be used to remove nutrients that are essential for plant or algae growth by addition of chemical activators which are added to the lake. There are many activators that are used for a variety of reasons, such as aluminum, alum, iron, ion exchange resins, polyelectrolytes, fly-ash, etc.

Aluminum and iron salts can be added directly to the lake to remove phosphorous from the lake water and carry it to the sediments.

The state will encourage the chemical inactivation of essential nutrients in the water column if:

1. Only a small watershed is involved.
2. The lake has a relatively long retention time (over .3 year)
3. Total phosphorous in water exceeds .03 mg/l
4. Sediments regenerate enough nutrients to promote moderate to excessive algal growth.
5. When nutrient loading from the watershed is not sufficient to promote eutrophic conditions in the pond without the contribution of internal nutrient loading.

Billington Sea has an average retention time of 55 days, and most phosphorous comes from in-lake sources, not from sediment release. The end result of this technique would not solve the basic problem. Long-term effectiveness would be limited by continual nutrient input.

CHEMICAL CONTROL BY ALGICIDES AND HERBICIDES

Herbicide control should not be used.

Chemical control of algae might have to be used until suggested programs are implemented, particularly if algae blooms render Billington Sea undesirable for recreation purposes. State aid can be applied for through the Department of Environmental Quality Engineering.

Three necessary conditions are:

1. Midday water temperatures do not exceed 27°c (80° F)
2. Dissolved oxygen within 2 meters of surface is above 4.0 mg/l.
3. Copper in sediments does not exceed 150-300 mg/kg (dry weight)

LAKE BOTTOM SEALING

Significant amounts of exchangeable nutrients are usually found in the benthos of a lake or pond and in some instances removal by dredging is recommended (ex. Morse's Pond, Wellesley) to reduce the nutrient content. However, at a greatly reduced cost, bottom sealing has been used instead. Several covering materials are showing promise of supressing the transport of nutrients from the sediments into the overlaying waters by either physically retarding exchange, or by increasing the capacity of surface sediments to hold nutrients.

Lake bottom sealing covers can have additional advantages such as:

1. Elimination of suitable substrates.
2. Erosion control by bottom stabilazation.
3. Minimization of water loss by infiltration.

A recent effort has been in Thirty-Acre Pond, Brockton, Massachusetts, where this technique has been applied as a corrective measure. The short-term effect of this technique seems to be desirable; however, long-range effects have still to be evaluated.

Large amounts of groundwater present in Billington Sea would in all likelihood preclude the possibility of state participation in such a project. The state would consider sealing if the following conditions prevailed:

1. If drawdown is possible.
2. If dealing with a limited area (generally less that 1 hectare)
3. If shallow area is being considered (littoral zone - less that 5 feet.)
4. If considerable groundwater seepage does not occur.

Generally, the state prefers chemical sealants over physical.

Physical sealants:

A. Plastic Sheeting

1. perforated
2. non-perforated

B. Rubber liners

Chemical sealants:

A. Clays

B. Zeolites

C. Flyash

Billington Sea has too much ground water influence to consider sealing methods. The high flush rate is one of Billington's greatest assets and should be maintained at any cost.

DRAWDOWN

In lakes and ponds where water level can be controlled drawdowns have been used to consolidate sediments, reduce their release of nutrients and kill aquatic plants. While exposed to air, sediments lose much of their water content and they may no longer release nutrients into lake water when the lake is refilled (DUNSET ETAL 1974). Beds of aquatic plants may dry out during drawdown and if their roots are exposed, some species may die or not be able to reproduce (BEARD 1973).

Drawdown is not possible in Billington Sea at present; water-level control technology would have to be applied before drawdown could be effectively used as a short-range control measure. This and other shortcomings have made it not feasible to consider this technique.

BIOLOGICAL CONTROL

The control of a particular problem species by manipulation of biotic interactions.

1. Predator-prey relationships (the White Amur is a well documented example).
2. Intra and interspecific manipulation (one plant species is introduced or manipulated in order to induce a limiting condition on another.)
3. Pathological reaction (controlling blu-green algae blooms by viruses has been attempted.)

Any use of biological control methods must be approved by the Division of Fish and Wildlife. The use of biological controls on excessive growths of algae and macrophytes has not been developed to the point where any potentially effective agents are likely to be found in the near future.

DILUTION

Dilution is a process whereby eutrophic lake water is replaced by water lower in nutrients. A lake can be flushed out with less productive water, or it can be pumped out to another watershed and allowed to refill through rain or groundwater infiltration. Dilution simply decreases the lake waters nutrient concentrations. The advantage of dilution is that many nutrients as well as plants are removed from a lake when it is flushed out.

1. Sufficient quantities of low-nutrient water may not be available for such a project.
2. Nutrients may flow into the lake and quickly replace those flushed away.
3. Cost problem on pumping in dilution water.

The State would encourage the implementation of dilution if:

1. Nutrient poor water diverted from it's natural course does not have an adverse effect on it's own ecosystem.
2. No point sources of nutrient rich water discharge directly or indirectly into the lake.
3. Dilution water is well below nutrient levels which promote eutrophication.
4. Nutrient rich sediments do not contribute significant quantities to overall nutrient flux of the lake.

No clearcut advantage could be gained by using this method for two reasons:

1. No significant source of nutrient-free water available.
2. Will not affect basic problems of nutrient influx from point and non-point sources.

With Billington's flush rate, the elimination of nutrient influx would result in a cleaning up of the problem in a relatively short time.

Hypolimnetic aeration would be encouraged by the State when:

1. Nutrient loading from watershed is not sufficient to promote eutrophic conditions in the lake without the addition of internal nutrient loading.

   (Billington Sea has a high enough nutrient level without addition by aeration.)

2. Where concentrations of DO in the hypolimnion are less than 3.0 mg/l and are not the result of natural springs or ground water seepage.

   (Dissolved oxygen in Billington is never this low; Dissolved oxygen in aquifers leading into Billington is relatively high.)

3. When an increase in hypolimnetic oxygen will significantly decrease the loss of nutrients from sediments in the water column and internal nutrient loading is an important factor contributing to the occurrence of planktonic algal blooms.

Billington Sea with it's physical characteristics, i.e. shallow depth (5.5 ft. average); large surface area (269 acres); and high flush rate (55 days) make it an unsuitable candidate for any long range benefits from any aeration or circulation techniques. Wind, sun, and flow would be enough to maintain high DO rates if the nutrient influx problem was solved or even curbed.

DREDGING

Dredging removes nutrient rich sediments and rooted aquatic plants from shallow water areas. A lake's annual process of self-fertilization and subsequent release of nutrients from sediments to overlying waters may, for some lakes, be one of the primary sources of the lakes nutrients.

Dredging has often been suggested as a means for removing nutrients stored in sediments. The sediments are usually rich in nitrogen and phosphorous and represent an accumulation of years of settled organic materials. Some nutrients may be recirculated within the water mass and furnish food for a new crop of organic growth. However, in an undisturbed mud-water interface nutrient transfer is very small.

The state encourages dredging if:

1. Nutrient loading is not from external sources.
2. Removing substrate would promote plant growth.
3. Sediments are important source of nutrients.
4. No toxic sediments are released during dredging.
5. Dredging will not increase water turbidity.
6. Dredged areas are less than 15 feet deep.
7. Does not affect downstream wetlands.
8. Dredged sediments do not pose a health or environmental problem.

Some problems encountered in dredging:

1. Nutrient content does not change drastically.
2. A possible resulting shift from rooted plants to algae.
3. The buffering capacity of a lake to external changes in nutrient loadings may be lowered.

Morse's Pond in Wellesley has been dredged after two or three nutrient inactivation efforts. Dredging was applied to reduce lily growth, but after a short period of time Milfoil took over as a target species. This project was funded under 314.

Before such a costly, chancey method is used, the more positive long-range efforts should be put into effect, combined with in-lake methods as recommended in this report.

C O N C L U S I O N

The very existence of Billington Sea as a future attractive recreational resource hinges on stopping the nutrient loading. In most lakes the short retention time of about 50 days would be more than adequate to flush the system, and if the soil series were different the problem would more than likely be within 100 feet of the shoreline; however, on the basis of this report, a broader range of recommendations, and long-range zoning programs are strongly recommended in order to cover the broad spectrum of contributing non-point sources. It is not physically possible for the soil series to tie up, ionically, any appreciable amount of non-point source loading. How much the watershed is involved will be better determined when data from other lakes and ponds in the area becomes available. It is inconceivable that this problem is exclusive to Billington Sea.

This report has enumerated counter pollution measures such as a voluntary ban on high phosphate detergents; this is considered a very important step - this ban could eliminate 50% of the phosphorous input from domestic sewage or about .8 kg. phosphorous per capita per year. The only cost would be ads in newspapers, radio or any source at the commissions disposal.

It is also recommeded that the "Septic Snooper" be applied to locate faulty septic systems and that such systems be replaced with non-water using systems. "The results of the Lake Region Planning Commission groundwater sampling and soil retention study have indicated the effluent from subsurface sewage disposal systems is a primary source of water pollution."

To put teeth into local and state laws it is stongly suggested that the definition of pollution be revised to include acceptable nutrient levels.

Stormwater run-off problem can be solved by initiating catch basins, recharge basins, settling pond and sediment basins; all of which can be designed and implemented by local DPW and engineers.

Zoning and percolation tests should be upgraded to the Lakes Region Planning Commission, State of Maine soil evaluation concept and Maine and New Hampshire set backs with lot sizes based on soil and ground water criteria.

Harvesting out to a 5 foot contour line will give some immediate relief until long-range techniques can be implemented and results achieved.

PERSONAL COMMUNICATIONS

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Jeff Kapell; Cranberry grower, Plymouth, Mass.

Ed Konieczny; Soil Conservation District; Raynham, Mass.

Howard Carr; Soil Conservation District; Raynham, Mass.

Damion Smith; Sewage Disposal, Plymouth, Mass.

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B I B L I O G R A P H Y

Bouldin, D.R., H.R. Capener, G.L. Casler, A.E. Durfee, R.C. Loeher, R.T. Oglesby, and R.J. Young. Information Bulletin 127, New York State College of Agriculture and Life Sciences at Cornell Univ., Ithaca, New York.

Department of Environmental Quality Engineering (DEQE) Publication on Eutrophication and Aquatic Vegetation Control Program, Boston, Massachusetts.

Eutrophication - Causes, Consequences, Correctives, Proceedings of a Symposium. Natural Academy of Sciences, Washington, D.C., 1969.

Eutrophication of Lake Tahoe Emphasizing Water Quality; U.S. EPA,Corvallis, Oregon.

Eutrophication of Surface Waters - Lake Tahoe's Indian Creek; U.S. EPA, Corvallis, Oregon.

Eutrophication in Vermont - 1975 Water Quality Surveillance Series,report no. 3; Dept. of Water Resources, Water Quality Div., Montpelier, Vermont.

Flushing of Small Lakes; U.S. EPA, Corvallis, Oregon.

Guide to Aeration and Circulation Techniques; U.S. EPA, Corvallis, Oregon.

Guide for Design, Operation and Maintenance of Small Sewage Disposal Systems, New Hampshire Water Supply and Pollution Control Commission.

Guidance for the Preparation of Lake Restoration Grant Applications, U.S. EPA, Washington, D.C.

Hogg, Thomas C., William D. Honey. A Research Strategy for Social Assessment of Lake Restoration Programs; U.S. EPA, Corvallis, Oregon.

Influence of Land Use on Stream Nutrient Levels; U.S. EPA, Corvallis, Oregon.

Lakes Region Water Quality Management Plan; Lakes Region Planning Commission, New Hampshire, September 1978.

Lee, G.F. Eutrophication, University of Wisconsin, Madison, Wisconsin.

MacKenthun, Kenneth. Toward a Cleaner Aquatic Environment U.S. Environmental Protection Agency.

Management of Bottom Sediments Containing Toxic Substances, U.S. EPA, Corvallis, Oregon.

Non Point Source - Stream Nutrient Level Relationships; U. S. EPA, Corvallis, Oregon.

Nutrient Diversion: Resulting Trophic State and Phosphorous Dynamics; U.S. EPA, Corvallis, Oregon.

Nutrient Inactivation as a Lake Restoration Procedure - Laboratory Investigations; U.S. EPA, Corvallis, Oregon.

Plumbing Code, Part 2 Subsurface Wastewater Disposal Regulations; Department of Human Services, Div. of Health Engineering.

Site Evaluation for Subsurface Waste Disposal in Maine; Maine Department of Human Services, Division of Health Engineering, September 1979.

Soil Survey, Plymouth County Massachusetts; U.S. Department of Agriculture, Soil Conservation Service.

Studies on Lake Restoration by Phosphorous Inactivation; U.S. EPA, Corvallis, Oregon.

Studies on Reclamation of Stone Lake, Michigan; U.S. EPA, Corvallis, Oregon.

Summary Analysis of the North American (U.S. portion) OECD Eutrophication Project; Nutrient Loading - Lake Response Relationships and Trophic State Indices; U.S. EPA, Corvallis, Oregon.

Survey of Lake Rehabilitation Techniques and Experiences, Technical Bulletin number 75, Dept. of Natural Resources, Madison, Wisconsin.

Tasker, Gary D. and John R. Williams. Water Resources of the Coastal Drainage Basins of Southeasten Massachusetts, Plymouth to the Weweantic River, Wareham; U.S. Geological Survey.

The Trophic Status and Phosphorous Loadings of Lake Champlain; U.S. EPA, Corvallis, Oregon.

Vermont Health Regulations, Chapter 5, Sanitary Engineering, Subchapter 10, Part 2, Wastewater Treatment and Disposal, Individual On-Site Systems; State of Vermont, Agency of Human Services, Montpelier, Vermont.

A L G A E

During the course of this study Billington Sea was susceptible to recurrent algal blooms, the target species were identified as Ankistrodesmus falcus and Chlamydomonas Polypyrenoideum. Copper sulfate treatment was undertaken.

Other Chemical Properties

Ph 7.6 (6-8 is common for natural freshwater)

Free acidity 0

Free alkalinity 0

Heavy metals

ZN	.53
CD	$< .01$
SN	$< .01$
Au	$< .01$
Fe	.34
Al	.09
Cu	$< .01$
Ni	$< .01$
AG	$< .01$

All heavy metal readings are within range for natural freshwater - low readings indicate absence of industrial waste.

A D D E N D A

ENVIRONMENTAL IMPACT

Land use

No effect on residential, agricultural, park, scenic, historical, archeological.

Physical

No construction other than sediment basins.

Air Quality

No effect.

Hydrology

No effect, no diversion, dredging or construction.

Aquatic Life

Fish or aquatic organisms - no adverse effect, possible beneficial effects

Cultural Impact

None

Economic Environment

None

Resource Impact

None

Energy Use

Not applicable.

Social Environment

Beneficial, better water quality

A D D E N D A

Revision of Pollution Definition

The general approach is to stress violation of coliform bacteria standards, research shows that nutrient pollution over a period of time is as important, or may be more important than bacterial pollution. A set of general standards should be put forth and it is suggested that violation of nutrient standards be incorporated in the pollution standards.

G E N E R A L G U I D E L I N E S

	Permissible Levels	Critical
Total phosphorous mg/l	.025	.04
Orthophosphorous mg/l	.004	.01
Organic Nitrogen mg/l	.20	.40
Ammonia mg/l	.02	.05
Nitrate mg/l	.10	.25
Nitrite mg/l	less than .001	.002
Inorganic Nitrogen mg/l	.12	.30

Incorporation of the above nutrient levels in the general pollution standards would be a positive approach toward solving the problem of nutrient loading from all sources and would redefine pollution as it is generally understood.

A D D E N D A

FURTHER CONSIDERATIONS

Sanitary Landfill Leachate:

This is not considered to be a problem in the Billington Sea impoundment.

Soil Erosion:

Erosion could be a factor in the Carver-Gloucester soil series. However, the problem is practically non-existent at present. Should more acres be opened to housing and development, the problem may arise.

A D D E N D A

The following data will provide the Town of Plymouth with necessary information to justify application to the U.S. Environmental Protection Agency for 50% matching funds to conduct the proposed programs, as authorized by Section 314 of the Federal Water Pollution Control Act Amendments of 1972 (PL92-500)

The preceeding report has established:

1. Water quality of Billington Sea
2. Lake restoration procedures
3. Environment Impacts
4. Expected results
5. Management Plans

Funding by the Commonwealth of Massachusetts:

722-1969- DEQE amended general laws
Chapter 40, Section 5 and Chapter 111, 5F
(A copy of this act is included in Addenda)

This usually covers chemical control and harvesting of aquatic nuisances.

Chapter 91 under DEQE, Waterways Div., is for dredging programs
208 covers sewage construction.

Billington Sea satisfies the anticipated benefits to the public.

1. Size of the population residing near the lake, number of people using the lake via Morton Park and public access.
2. No other clean lakes adequately serve the population in the area.
3. Private land owners are not the prime benefactors; the public benefits the most.

A D D E N D A

M A N A G E M E N T   P L A N S

Any program implemented on Billington Sea will be directly managed by the Plymouth Conservation Commission and coordinated with any other town departments that are needed. The Billington Sea Association should also take an active part in all programs.

The voluntary phosphate ban should take place immediately.

Two year harvesting program (1980 - 1981)

Sediment basins - engineering study by D. P. W.

Construction of non-water using toilets where needed.

Septic snooper program - (1980).

Updating faulty septic systems (1980 - 1981).

A D D E N D A

BILLINGTON SEA - BENTHOS

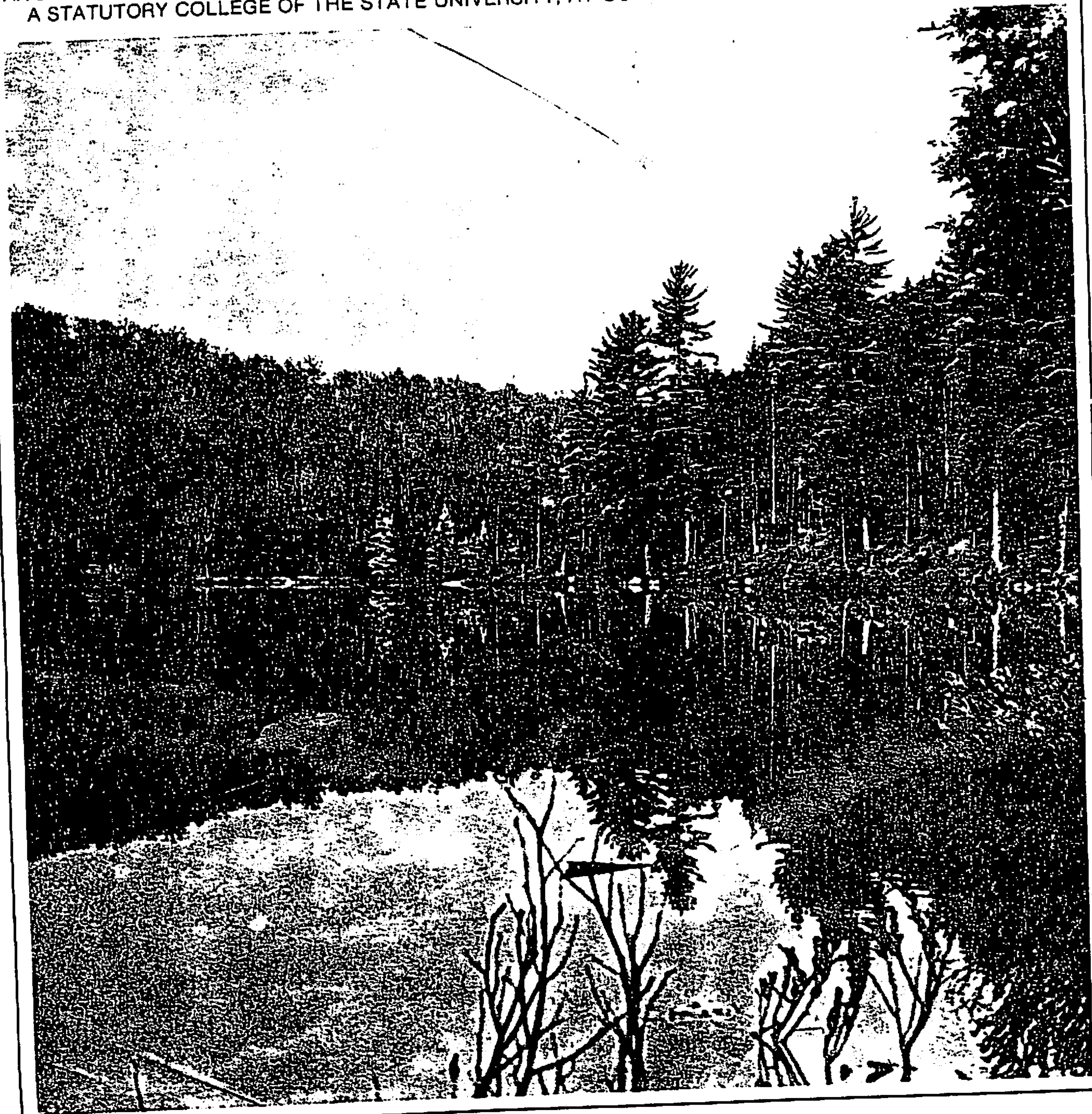
Total Phosphorous	112 mg/kg
Nitrate (N)	152 mg/kg
Copper	7.7 mg/kg
Arsenic	1.9 mg/kg
Percent solids	15.0 %

Lakes and Phosphorus Inputs

A Focus on Management

D. R. Bouldin, H. R. Capener, G. L. Casler, A. E. Durfee, R. C. Loehr, R. T. Oglesby, and R. J. Young

AN EXTENSION PUBLICATION OF THE NEW YORK STATE COLLEGE OF AGRICULTURE AND LIFE SCIENCES, A STATUTORY COLLEGE OF THE STATE UNIVERSITY, AT CORNELL UNIVERSITY, ITHACA, NEW YORK



Lakes and Phosphorus Inputs

A Focus on Management

Highlights

Dissolved phosphorus is the element that most influences the productivity of freshwater lakes and impoundments. Algae affect the quality and appearance of water. They affect the level of fish production. They also affect the costs of filtering water supplies for domestic and industrial use. Ultimately, the level of algae found in most temperate latitude lakes is dependent upon the amount of dissolved phosphorus discharged to the lake. The emphasis on dissolved rather than total phosphorus inputs to lakes represents an extremely important distinction, one to be kept in mind by anyone measuring phosphorus inputs, identifying sources, or making management and policy decisions about water quality.

In the watersheds studied the dissolved phosphorus came from sewage (55%), agricultural runoff (18%), forest runoff (15%), residential runoff (6%), and atmospheric fallout (6%). Studies of control measures showed that after a ban on phosphate detergents, lowest costs per unit of dissolved phosphorus prevented from entering lakes were associated with tertiary treatment of sewage. Next lowest costs were markedly higher and were for control of dissolved phosphorus from unsewered populations and from barnyard runoff.

Drawing on data that show that lakes vary widely in their natural state and that lake changes caused by inputs of soluble phosphorus are reversible, the scientists made extrapolations for 13 lakes in central New York State. These demonstrated the feasibility of using control policies flexibly and gradually. The policies included: (a) no action for lakes in which algae are not a problem, (b) a ban on phosphate detergents in areas where there are water quality problems, (c) tertiary treatment of sewage to remove phosphorus, and (d) control of agricultural and residential runoff. A fifth policy of removing all human activity from a watershed would be impractical on a large scale but might be necessary in certain rare instances.

The full research report has been given wide circulation among scientists interested in water quality and associated problems. This brief summary is intended for use by decision makers in government, the leaders of various organizations and agencies, and interested citizens. It has attempted to point out that there are differences in appropriate control strategies that can be applied and differences in perceptions of the individual families and communities involved. Consequently, flexible policies and institutional arrangements will be needed and can be used without irreversible damage being done to lakes during a progressive "test-and-evaluate" approach.

Introduction

This is a brief account of research findings to help protect and improve the water you and I drink, swim in, fish in, and use in so many other ways.

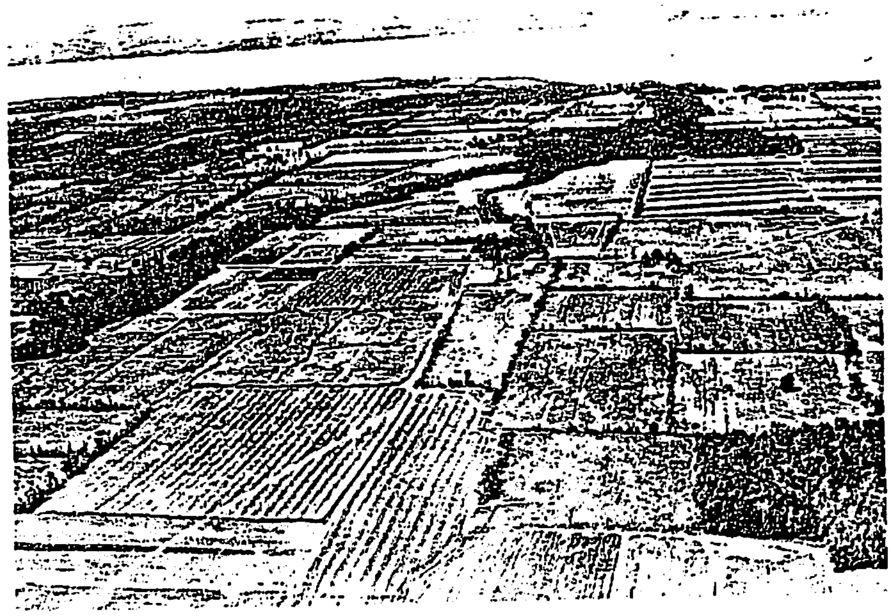
Objective:

The objective of this publication is to help decision makers concerned with lakes assess management proposals.

By 1970, scientists, pollution control experts, health authorities, and informed laymen had all recognized that one cause of deteriorating water quality was the introduction of excessive quantities of nutrients, such as nitrogen and phosphorus, into streams and lakes. These nutrients acted to stimulate the production of algae. Because of accumulations of these minute plants, the water became more expensive to filter, unpleasant to swim in, and, in some cases, so short of oxygen that production of some game fish was inhibited. Also, excessive quantities of nitrates in water were a potential health hazard.

The Water Pollution Control Act of 1972 (PL92-500) focused additional attention on these

Figure 1. *Farmland is but one source of dissolved phosphorus inputs to lakes.*



issues. This act required the development of information, including: "(1) guidelines for identifying and evaluating the nature and extent of non-point[1] sources of pollutants, and (2) processes, procedures, and methods to control pollution resulting from . . . agricultural and silvicultural activities, including runoff from fields and crop and forest lands . . . ." The legislation forced a recognition of the need for procedures for identifying and evaluating "non-point" sources. It underlined the need for unambiguous data defining the contribution agriculture was making to the nitrogen and phosphorus content of water.

An interdisciplinary group of scientists at the New York State College of Agriculture and Life Sciences at Cornell University began an investigation of some of these problems in 1972 with financial support from the Rockefeller Foundation. Among the questions they addressed were how nutrients affected plant growth in lakes, how nutrients reached the lakes, sources of nutrients in the landscape, ways in which agricultural sources could be reduced, and the effects of controlling agricultural sources on food production and food costs. The Cornell team included aquatic biologists concerned with physical, chemical, and biological conditions in freshwater lakes and ponds; agricultural engineers with understandings of manure handling, waste disposal, fertilizer application, and drainage problems; agronomists experienced in movement of chemicals and water in various soil types; economists skilled in cost analysis and in measuring benefit-cost relationships, and sociologists with years of experience in sampling public attitudes, beliefs, concerns, and predispositions.

A major part of the research was a study of 13 lakes in central New York and an intensive study of the 80,000-acre Fall Creek watershed which is a tributary of Cayuga Lake.

The important generalizations resulting from these specific studies and other information in the scientific literature have been published in a 372-page book cited in the acknowledgement. This bulletin summarizes the results with respect to phosphorus and some social and political aspects of pollution control.

Role of Phosphorus in Lake Ecosystems

A historical review of scientific literature concerned with lake eutrophication shows a rather dramatic focusing in recent years on phosphorus supply as the critical factor. Initially, this was in part due to the realization that of the nutrients essential for plant growth, carbon, nitrogen, and phosphorus, phosphorus was the only one that could feasibly be controlled in most cases. Increasing evidence has been accumulating that phosphorus is indeed the substance that limits the productivity in most temperate latitude lakes.

Arguments concerning the unique importance of phosphorus fall into three general categories. The first recognizes that, relative to the needs of aquatic plants for substances to support their growth, phosphorus is the element of greatest geochemical rarity. This factor is enhanced

1. "Non-point" source — refers to any nonspecific, unidentified, or diffuse source from which organic and inorganic materials enter surface or ground water. Examples are runoff from a golf course or a farmer's field, the seepage from woods or forest, or natural fallout from the atmosphere.

"Point" source — refers to any specific, clearly identifiable location at which accumulated quantities of pollutants such as sewage, industrial wastes, plant nutrients, or other liquid residues are discharged. This could be a pipe, ditch, channel, or tunnel. Specific examples are an outlet from a sewage treatment plant, a drain from a septic tank field, a farmer's tile drain, a parking lot storm tile line, or a drain from a packing plant.

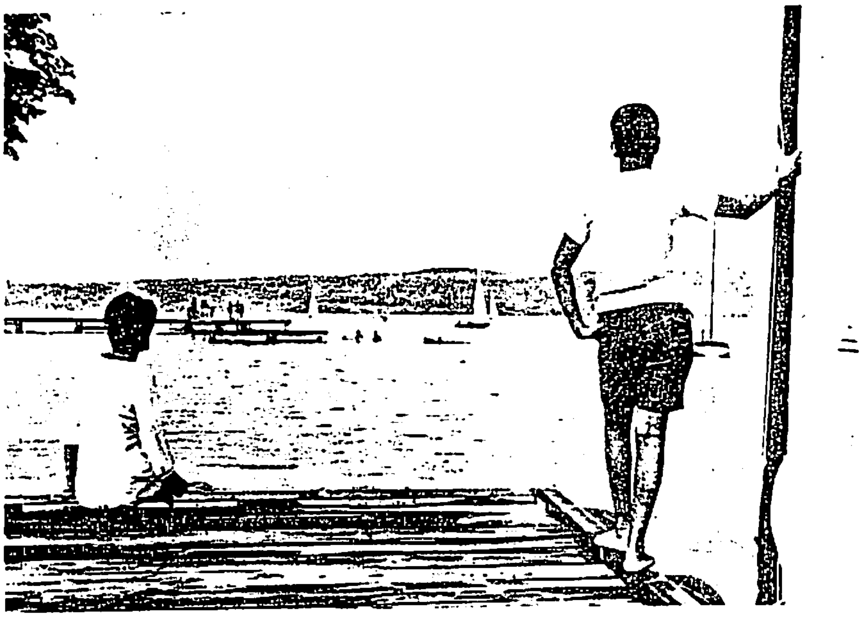


Figure 2. *Less algal growth makes lakes more attractive for swimming and boating.*

in the aquatic environment by the insolubility of many phosphorus compounds and the tendency of phosphates to be adsorbed to soil particles and hence to settle to the bottom of lakes where they become unavailable to algae. The second category addresses the questions of sources of nitrogen and carbon available to algae. Some (the blue-greens) can use N_2 directly and hence are able to draw on the almost limitless reserves of this gas in the biosphere. Many algae can use the bicarbonate ion as a source of carbon. This, together with the high solubility of CO_2 in water, suggests that carbon is never likely to be more than temporarily limiting to the growth of algal communities. Finally, as shown in the present study and its later extension to lakes in temperate regions in other areas of the world, algae are present during the summer at concentrations closely proportional to the annual inputs of dissolved phosphorus per volume of water in the upper layers of lakes. This relation holds true even for most of those lakes characterized by persistently low nitrate concentrations which might tend to limit algal production.

Recognition that the amount of phosphorus introduced into a lake acts as the primary factor in controlling algae growth raises numerous questions: How does this nutrient function? How does it come into lake water? What are the various sources of phosphorus? Are there alternatives for removing it from water or keeping it from entering a lake? What are the techniques and the costs involved?

The research summarized here offers reasonably clear answers for many of these questions and has suggestions about others. However, the measurements involved and their interpretation are complex. The following sections highlight the principal findings that can have meaning in public discussions and decision making.

Sources of Phosphorus

Time of Measurement

Efforts to measure phosphorus in streams led to the discovery that samples taken at some predetermined interval or frequency (e.g., once per week) are not likely to provide accurate estimates of the amounts carried by a stream over a period of time. It is essential that measurements include the periods of high runoff during and immediately after rains or snow melt. These high runoff intervals contain most of the water leaving the watershed, including most of the surface runoff, since the latter occurs almost exclusively during periods of rain or snow melt. In addition, the concentration of dissolved phosphorus changes greatly with rate of flow.

Observation:

Most of the dissolved phosphorus carried by streams is transported during or immediately after rainstorms or snow melt.

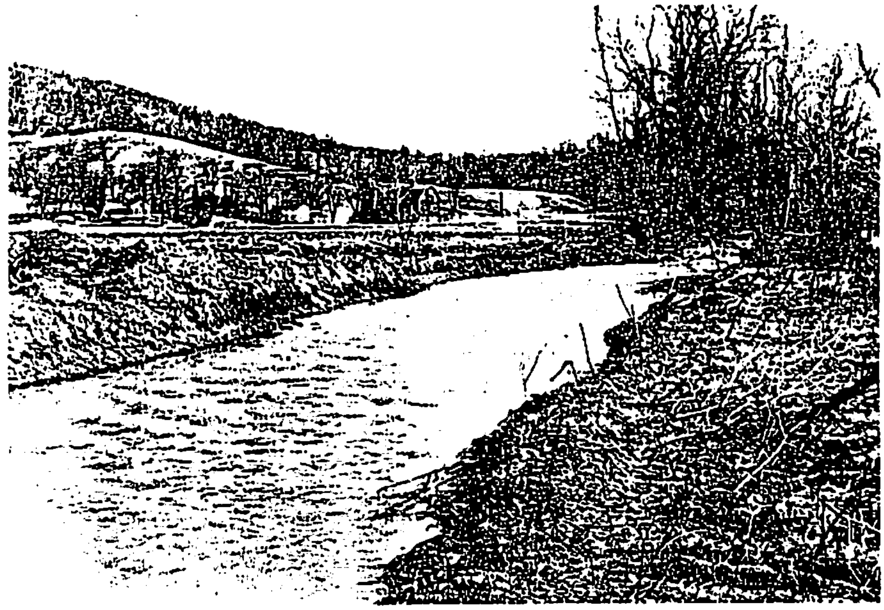
Implication:

Measurements of dissolved phosphorus must be made during periods of high stream discharge if the contributions of dissolved phosphorus from watersheds are to be estimated correctly.

Dissolved versus Particulate Phosphorus

Phosphorus in runoff occurs in three general forms: dissolved organic, dissolved inorganic, and particulate (most of which is attached to soil particles). With which, then, should researchers and water quality managers be concerned? With total phosphorus or with only one or two of

Figure 3. *Stream sampling during high flow is essential in estimating sources and amounts of dissolved phosphorus inputs to lakes.*



the chemical forms? This study, along with information already in the scientific literature, led to the important conclusion that *"dissolved" phosphorus (organic and inorganic) has a far more important influence on algal growth than has the phosphorus attached to soil particles.* Dissolved phosphorus controls the quantities of algae occurring in most temperate latitude lakes during the summer months. The study of 13 New York lakes led to quantitative expressions of the relations between phosphorus loading and concentration of algae. Furthermore, the yield of fish from lakes has been shown to be a function of the crop of algae and so is indirectly dependent on dissolved phosphorus loading. This research project has emphasized the sources and transport of *dissolved phosphorus* because this phosphorus is of biological importance to receiving lakes.

Observation:

The levels of algae in a lake are determined by the dissolved phosphorus present in the water entering the lake rather than on other forms of the chemical, such as the particulate phosphorus attached to soil particles.

Implication:

Studies and management practices should concentrate on dissolved phosphorus.

Sources of Dissolved Phorphorus

What are the sources of the dissolved phosphorus reaching a lake? The dissolved phosphorus reaching the 13 lakes studied in central New York was calculated to be from the following six major sources:

Sewage	55%
Agricultural runoff	18
Forest runoff	15
Residential runoff	6
Atmospheric fallout	6
	100

These relative contributions contrast sharply with land use in the area; 50% of the land was in forest, 48% in agriculture, and only 2% in residential use. The residential area included scattered houses as well as the concentrations in communities of various sizes. If one adds the dissolved phosphorus from sewage to that from agricultural and residential runoff, human activity accounts for nearly 80% of the dissolved phosphorus reaching the lakes in these watersheds.

Observation:

Dissolved phosphorus in the 13 lakes studied was from sewage (55%), agricultural runoff (18%), forest runoff (15%), residential runoff (6%), and atmospheric fallout (6%).

Implication:

Human activities are responsible for 75 to 80% of the dissolved phosphorus reaching the lakes in central New York.

Sewage from treatment plants. As indicated, sewage is one of the principal sources of the dissolved phosphorus that finds its way into our freshwater systems. The sewage may be discharged from municipal treatment plants, or it may leak from the disposal systems of unsewered households. In either case, the phosphorus content of domestic sewage ranges from 1 to 2 kilograms per capita per year depending primarily on whether laundry detergents containing phosphates are being used by householders. More information about detergents and effects of a ban on use of phosphatic detergents will be included in a later section of this report.

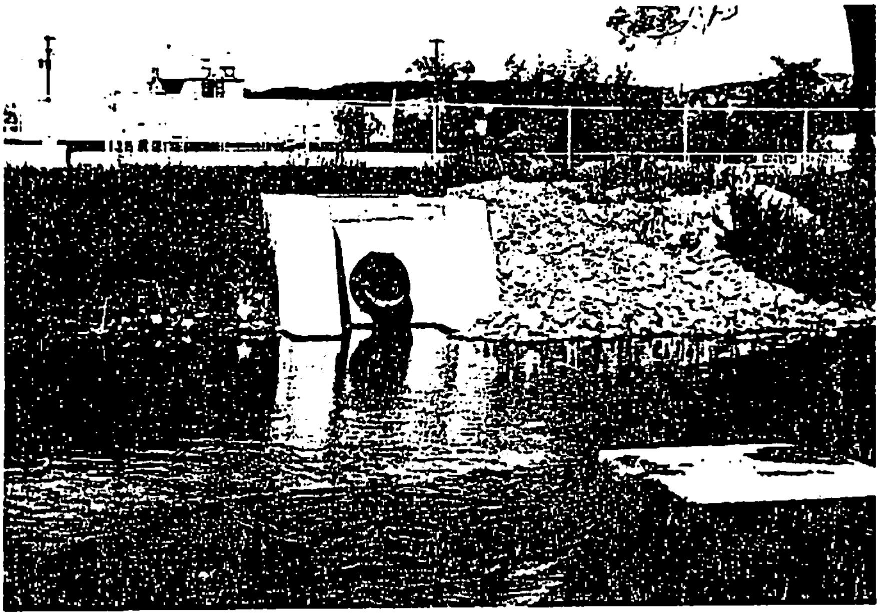


Figure 4. *Domestic sewage was the largest source of dissolved phosphorus inputs to lakes in the watersheds studied. This input can be greatly reduced by a ban on phosphate detergents or tertiary treatment of sewage for phosphorus removal.*

Aside from the size of a treatment plant, the amount of dissolved phosphorus that a particular installation contributes to a lake depends upon the level of treatment (primary, secondary, or tertiary) the plant provides. Most sewage treatment plants in New York State are designed for primary or secondary treatment. Secondary treatment removes approximately 20% of the phosphorus in the influent. With tertiary treatment for phosphorus removal, 75 to 90% of the influent phosphorus is taken out.

Unsewered households. Estimates of phosphorus contributed to lakes by unsewered households vary from 50% of that contained in domestic sewage to as low as 10%. The higher figures represent inputs from unsewered households in populated areas. These tend to be concentrated near streams and lakes and may have less area for disposal fields. The lower figures represent inputs from dispersed housing units in rural areas. These are more likely to be located farther from streams or lakes. Regardless of which estimate is chosen, on a per capita basis, septic tank disposal fields appear to "leak" less phosphorus to lakes than most municipal sewage collection and disposal systems. Even when home disposal systems are not well designed and maintained, they may put relatively less phosphorus in the streams and lakes than municipal treatment plants with only secondary treatment. Much of the phosphorus from septic systems becomes adsorbed to soil particles whereas that from secondary plants is deposited in lakes or streams.

Agricultural activities. Farming operations use large amounts of phosphorus. For example, farmers in the United States annually apply about 2 million tons of phosphorus as fertilizer, which is roughly 5 times the amount in household detergents. Farm animals excrete manure containing 2.5 million tons of phosphorus each year. Such data justify a searching study to discover what happens to this phosphorus. The effects of farming operations in central New York on dissolved phosphorus in streams were determined by a comparison of the dissolved phosphorus in streams draining farmed land with that in streams draining forested land. The average concentration of dissolved phosphorus from farmed land was about double that from forested land. As stated earlier, about 18% of the soluble phosphorus reaching the lakes in central New York was from farmed land.

Alternatives and Costs of Control

After identifying the principal sources of dissolved phosphorus in streams, the researchers turned their attention to alternatives for controlling the quantities reaching lakes. They also studied the costs that might be involved in implementing some of the alternatives.

Ban of Phosphates in Detergents

In recent years, biologists and others have pointed out that household laundry detergents containing phosphates are an important contributor to the phosphorus content of sewage. New York State, in June 1973, imposed a ban on the use of such detergents. A similar ban was imposed earlier in Erie County, New York. A study of three large sewage plants near Buffalo in that county indicated a reduction of 50 to 60% in effluent phosphorus (most of which was dissolved) as a result of the ban. If a similar reduction occurred at other New York sewage plants, the ban would result in about a 30 percent reduction in the total amount of dissolved phosphorus entering the 13 central New York lakes from *all* sources.

Observation:

Laundry detergents have contributed heavily to phosphorus input in the watersheds studied. The 1973 New York ban on such detergents appears to have brought a marked reduction in phosphorus loading to water.

Implication:

Bans on phosphate detergents may be an efficient way to reduce dissolved phosphorus supplied to lakes.

The research did not attempt to assess the costs associated with the ban on phosphate detergents. Consumers may have "paid" something in terms of loss of convenience and reduced whiteness in the family wash, but the effectiveness of the ban in reducing phosphorus inputs to streams and lakes suggests that it was a good policy.

Sewage Treatment

An analysis of other alternatives for reducing the dissolved phosphorus finding its way into lakes revealed that the lowest costs for removing dissolved phosphorus are associated with the largest source — sewage. This is illustrated for the Fall Creek watershed in table 1.

The source of dissolved phosphorus least costly to control is that from the sewage treatment plant, followed by that from barnyard runoff. The other sources are much more expensive to reduce. In addition to cost considerations, a greater reduction in dissolved phosphorus input could be made from the sewage treatment plant source than from any other listed in table 1, except possibly for barnyard runoff. This conclusion is based on data for the period *after* the New York ban on phosphate laundry detergents.

Tertiary treatment to remove phosphorus from the Dryden sewage treatment plant effluent would cost $9,600 annually and would remove about 18% of all dissolved phosphorus transported by the creek to the lake. Because this is a relatively small plant, the cost would be about $12 per kilogram of phosphorus removed. Larger plants, such as some of those discharging directly to lakes, can operate at costs as low as $5 per kilogram removed.

Observation:

In this study, tertiary treatment of sewage for phosphorus removal was the most economical step in controlling dissolved phosphorus inputs to lakes—after phosphate detergents had been banned.

Implication:

Tertiary treatment of sewage plant effluent should be the second step in phosphorus control in many watersheds.

Data collected from the watersheds of 13 lakes in central New York suggest that the Fall Creek situation (table 1) can be extrapolated, to some extent, to other watersheds. As in Fall Creek, many lake watersheds include a city or village that discharges sewage effluent into a stream. Others, of course, may discharge directly to a lake. In fact, sewage represents a greater part of the total problem in the 13 lakes as a group than it does in the Fall Creek watershed.

Wastes from unsewered households. Removal of phosphorus from wastewater by the collection and treatment of wastes from the currently unsewered population would be quite expensive. Costs were estimated to be between $15 and $50 per kilogram of phosphorus removed. Not all of the costs of such a system should be charged to phosphorus removal, for there are also public health benefits. The estimated cost of removing half of the soluble phosphorus reaching the lakes from unsewered populations would be higher than that for the removal of phosphorus from the discharges of existing sewage treatment plants. Recall that only a fraction of the soluble phosphorus in the wastes from unsewered systems is presently entering the lakes. Collection and treatment of such wastes will not

Table 1. Summary of estimated costs of reducing dissolved phosphorus loading from Fall Creek to Cayuga Lake

Method of phosphorus reduction	*Reduction in dissolved phosphorus loading*	*Annual cost to watershed*	*Cost per kg of reduction in dissolved phosphorus loading*
	kg	*$*	*$*
Reduction in corn acreage	680	278,000	409
Avoidance of winter spreading of manure			
Liquid storage	385	398,000	1,034
Stacking	385	221,000	574
Control of barnyard runoff	300 to 1,500	45,000	30 to 150
Tertiary treatment of Dryden sewage	800	9,600	12

NOTE: For details see chapter 5 in *Nitrogen and Phosphorus: Food Production, Waste and the Environment*, edited by K. S. Porter (Ann Arbor, Mich.: Ann Arbor Science Publishers, Inc., 1975).

reduce phosphorus inputs as much on a per-capita or per-dollar basis as removing phosphorus from existing sewage treatment plants.

Agricultural Runoff

A substantial reduction of the soluble phosphorus input from agriculture could be achieved by controlling barnyard runoff but at a cost of $30 to $150 per kilogram of phosphorus removed. Reduction also could be achieved by modification of manure handling practices but at much greater costs.

Observation:

Costs for removing phosphorus inputs from unsewered and agricultural runoff were higher — ranging from $15 to $150 or more per kilogram of phosphorus removed — than for detergent bans or tertiary treatment.

Implication:

Management practices for reduction of phosphorus from unsewered wastes or barnyard runoff may necessitate installation of sewage treatment facilities in thinly populated areas or retention ponds for barnyard runoff. The costs are relatively high.

No attempt was made to estimate the cost of reducing the phosphorus inputs from human activities to zero. So far as is known, there is no practical means of doing this. Removal of all human activity seems the only way to achieve such a reduction. This would be both drastic and impractical in all but a few unusual cases.

Lake Management

A Reversible Process

Nutrient enrichment of lakes due to human activities is a process that accelerates the production and accumulation of algae in lakes. Despite statements in the news media and by some scientists suggesting that this process may be irreversible, considerable evidence gathered in recent years shows that if nutrient loadings to lakes are reduced, the lakes can, in large measure, be restored to their former conditions.

For example, a 14-year study of Lake Washington in Seattle, Washington, suggests two conclusions: (1) summer chlorophyll (a measurement of algal concentration) in a lake will increase if the phosphorus content of the water is increased, and (2) a reduction in the phosphorus content of the water (in this case as indicated by phosphorus measured during the winter) will be followed quickly by a reduction of chlorophyll in the water. Between 1957 and 1963, inputs of phosphorus to this lake from domestic sewage were high and increasing. Starting 1963, sewage was diverted, and in February 1968, it ceased to enter the lake. Figure 5 shows the buildup of chlorophyll in summer as phosphorus content of the water increased from 1957 to 1963. After a peak in 1964, chlorophyll concentration dropped off as phosphorus inputs decreased. The final measurement in 1971 shows less chlorophyll than was present at the beginning of the study in 1957.

Observation:

Phosphorus enrichment of lakes appears to be a reversible process. Effects of a particular source of phosphorus can be reversed when the source is removed.

Implication:

A delay in the introduction of control measures is not likely to cause irreversible changes in lakes. Reversibility suggests an evolutionary policy for phosphorus control in which controls are instituted on a source-by-source basis.

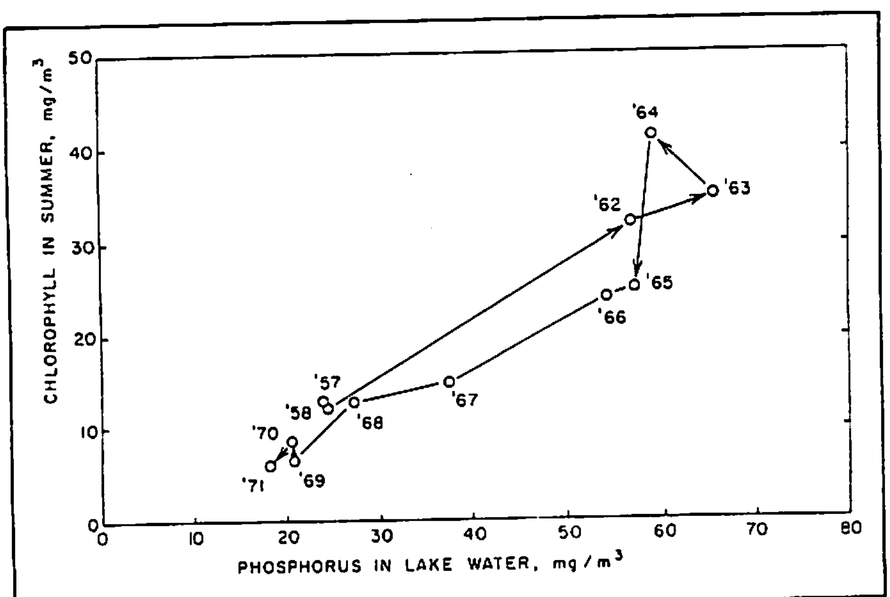


Figure 5. *This graph shows the changes in phosphorus (measured during the winter when biological activity was minimal) and changes in chlorophyll concentration (averaged for the upper 10 meters of the water column) corresponding to changing inputs of sewage to Lake Washington. Data were taken from studies by Prof. W. T. Edmondson, a scientist at the University of Washington.*

Lake Restoration

Five specific policies that might affect the dissolved phosphorus input and the resulting clarity of water in lakes were examined. They are:

I. No control. Return to pre-1973 conditions by removing the ban on phosphorus in laundry detergents.

II. Maintain the ban on phosphorus in laundry detergents. This would be a continuation of present policy.

III. Remove 80% of the phosphorus from the effluent of sewage treatment plants. If this treatment were universally applied, the ban on phosphorus in laundry detergents could be eased.

IV. Establish community collection and treatment systems (including phosphorus removal) in unsewered areas, and control barnyard runoff.

V. Control all sources of phosphorus associated with human activity in the watershed.

Figure 6. *The Secchi disc is used to measure water transparency in lakes. Transparency is an indicator of the concentration of algae.*

Table 2. Alternatives, policies, and costs for controlling dissolved phosphorus inputs to lakes

Policy	*Costs per kilogram of phosphorus controlled*
I. No ban on phosphate detergents	—
II. Ban on phosphate detergents	No cost to municipalities or agriculture (cost to consumers was not estimated)
III. Tertiary sewage treatment	$5 to $12/kg
IV. (a) Collection and treatment of unsewered waste	$15 to $50/kg or more
(b) Limit barnyard runoff	$30 to $150/kg
V. Removal of all human activity	Impractical in most situations

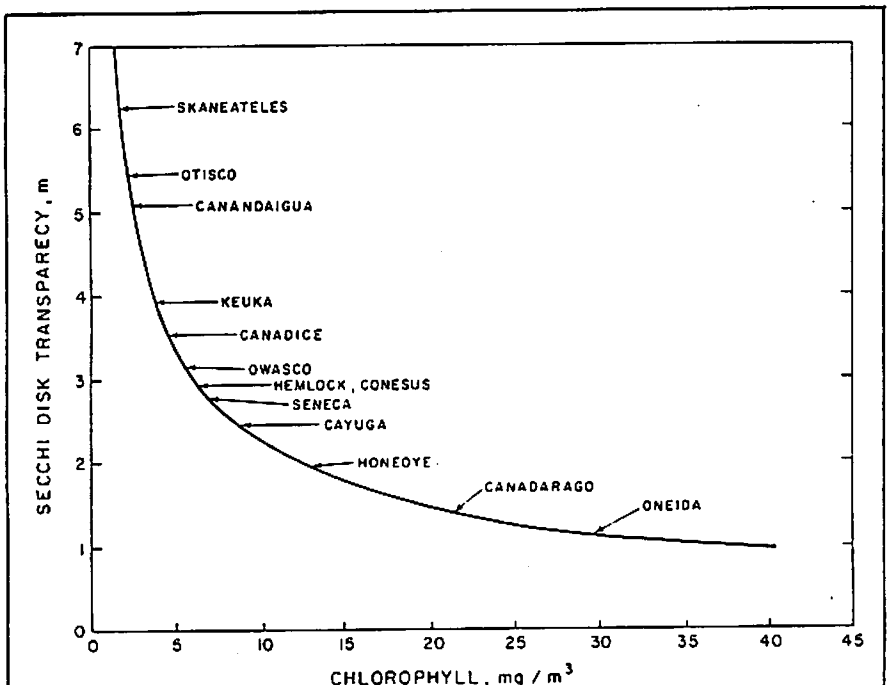


Figure 7. *State of 13 lakes in central New York according to the Secchi disc transparency and chlorophyll relation, prior to the ban on phosphatic laundry detergents.*

The costs of implementing such policies were described in previous sections and are summarized in table 2. The sequence of policies is such that after the first policy of no control, the least expensive source is controlled first, followed successively by the next least expensive method.

Observation:

Dissolved phosphorus input to a lake can be reduced by a series of incremental policies.

Implication:

Since costs vary among policies, decision makers should examine alternatives carefully before taking action.

The effect of each of the five policies on clarity of the water in three New York lakes was estimated by using a three-step procedure. First, the input of dissolved phosphorus to each lake was calculated for each policy on the basis of coefficients for sewered and unsewered populations, agricultural land, and land in the absence of human activity. Second, the chlorophyll concentration in the lake water (a measure of the concentration of algae), as related to dissolved phosphorus input, was estimated for each policy by an equation developed from a study of 13 central New York lakes. Finally, the Secchi disc transparency[2] (a measure of water clarity), as related to chlorophyll concentration, was estimated for each policy by another equation developed from data on 13 New York lakes and Lake Washington. This relationship and the approximate situation for each of the 13 lakes prior to the ban on phosphatic household laundry detergents are shown in figure 7. The expected results of incrementally applying the five policies to the three lakes are shown in figure 8.

For example, with policy II, ban on phosphatic laundry detergents, the Secchi disc transparencies in the three lakes would be approximately:

Lake	*Secchi disc transparency, meters*
Canadarago	1.5
Cayuga	2.6
Skaneateles	6.0

Figure 9 suggests that a set of policies producing desired results for one lake may be insufficient for another or represent unnecessary costs for a third. For ex-

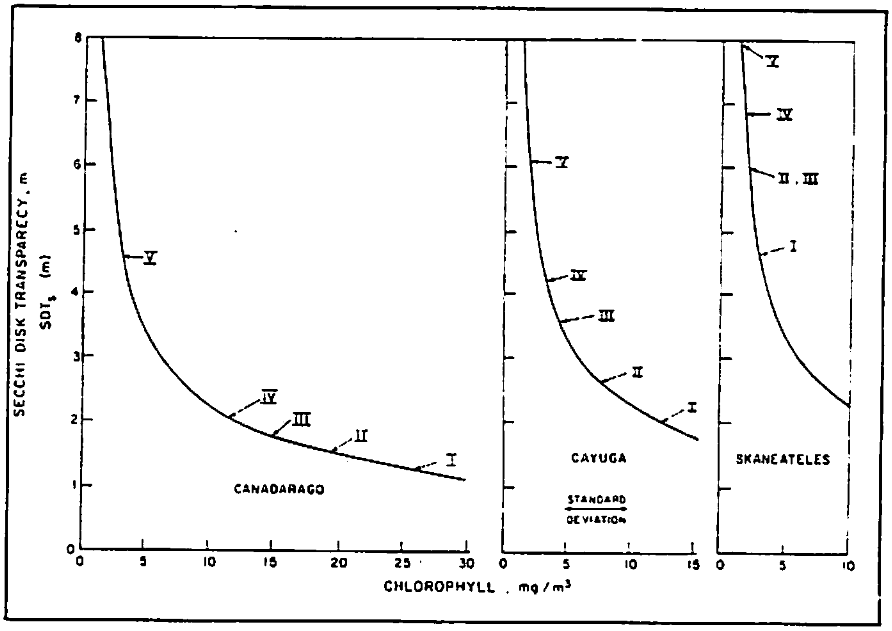


Figure 8. *Responses of the three lakes to the five management policies, showing the expected increases in the clarity of the lake waters.*

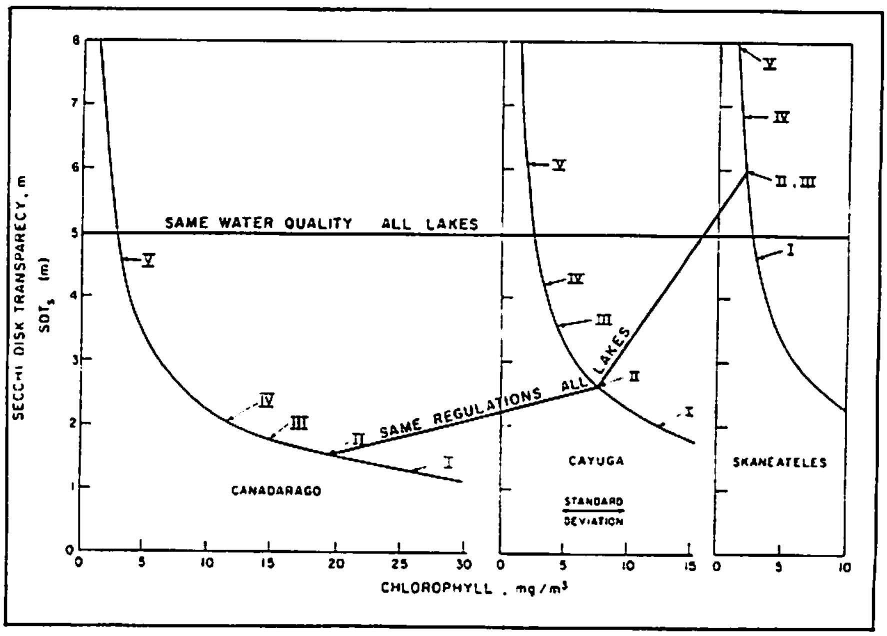


Figure 9. *Comparison of (1) a policy of attempting to achieve the same water quality in all lakes vs. (2) a policy of requiring the same regulations in all lake watersheds.*

2. Measuring the clarity of lake water as Secchi disc transparency involves lowering a reflective target (Secchi disc) into the water on a calibrated line. A reading is taken just as the disc disappears from view because of the turbidity in the water. Low readings indicate large quantities of algae as long as readings are taken when the water is not turbid from suspended particles of sediment. Higher readings indicate clear water with less algae.

ample, the application of all five policies (including the removal of all inputs caused by human activity) in the Canadarago Lake Basin would improve water clarity to a point less than the clarity found in Skaneateles before policies were applied. This difference is due, primarily, to the size of the watersheds relative to lake volume. Skaneateles has a small watershed relative to lake size and greater depth. Consequently, it gathers fewer nutrients in relation to volume, and algae are less dense.

In the judgment of the researchers, this discussion represents the most reasonable interpretation of what is known about the relationships between phosphorus inputs from human activities and chlorophyll in the lakes in central New York. Any major improvements in reliability of the relations will result only from the collection of more data. Refinements of the methods of analysis of the data now available might improve the relationships somewhat, but such refinements are not likely to make a major change in the general conclusions. What, then, is a reasonable course of action?

First, substantial evidence now in the literature indicates that over a period of years, the phosphorus available to algae is not conserved; that is, high levels of algal growth appear to depend upon continuing inputs of dissolved phosphorus. The effects of a particular source of phosphorus appear to be reversible whenever a control measure is implemented. Therefore, delay in introducing controls will probably not cause irreversible changes in the lakes.

The reversibility of changes suggests an evolutionary policy in which controls are gradually instituted on a source basis. Information obtained about selected study lakes could be applied to others.

Figure 10. *Fish production in lakes is dependent on algal growth which in turn is largely dependent on inputs of dissovled phosphorus.*

The first step of the evolutionary process is now in progress. The New York ban on phosphorus in detergents was instituted in 1973. Tertiary treatment for phosphorus removal is being installed in several sewage plants that discharge effluent to lakes. As the detergent ban and the removal of phosphorus from sewage take effect, it is essential that corresponding changes in the lakes be adequately monitored and assessed. The knowledge gained could be applied in the formulation of further management policy not only for the lakes directly affected, but also for similar lakes elsewhere.

If policies were based on such systematic use and transfer of information between lakes, a framework would be established to assess the costs of reducing nutrient inputs to lakes. For example, figure 7 shows the relation between Secchi disc transparency and chlorophyll in the lakes of central New York in the period prior to the ban on phosphatic household detergents. With this relation, the costs could be stated in the terms that it would probably cost X dollars to transform conditions in lake Y to those existing in lake Z. This would provide a graphical basis for evaluating the effects of management policies proposed for the lakes. With appropriate data, further relations between the levels of phosphorus input to lakes and their use, such as for fish production and water supply, could be derived and used in an analogous manner.

Should the goal of management policy be to achieve uniform water quality in all lakes or to apply equal restrictions in the watersheds of all lakes? Uniform water quality (e.g., Secchi disc transparency of 5 meters) in the three lakes would require policy V in Canadarago Lake, policy IV in Cayuga Lake, but only policy I (no restrictions) in Skaneateles Lake (fig. 9). On the other hand, if the same policy, say II, was applied in all watersheds, transparency would be high (6 meters) in Skaneateles, medium (2.5 meters) in Cayuga, but less than 2 meters in Canadarago Lake. Perhaps neither uniform quality nor uniform restrictions should be the goal of lake management policy. It is probably not possible to achieve the same quality in the three lakes with any set of management policies. On the other hand, uniform application to all lakes of a policy needed for Canadarago may be a waste of resources.

No attempt has been made to estimate the benefits of reductions in phosphorus inputs to lakes. Such estimation is complicated; reduced phosphorus inputs will make lakes more valuable for some purposes such as swimming and water skiing, but the same reductions may make these lakes less valuable for fishing, as would be the case for most, if not all, of the Finger Lakes.

For a given lake, the cost of instituting a particular policy can be estimated and compared with the likely change in chlorophyll and transparency. Policy makers can then make a judgment of whether they think the benefits justify the cost. For example, the cost of moving from policy II to policy III on Canadarago Lake would be about $10,000 per year, based on a sewered population of 1,500 people. For Cayuga Lake with 50,000 sewered population in the watershed, the cost for the same policy would be about $280,000 per year. In these examples, one must keep in mind that the surface area of Cayuga Lake is more than 10 times, and the volume more than 100 times, that of Canadarago Lake. In either case, although no good estimate of the dollar value of benefits is available, policy makers would at least have some basis for comparing costs with likely changes in algal production in the lake.

A Note of Caution

The lake restoration discussion centers on the supposition that minimizing the concentration of algae in a lake is universally desirable. However, fish production is ultimately dependent upon algal production in all but a few special cases. Quantitative relations defining this have now been developed for a wide variety of lakes located throughout temperate regions of the Northern Hemisphere. Translated in terms of this report, such findings mean that fish yields to anglers and commercial fishermen are greater at higher rates of dissolved phosphorus supply as long as plant growth is not so great as to deplete oxygen. As a management consideration, the question of the kinds, as well as the total amounts, of fish produced must be addressed. Nevertheless, the relations of fish to phosphorus supply and algal concentration provide a cautionary "look-before-you-leap" note to those who would institute wholesale programs of phosphorus control.

Implications:

Policies for phosphorus removal can be applied selectively to reduce total costs.

Identical policies applied to different lakes will not produce water of similar quality.

Appropriate water quality can be achieved at lowest cost by selective use of policies.

The Human Factor in Nutrient Management

The presence of the human population was identified as a major source of nutrient input to the streams and lakes of watersheds. More specifically, the introduction of nutrients into streams and lakes is often the result of the disposal of solid waste, sewage, kitchen and laundry detergent, barnyard waste, and other agricultural runoff.

Analyzing a stream or lake watershed from a social and ecological perspective reveals that a stream like Fall Creek traverses social, economic, and political boundaries which are just as real as the physical and geographical terrains. These invisible manmade boundaries have important implications for nutrient management. One clear implication is the complex nature of the administrative problems created by these various boundaries. Questions arise as to where responsibilities rest for nutrient disposal problems of individual homes, barnyards, or farm land on the one hand and for villages, townships, or municipalities on the other.

Who Is in Charge of a Watershed?

A populated watershed constitutes both an ecological and sociological unit, but seldom is there a recognized administrative authority to govern. The Fall Creek watershed, though modest in size, traverses sections of three counties. Within these three counties the watershed cuts across eight townships and six villages. Each of the three county health departments legislates and supervises its own separate standards for installation and use of septic tanks. Likewise, three separate county planning offices proceed with independent policies. In addition, there are three county boards of legislators and multiple village councils and township governments. Furthermore, several organizations with peripheral interests, such as county environmental councils, the Cayuga Basin Board, the New York State Department of Environmental Conservation, and the Soil Conservation Service, all legitimately claim some responsibility for the planning and control of land and water use within the watershed.

Such a situation suggests that many features of social and environmental systems are not meaningfully organized. Additional evidence for this hypothesis was provided by residents of the watershed who, when interviewed in a formal study, indicated they were at a loss to know to whom to turn for violations or remedial action in safeguarding the streams and lakes.

Survey Results And Implications

The Study

A sociological investigation was made by interviewing one out of every six household heads in the Fall Creek watershed. Similar samples were studied in the Owasco and Canadarago watersheds for the purpose of comparing and verifying the findings. The major purpose of the investigation was to determine the levels of awareness and concern residents of the watersheds held about the streams and lakes and their propensity to act or support action to safeguard those resources.

Public Awareness

It was clear from the survey that the public was sensitive to environmental issues. Half the respondents in the watersheds considered water quality to be a serious problem. One-third of all respondents believed that water quality was deteriorating, and 98% felt that the quality of the environment should be improved. Interestingly, 80% of the people interviewed in the Owasco and Candarago lake watersheds were optimistic that improvements could be made, whereas less than 50% of the Fall Creek respondents shared this optimism.

Public Willingness

The best indicator of a cumulative impact of environmental awareness that had been built up was the expression from three-fourths of the residents that all available pollution control techniques should be applied despite the cost. This response is even more surprising when it is realized that one-third of the people believed the costs of pollution control to be high. Two-thirds of the respondents stated they would pay an average of 8.5¢ more per half gallon of milk or per dozen eggs if it would permit farmers to produce these products without polluting the environment.

The Gap between Attitude and Behavior

A note of caution needs to be sounded, however, in terms of what respondents said they would do and what they actually may do. Two examples will serve to illustrate this point. First, when residents were asked their reactions about a neighbor's septic tank being defective or overflowing into the stream, strong feelings were expressed that immediate remedial action should be required at the owner's expense. When the same residents were subsequently asked whether their own septic systems had ever been inspected, nearly all indicated no inspection had been performed since the original installation, even though in some cases 20 or 30 years had elapsed. In the second example, at a time when there was a lot of publicity about the beneficial effects to the environment of using low phosphate detergents, homemakers were asked whether or not they were using low-phosphate detergents. Forty-three percent said they were, but a subsequent check on the available brands in the kitchen and laundry revealed that only 21% were actually using low-phosphate products. Another 27% reported they weren't sure but thought they were using low-phosphates whereas the brand checks showed they were using high-phosphate detergents.

This apparent dissonance between stated attitude and the actual behavior is explained by social psychologists as residing in the realm of perception. In other words, the respondent does not relate the general case to her or his specific situation. The respondents tend to respond that "pollution" is undesirable (the general case) without relating that perception to whether or not the detergent brand on hand (the specific case) is in opposition to the stated belief. Socially acceptable or normative attitudes are usually expressed in terms of what respondents feel or think is the expected or appropriate response. Only when confronted with the behavior-attitude dichotomy do respondents tend to perceive or redefine the real behavior as internally inconsistent with the stated intent.

The gap between stated belief and actual behavior may be great or small. Whether it is great or small has important implications for trying to forecast future behavior. In general, there are a number of factors that, when present, usually indicate there will be little difference between stated belief and actual behavior. The greater the background of individuals on an issue, the higher their education, the greater their motivation, the more they understand the technical, economic, social, and political feasibility of alternatives, then the more likely it is that these factors will undergird and support their grasp of the full spectrum of the issue and that their actual behavior will tend to conform to their stated attitude.

Sources of Financial Support

The watershed residents believed certain groups should receive more financial assistance than others in their efforts to combat water pollution. One-third supported aid for businesses, one-half thought households should receive aid, and two-thirds supported help for farmers. However, there was no consensus on the source of these funds. Increases in income taxes, property taxes, and food prices; reordering of governmental budget priorities; and special water-use taxes all received about equal support. It was evident that people supported the notion of fair distribution of costs as well as clear delineation of expenditures. The findings related to public interest and concern about water quality, and expressed willingness to pay to protect or improve it were in keeping with national opinion surveys completed in the early 1970s by Erskine and published in the *Public Opinion Quarterly*.

The "Yuk Effect"

Interestingly the viewpoint of the respondents in the three watersheds was found to be in agreement on another point: sewage disposal was viewed as a more important pollution control problem than farm runoff of fertilizers or insecticides. Related to the concern about sewage disposal and its effect on water quality was a discovery of what the investigators came to identify as the "yuk effect." This was the expression people would utter at the notion of drinking other people's sewage effluent. The interesting thing about this reaction was that from any given individual's perspective there was more concern about the impact of sewage disposal upstream than downstream.

Failure to See "The Big Picture"

The study suggested that few people yet comprehend the existence and functioning of the larger ecosystem of which they are a part. They fail to recognize that, insidiously, their "little bit" of wastewater joins other waste disposal to cause the pollution they know instinctively must be avoided. They accept and verbalize the concept that people must learn to live in harmony with nature. But they have not fully grasped the conceptual implication that neighbor must live in harmony with neighbor, community with community, and larger political entities must learn to work with one another to insure that people are not drinking others' untreated sewage and that watersheds are not being despoiled.

Observations:

The study of the residents in three rural watersheds revealed that:

The social, political, and administrative boundaries do not correspond with the physical and geographic boundaries of the watersheds.

People are aware of, and concerned about, water pollution.

They feel that water quality improvement and protection cannot be left to individual action and that government action is required.

They prefer government action to be subject to local control.

They believe costs of maintaining or improving water quality will be high but expressed willingness to help pay the bill.

Individual actions are not perceived as having any significant effect on the overall status of a watershed. The feeling expressed is that all residents must act in concert to assure desired results.

Contrariwise, there is evidence of a kind of wilderness psychology in which people seem to feel that their small contribution to water pollution won't hurt anyone. They are more concerned, however, about drinking someone else's sewage than they are about where their own sewage is going.

Despite a feeling that water quality is declining and that action is important, there appears to be a lack of comprehension that the total ecosystem must be in balance. There may be a growing understanding that people's activities must be brought into harmony with nature, but it is offset by a protective sense of individual rights and a feeling of futility over what one can do by oneself.

Some Implications:

The administration of uniform regulations and controls for residents of watersheds is more likely to produce desired results toward safeguarding water quality than dependence upon uncoordinated individual action.

An administrative unit fitted to the watershed boundaries will be better able to address the needs of the watershed; however, its source of economic, political, and social powers will have to be carefully spelled out.

Respondents are willing to participate in environmental management. They are willing to pay more to safeguard water quality. What is lacking is the necessary coordinated governmental effort to capitalize on the willingness of the watershed residents to follow necessary environmental controls and guidelines.

Watershed administrative units that face long delays in undertaking needed action to safeguard water quality in streams or lakes will tend to leave the local residents in an uneasy state of uncertainty. Environmental educational-motivational programs with little or no structured or prescriptive action tend to produce a kind of burned-over territory wherein it is more difficult to ignite sparks of interest the next time around.

With the updated guidelines of the Federal Water Pollution Control Act contained in the 1972 Public Law 92-500, it will be interesting to observe whether the desired ends of clean waters can be achieved. The provisions of section 208 which address the nonurban, undesignated areas, such as the rural watersheds included in this study, will not come under the proposed comprehensive planning process until the late 1970s. Public interest and participation, if properly mobilized along viable administrative options, can make significant contributions.

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EDUCATION
RESEARCH

THE DANGERS OF DETERGENTS

On the other side of the page is a list of phosphate content in obtainable washing compounds. We do not endorse any of the brands - there has been simply too little research to predict confidently the environmental effects of detergents, whether they contain phosphates or other substances.

A BRIEF HISTORY

Biodegradability of detergents is no longer a problem; all washing and cleaning products sold in the U. S. since mid-1965 have been biodegradable (able to break down readily in the environment.) When industry switched from "hard" detergents to biodegradable "soft" detergents, phosphates were added.

At the time of the change, several ecologists warned that phosphates might cause even greater problems than the hard detergents, which produced layers of foam in our streams. Several men predicted exactly what has happened; phosphates stimulate enormous production of algae, and the luxuriant algae, in breaking down, exhaust the oxygen supply in the water. The result is a wet desert devoid of life.

This process by which a lake "dies" from too many nutrients is called eutrophication. It can happen slowly and naturally in a lake that has existed for millions of years; however, man is causing eutrophication of many bodies of water in less than a decade. Phosphates are not the only villains in this speeded-up process. Nitrates are also suspect, but too little research has been done to pinpoint exactly what does trigger a growth explosion in algae. Dumping of untreated or inadequately treated sewage also contribute to an overabundance of nutrients. We need better sewage treatment and disposal methods, fewer unnatural substances funneled into our waste water, and much more research on the subject.

Now replacements for phosphates are being considered. NTA (nitriolo-triacetic acid) is being used by Lever Brothers already in their Cold Water All (powder form) and by Procter and Gamble in varying amounts in nearly 1/3 of their products. Yet the Vice President of Lever Brothers told a Senate Subcommittee that he doubted NTA would be the final answer, and the fact is no one knows what the environmental effect of tons of NTA would be. As had been proven time and again, we should not allow a product to be used by the public until its side effects as well as major benefit are known.

SOAP AND SODA

We do know that you can get a white wash with less than one percent phosphate and no bad environmental effects by using soap and washing soda. And as an added benefit, soap destroys germs more effectively than detergents.

- over -

SOAP AND SODA (Cont'd)

When switching to soap from detergents, first "strip" all clothes of detergent residue by washing them in the machine with hot water and 1/4 cup of washing soda. Otherwise your clothes may yellow.

After stripping, soap and soda will give you a "white" wash. For the amount of soap read the package directions (usually 1/2 - 3/4 cup) and add 1/8 - 1/4 cup of soda to the machine depending on the hardness of your water. (New England water is fortunately fairly soft).

NOT THE LAST WORD

The following list is purposely general and subject to change. This is not the last word on the phosphate problem, merely a reasoned assessment of the present situation. Industry does indeed respond to public pressure and is changing the contents of detergents, and even the same brand may contain different proportions of ingredients in different parts of the country to cope with various hardnesses of water. Use the list only as a relative comparison, and stick to soap and soda if you can.

Realize that, until enough research is done to clarify the many causes of unnatural eutrophication, the two most valuable objectives you will accomplish by switching from high phosphate detergents are psychological. You will have taken a personal step indicating your willingness to be selective in favor of environmental quality, and you will have indicated to the soap and detergent manufacturers it is worth their while to be ecologically aware. Whatever you use, follow package instructions and don't waste a product or multiply its ill effects by using more than is recommended. It's just not true that detergents will give you a whiter wash.

OVER 20 GRAMS OF PHOSPHATE PER WASHLOAD

A & P Blue Sail
Salvo
Dash
Tide XK
Concentrated All
Cold Water All (powder)
Drive
Breeze
Oxydol
Duz Detergent
Punch
Ajax Laundry
Surf
Sears Laundry Detergent
Fab
Dreft
Cold Power
Bold
Gain
Cheer
Brillo Detergent

BETWEEN 2 AND 20 GRAMS PER LOAD

A & P White Sail
Jet Power
Amway S-A-8
Shop Rite All Purpose
Wisk

NO PHOSPHATE PER LOAD

Cold Water All (liquid)
Duz Soap
Ivory Flakes
Ivory Snow
Lux Flakes
Whirlpool Laundry Detergent
Sears Enzyme Laundry Detergent

Dishwashers are a special problem - as presently designed they are geared to operate effectively only on phosphates in some amounts. Electrasol and Finish have only 4 plus grams per load; Cascade, Finish, All, Calgonite and Amway have 8 or higher.

This list is based on several sources and subject to constant change. pr 9 D 70

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY
U. S. ENVIRONMENTAL PROTECTION AGENCY
200 S.W. 35TH STREET
CORVALLIS, OREGON 97330

POSTAGE AND FEES PAID
ENVIRONMENTAL PROTECTION
AGENCY
EPA 335

NORTHEAST WEED CONTROL COMPANY
INCORPORATED
147 WHITEWOOD ROAD
WESTWOOD, MASS. 02090

ENVIRONMENTAL NEWS

FOR IMMEDIATE RELEASE
December 22, 1975 (75-53)

Contact: Karen Manthe
(503) 752-4211, Ext. 4316

EPA NEARING MILESTONE IN SCIENTIFIC EFFORTS TO RESTORE AMERICA'S POLLUTED LAKES

CORVALLIS, OR. -- For the first time -- anywhere in the United States -- a lake polluted by nutrients from municipal wastewater is being restored to near-pristine quality without eliminating or diverting the wastewater flow.

Although other lakes have been restored to varying degrees by other methods, Shagawa Lake (Minnesota) is the only place where restoration is being demonstrated by removing phosphorus, a critical nutrient, from treated wastewater flowing into the lake.

This significant progress in efforts to save polluted American lakes was announced today by the U.S. Environmental Protection Agency's Environmental Research Laboratory in Corvallis, Oregon.

Dr. A. F. Bartsch, Director of the Corvallis Laboratory, said "This environmental success story is the fruitition of more than nine years of research, testing, and practical application by scientists here and at our Ely Field Station in Ely, Minnesota.

(MORE)

"Although it's extremely difficult to place an actual dollar value on what we're achieving at Shagawa Lake, there's no doubt that the economic benefits have been enormous in terms of rapid recovery time and the immediate improvement of an important recreation area."

In contrast to the hundreds of relatively-pure lakes in the surrounding wilderness, Shagawa Lake -- impacted by municipal wastewater for more than 75 years -- provided a classic example of a lake reacting unfavorably to the pressures of civilization.

The 2,500-acre lake's problems began in the late 19th Century when iron mining and logging activities saw Ely emerge as a boom town on the Southeast shore.

Although the mining industry still undergirds the area's economy, tourism now surpasses it in importance to the City of Ely. Local Chamber of Commerce information indicates that on any summer weekend, Ely's normal population of 5,000 swells to some 15,000 as outdoor enthusiasts head for holidays in the Boundary Waters Canoe Area of the Lake Superior National Forest.

Stretching approximately 200 miles along the Canadian border, this boundary wilderness area has some 1,200 miles of canoe routes meandering through more than one million acres of land and water in the northern part of the Superior National Forest.

In Ely, the main street is lined with stores with such names as "Wilderness Outfitters" and "Canadian Waters." Canoes are displayed much as new and used cars are shown in other cities.

Sun-bronzed young men and women carrying back packs and wearing hiking boots are seen all over the city. A large sign in the middle of Ely announces "Welcome to Ely -- Canoe Capital of the World."

In the winter when Shagawa Lake freezes over, the All-American Championship Sled Dog Races are held on the lake.

Thus, Ely's lucrative recreation industry is closely tied to the water quality of the numerous lakes of the area, such as Shagawa Lake -- and for years, this lake had been in trouble.

Scientists know that when human waste is discharged into lake waters it carries large amounts of nutrients that promote heavy growth of algae. Since the turn of the century, Ely's phosphorus-loaded wastewater had been dumped into the lake, until the resulting heavy algae blooms and bacterial contamination made the lake unfit for drinking or recreation uses.

(MORE)

In 1912, townspeople built a primary treatment plant to remove solids from the wastewater, but by 1932 the contamination in the lake was so serious that a pipeline was installed to bring drinking water from Burntside Lake, a few miles upstream from Shagawa.

A secondary treatment plant -- a high-rate trickling filter operation -- was built in 1954. Neither plant removed significant amounts of nutrients.

To find out just how much phosphorus was coming into the lake from from wastewater and learn how it affected algae growth, researchers began sampling and analyzing effluent from the secondary treatment plant in 1967. They found that the wastewater accounted for about 80 percent of the phosphorus -- but only 2 percent of the water -- entering Shagawa Lake.

Although a variety of promising lake restoration techniques was being tested, the scientists felt that the possibility of treating the wastewater to remove phosphorus needed more study.

The Federal Water Pollution Control Administration, one of EPA's predecessor agencies, set up a pilot tertiary treatment system at Ely to remove phosphorus and show that the treated wastewater, when diluted by incoming river water, would not support significant algae growth.

As a result of the pilot plant success, EPA in 1972 awarded the $2.3 million grant for design and construction of a tertiary wastewater treatment plant and full-scale operation until 1976. This covers about 93 percent of the cost with the City of Ely providing the remaining funds.

Robert M. Brice, Chief of the Corvallis Laboratory's Ely Field Station, is on-site manager of the project. The Wastewater Research Division of EPA's Municipal Environmental Research Laboratory in Cincinnati, Ohio, has provided assistance in operation of the plant.

The treatment plant went into full operation in early 1973. After nearly three years, all indications are that it's working. Phosphorus levels in water leaving the new plant have been consistently less than 0.05 milligrams per liter (a level that will restrict algal growth after mixing with water entering the lake from other sources).

(MORE)

This small amount is equal to a scant one-seventh of a pound of phosphorus per acre of water one foot deep.

EPA scientists are quick to emphasize that although significant progress has been made, a certain amount of phosphorus also reaches Shagawa Lake from natural sources. In addition, phosphorus from years past remains in lake-bottom sediments.

EPA scientist are quick to emphasize that although significant progress has been made, the lake has not yet had time to respond fully to the reduced supply of phosphorus. There is still enough phosphorus available in the water and bottom sediment to cause occasional algal blooms under certain conditions.

Even so, the problem is nothing like it has been in years past. The important thing is that Ely residents and tourists can tell a vast difference.

The chief pilot at a U.S. Forest Service seaplane base on Shagawa Lake has lived near there all of his life. "The lake used to get so filthy with algae that it really sickened me," he said. "Scum was everywhere. But now in the past two or three years there has been a real improvement in the condition of the lake, no question about it."

Another lifelong resident noted that "Last summer (1974) was the first time I've seen the lake so free of algae."

The owner of a tourist cabin business, who moved to Ely 50 years ago and used to swim in Shagawa Lake, voiced the sentiments of many resort owners when she said "The lake had become progressively worse, until this last summer (1974) when it was the cleanest I've seen since I was a child."

Dr. J. P. Grahek, Mayor of Ely, said that the swimming beach of Shagawa Lake was open for a full season this year for the first time in many years.

EPA scientists also are pleased with the success of the project and feel the phosphorus removal technique could help restore other lakes with similar problems.

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NOTE TO EDITORS: Photos depicting the tertiary treatment plant and Shagawa Lake recreational activities are available through the Office of Public Affairs, Corvallis Environmental Research Laboratory, 200 S.W. 35th Street, Corvallis, OR 97330.

A DESCRIPTIVE SUMMARY OF THE

ENDECO[R] TYPE 2100 SEPTIC-SNOOPER[TM] SYSTEM

What is the SEPTIC-SNOOPER?

This unique monitoring system was developed by Environmental Devices Corporation in response to a need for an economical means of locating areas of septic system and sewage effluent discharges entering streams, lakes, rivers, reservoirs and harbors. It is a portable field unit that can be operated continuously to scan expansive shorelines in a comparatively short period of time. Real time feedback provides on-site determination of problem areas.

How does the system work?

The SEPTIC-SNOOPER System monitors two parameters, fluorescence (organic channel) and conductivity (inorganic channel). This unique system is based on the theory that a stable ratio exists between fluorescence and conductivity in typical septic leachate outfalls. Readings for each channel appear visually on panel meters while the information is recorded on a self-contained strip chart recorder. Recording modes include individual channel outputs cr a combined output.

The submersible lift pump in the probe draws water from the bottom and passes it through the fluorometer unit which is sensitive to fluorescing organic molecules from laundry whiteners and septic wastes. The water then passes through a graphite electrode type conductivity cell sensitive to inorganic ionic components such as chloride (Cl^-) and sodium ($Na+$). Fluorescence and conductivity signals are generated and sent to an analog computer circuit that compares the signals against the background to which the instrument was calibrated. The resultant output is expressed as a percentage of the background and is continuously documented on the strip chart recorder. Full scale recorder output is provided for less than 1% septic leachate concentration. When higher than normal readings are encountered, discrete water samples can be taken directly from the instrument's discharge for later analysis of actual water quality. The system is powered by a standard 12 volt automobile battery or a portable generator. The system can be operated from a small boat moving at walking pace along shorelines or in fixed locations for static monitoring applications. The entire system is completely portable.

What are the system's applications?

The SEPTIC-SNOOPER System has a number of applications which include:

- assistance for regulatory agencies in monitoring the condition of shoreline septic systems and enforcing public health regulations

- determination of the presence of septic leachate in potable or recreational waters

- assistance in determining optimum lake levels and other facets of in-lake management programs

- help in planning future property development

- identification of the direction and relative amplitude of groundwater inflows

- monitoring of groundwater resources

- monitoring downstream effects of municipal waste treatment outfalls

- on-line monitoring of sewage effluent discharges

How does this method compare to other techniques?

Conventional methods of leachate detection are primarily dye studies and in-depth water sampling programs. Simple visual observation is also used. All of these methods have their advantages as well as their disadvantages The following matrix compares the characteristics of these methods with respect to accurate location of problem areas:

Technique	Survey Time Involved	Access Problems	Ease of Operation	Effectiveness	Total Cost
dye studies	extensive	yes	complex	good	high
water sampling	extensive	no	complex	fair	high
observation	minimal	no	simple	poor	low
SEPTIC-SNOOPER	minimal	no	simple	excellent	low**

What is the system's track record to date?

The SEPTIC-SNOOPER System was originally developed in 1976 through the combined efforts of Environmental Management Institute and Environmental Devices Corporation. The system has been used in a number of water quality surveys to help determine the extent of faulty septic systems allowing excessive amounts of nutrient concentrations to reach lake waters.

**The purchase cost of one complete SEPTIC-SNOOPER unit is far less than the cost of a single leachate outfall survey done by most other techniques. The system's flexibility to meet a number of applications and its continued use as a periodic check on existing conditions allows long term amortization which further reduces overall cost.

Studies have shown that septic leachate is now a major cause of lake eutrophication. The introduction of excessive amounts of dissolved nitrate, ammonia, phosphate and organic substances results in an abundance of bacteria and algae growth that can have serious effects on recreational and potable waters, including groundwater reserves.

The SEPTIC-SNOOPER System has been used in a number of surveys to determine the extent of septic leachate discharges and to locate their sources. Major surveys in New Hampshire have been conducted during comprehensive studies of Ossipee and Squam Lakes as well as Lake Winona and Lake Winnepesaukee. An in-depth study of Johns Pond in Mashpee, Massachusetts resulted in the location of a number of malfunctioning septic systems. The data derived from the study served as the basis for sound pond management and planning for future development of shoreline property.

A number of studies have subsequently been scheduled, further emphasizing the awareness by various governmental agencies and private consulting and environmental organizations that a serious health hazard can result from sewage and septic system pollution of wetlands.

In terms of cost and long term environmental impact, the most effective cure for sewage and septic leachate problems is generally regarded as prevention of them or at lease the arresting of them at early stages. Water resources planning and management programs must address the need for periodic septic system monitoring as an integral part of overall water quality assessment. The SEPTIC-SNOOPER System is designed to meet that need in various applications which include lakes, rivers, harbors, groundwater reserves and municipal waste treatment facilities. Water resources management programs that incorporate the periodic use of the SEPTIC-SNOOPER System should realize tremendous cost savings and long term environmental benefits. The only real alternative is to wait until a major environmental problem becomes plainly evident, at which time, costly research, evaluation and corrective measures must be undertaken.

Who could benefit from the use of this system?

Users of this unique method of leachate detection can best be categorized as having a continuous need or an occasional need.

Continuous users include those who have developed effective water resources management programs at the municipal or regional level of government, state and county regulatory agencies concerned with the preservation of water quality standards, private consulting firms engaged in water quality evaluation programs.

Occasional users include those who are not directly involved in comprehensive assessment programs but who wish to determine the exact nature and extent of localized problems. Local and regional lake management associations, environmental groups and private consulting firms can benefit from the results of SEPTIC-SNOOPER surveys that verify and quantify actual conditions in recreational areas and potable waters where septic leachate is suspected.

<u>For additional information contact:</u>

Environmental Devices Corporation
Tower Building
Marion, MA 02738

Telephone: 617/748-0366
Telex: 929451

January 1978

TO:

APPROVED UNITS - MAINE PLUMBING CODE, PART II - PRIVATE SEWAGE DISPOSAL REGULATIONS

A. RECIRCULATING TOILETS

1. Thetford Corporation
(Cycle-Let)
Ann Arbor, Michigan

2. Monogram
Monogram Industries
1165 East 230th Street
Carson, California 90745

3. Pureway Corporation
Pureway
301-42nd Avenue
East Mobile, Illinois 61244

4. Vapor Corporation
Main Office
6420 West Howard Street
Chicago, Illinois 60648

5. Sears-Roebuck Company

6. Montgomery Ward

7. J.C. Penny

8. Thiokol MPB-10 Chemical Toilet System
Thiokol Chemical Corporation
Wasatch Division (Model MPB-10)
P.O. Box 524
Brigham City, Utah 84302

9. Multi Flo Home System for Recycling Wastewater
(Unit RS-1) (Unit RS-2)
Multi-Flo, Inc.
500 Webster Street
Dayton, Ohio

10. Chrysler Corporation
(Aqua-Sans)
Dept. 2100
P.O. Box 29200
New Orleans, Louisianna 70129

B. GAS INCINERATING TOILETS

1. (Destroilet)
LaMere Industries, Inc.
227 N. Main Street
Walworth, Wisconsin 53184

2. (Incinolet)
Research Products Mfg. Co.
P.O. Box 35164
Airlawn Station
Dallas, Texas

3. Tekmar Corporation
(Thermajon)

4. Clear Water Inc. (Pyrolet)
P.O. Box 644
Sheboygan, Wisconsin 53081

5. Lake Geneva A & C Corporation
Box 89
200 Elkhorn Road
Williams Bay, Wisconsin 53191
(A.C. Storburn)

C. ELECTRIC INCINERATING TOILETS

1. Incinolet
Research Products Mfg. Company
P.O. Box 35164
Airlawn Station
Dallas, Texas

2. Incinomode
Incinomode Sales Company
P.O. Box 879
Sherman, Texas 75090

3. N-Con Systems Company, Inc.
Thermox

D. COMPOST TOILETS

1. Ecolet
   Recreational Ecology Conservation of United States, Inc.
   9800 West Bluemound Road
   Milwaukee, Wisconsin 53226

2. Clivus-Multrum
   14A Eliot Street
   Cambridge, Massachusetts 02138

3. Biu-Let
   Bio-Utility Systems, Inc.
   P.O. Box 135
   Narberth, Pennsylvania 19072

4. A&A Adhesives & Plastics
   P.O. Box 302
   Stow, Massachusetts 01775
   (Soddy Potty)

5. Toa-Throne Compost Toilet
   P.O. Box 752
   Corona del Mar, California 92625

E. CHEMICAL TOILETS

1. Fiberglass Chemical Toilets
   Chic-Sales Company, Inc.
   P.O. Box 689
   Hillview Building
   Santa Ana, California

2. Vapor-Monogram New-Matic Toilet
   Vapor Corporation
   6420 West Howard Street
   Chicago, Illinois 60648

3. Mansfield Sanitary, Inc.
   Perrysville, Ohio
   (Sani-Pottie 947)

4. Mile Ahead Industries Inc.
   41 West Putnam Avenue
   Greenwich, Connecticut 06830

5. Waterless Comfort Station
   Burlway Road
   P.O. Box 1026
   Burlingame, California 94011

6. Thetford Engineering Corporation
   P.O. Box 1285
   Ann Arbor, Michigan 48106
   (Aqua Magic, Porta Potti)

7. Sani-Mate
   Zurn Industries, Inc.
   Erie, Pennsylvania

8. Todd Enterprises, Inc.
   Providence, Rhode Island
   (Mini-Pot)

9. Sani-Matic Corporation
   (Uncle John Dry flush)

10. Monogram Industries
    (Tota-toilet)

F. LOW WATER FLUSH TOILETS

1. Safeway Toilets
   Safeway Sanitation
   75 Argyle Avenue
   Buffalo, New York 14226

2. Microphor Toilets
   Microphor, Inc.
   475 East San Francisco Avenue
   Willits, California 95490

3. American Standard
   P.O. Box 2003
   New Brunswick, New Jersey 08903

4. Kohler Company
   Kohler, WS 53044
   (Water guard toilet)

G. VACUUM TOILET

1. Airvac/Division of National Homes Construction Corp.
   P.O. Box 109
   Rochester, Indiana 46975

2. Colt Industries
   (Envirovac)

3. Mansfield
   (Model 200 Vacu Flush)

H. SEWERLESS TOILET

1. Aera-Filt Systems, Inc.
   P.O. Box 567
   Lafayette, Indiana 47901

AERATED TREATMENT TANKS - NSF - AEROBIC

1. Bi-A-Robi Systems, Inc., P.O. Box 133, Hamlin, Pennsylvania 18427
2. Coate Burial Vault, Inc., P.O. Box 159, West Milton, Ohio 45383
3. Cromaglass, P.O. Box 1146, Williamsport, Pennsylvania 17701
4. Eastern Environmental Controls Inc. 210 Cross Street, P.O. Box 475, Chestertown,
5. Hitachi Chemical Company America Ltd. 437 Madison Avenue, New York, NY 10022
6. Jet Aeration Company, 750 Alpha Drive, Cleveland, Ohio 44143
7. Multi-Flo, Inc., A Subs. of Tait, Inc. 500 Webster Street, Dayton, Ohio 45401
8. Nayadic Sciences, Inc. 148 Bridge Street, Phoenixville, Pennsylvania 19460
9. New England Oxyvor, P.O. Box 943, Lewiston, Maine 04240

APPROVED CHAMBER MANUFACTURERS

1. Genest Bros., Inc., Sanford, Maine 04073
2. Maine Cement Products, P.O. Box 3546, Thompson's Point, Maine 04102
3. Pre-Cast Concrete Products of Maine, Inc., P.O Box 307, Topsham, Maine 04086
4. Superior Concrete Co., Inc., Minot Avenue, Auburn, Maine 04210

APPENDIX G

MODEL AQUIFER PROTECTION ORDINANCE

Section I. Purpose and Intent

The Town of ________ adopts this Ordinance for the promotion of the health, safety, and general welfare of its residents by protecting the ground water resources of the Town from adverse development or land use practices (such as but not limited to the disposal or storage of solid wastes, sludge, subsurface waste disposal, road salting materials, gas or other petroleum products) that might reduce the quality and quantity of water that is now--and in the future will be-- available for use by municipalities, individuals and industries.

Section II. District Boundaries

The Aquifer Recharge District is defined as those areas which are delineated as potential groundwater recharge areas by the U.S.G.S. and shown on the Town Aquifer Recharge District Map.

Where the bounds, as delineated, are in doubt or in dispute, the burden of proof shall be upon the owner (s) of the land in question to show where they should properly be located. At the request of the owner (s), the Town may engage a professional geologist or soil scientist to determine more accurately the location and extent of an aquifer or recharge area, and may charge the owner (s) for all or part of the cost of the investigation. The delineation can be modified by the Board of Adjustment upon receipt of findings of the detailed on-site survey techniques.

Section III.

For the purposes of this Ordinance, the following regulations shall apply:

1. The following uses are prohibited:

   a. disposal of solid wastes, other than brush and stumps;

   b. storage of petroleum or gasoline, and the transmission of petroleum or gasoline through pipelines;

   c. the disposal of liquid or leachable wastes;

   d. the paving of more than 10% of any lot.

2. The following uses are permitted by Conditional-Use Permit: that is, subject to the approval of the Planning Board, with such conditions as they may attach to their approval. The Planning Board or the Code Enforcement Officer shall issue the Conditional-Use Permit.

a. storage of road salt, provided that the salt is kept under cover and on an impervious surface.

b. septic tank or sewage disposal field installation for a single-family residential dwelling with a minimum acreage of ____ (LRPC recommends two acres);

c. enlargement or alternation of an existing septic tank or sewage disposal field provided it will not be utilized for an increased use;

d. manure pile;

e. animal feedlot;

f. the flooding or mining of land;

2. A non-conforming use may be continued and/or expanded by not more than a 25% increase in the structure, floor space, bulk or size, or land area and may be replaced or repaired, with the approval of the Planning Board, if the Board believes that the continuing use will not be more detrimental to the protected areas. A non-conforming use which has been discontinued for 18 months may not be resumed.

Section IV. Administration and Enforcement and Violations

Use Permits: No use as listed in Section III, 2 and 3, shall be conducted within an Aquifer Recharge District until the use has been approved by the Planning Board and a Conditional-Use Permit has been issued by the Planning Board or the Code Enforcement Officer.

The application for a Conditional-Use Permit shall be submitted to the Planning Board and accompanied by a site plan drawn to an indicated scale and showing the location and dimensions of all significant structures and uses present and proposed. A reasonable fee established by the Planning Board may be required to accompany the application to cover processing costs. In the event that the Planning Board determines to hold a public hearing on an application, it shall hold such hearing within 30 days of receipt by it of a completed application, and shall cause notice of the date, time and place of such hearing to be given to the person making the application and to be published in a newspaper of general circulation in the municipality at least two times, the date of the first publication to be at least seven days prior to the hearing.

The Planning Board shall, within 30 days of a public hearing or within 60 days of receiving a completed application, if no hearing is held, or within such other time limit as may be otherwise mutually agreed to issue an order denying or granting approval of the application. Both the approval and the denial of an application for a Conditional-Use Permit by the Planning Board shall be in writing and shall state the reason for that decision. A copy shall be given to the applicant.

In considering an application for a Conditional-Use Permit, the Planning Board shall evaluate the immediate and long-range impact of the proposed use on the ground waters and the possible effects of the proposed use upon the maintenance of safe and healthful conditions. In making such evaluation, the Board shall consider such factors as:

1. The amount and type of wastes to be generated by the proposed use and the adequacy of the proposed disposal system.
2. The capability of the land and water to sustain such use without degradation.
3. Topography and drainage of the site and susceptibility to flooding.
4. The need of a particular location for the proposed use.
5. The compatibility of the proposed use with adjacent land uses.

The Planning Board, in approving an application for a conditional use, may impose such reasonable restrictions concerning the setback of the structure from an aquifer or recharge area, the quantity of potential pollutants to be permitted within the Aquifer Recharge District, and like matters, as it deems advisable in order to protect the purity of the groundwater.

Section IV. Enforcement

It shall be the duty of the Planning Board or the Code Enforcement Officer to enforce the provisions of this Ordinance and to see that its requirements and restrictions are duly complied with.

Section V. Violations

It shall be the duty of the Planning Board or the Code Enforcement Officer to warn any person, firm, or corporation of violations of this Ordinance by them and to inform them of their right to seek a variance or other relief. A Conditional-Use Permit may be withdrawn by the Town if the use is not conducted in accordance with the regulations of this Ordinance or the conditions of the permit.

The Municipal Officials of the town or City shall institute or cause to be instituted, in the name of the Town, any and all actions, legal and equitable, that shall be appropriate or necessary for the enforcement of the provisions of this Ordinance.

Any person, firm or corporation, being the owner or occupant of or having control or the use of, or being engaged in the construction or moving of, any structure or land or part thereof, found to violate any provision of this Ordinance, shall be guilty of a civil,violation and upon conviction thereof, shall be punished by a fine of not less than $25.00, and not more than $100.00. Each day such violation is permitted to exist after notification thereof by the Planning Board or the Code Enforcement Officer shall constitute a separate offense. Such persons shall be liable for any court costs and incurred reasonable attorney fees.

Section VI. Appeals

Appeals to the Board of Adjustment may be taken by any person aggrieved or by any officer, department, board or bureau of the municipality affected by any decision of the Board. Before taking action on any appeal, the Board of Appeals shall hold a public hearing advertised in advance in a local newspaper at the expense of the appellant. In appeals involving the use of buildings, the Board of Appeals shall notify by mail the owners of all property within 500 feet of the property involved of the nature of the appeal and of the time and place of the public hearing thereon.

Section VII. Validity and Conflict With Other Ordinances

A. Validity: Should any section or provision of this Ordinance be declared by the courts to be invalid, such decision shall not invalidate any other section or provision of this Ordinance.

B. Conflict with Other Ordinances: This Ordinance shall not repeal, annul, or in any way impair or remove the necessity of compliance with any other ordinance, law regulation or by-law. Where this Ordinance imposes a higher standard for the promotion and protection of health, safety and welfare, the provisions of this Ordinance shall prevail.

Section VIII. Amendments

This Ordinance may be amended by a majority vote of the Town Meeting.

Section IV. Effective Date

This Ordinance shall become effective upon the date of adoption by the Town.

Section X. Definitions

Animal Feedlot: A plot of land on which 25 livestock or more per acre are kept for the purposes of feeding.

Aquifer: Geologic formation composed of rock or sand and gravel that contains significant amounts of potentially producible potable water.

Ground Water: All the water found beneath the surface of the ground. In this Ordinance the term refers to the slowly moving subsurface water present in aquifer recharge areas.

Leachable Wastes: Waste materials, including solid wastes, sludge and agricultural wastes that are capable of releasing contaminants to the surrounding environment.

Mining of Land: The removal of geologic materials such as topsoil, sand and gravel, metallic ores, or bedrock to be crushed or used as building stone.

Non-Conforming Use: Any building or land lawfully occupied by a use at the time of passage of the Ordinance or amendment thereto which does not conform after the passage of this Ordinance or amendment thereto with the regulations of the district in which it is situated.

Sludge: Residual materials produced by water and sewage treatment processes and domestic septic tanks.

Structure: Anything constructed or erected, except a boundary wall or fence, the use of which requires location on the ground or attachment to something on the ground. For the purposes of this Ordinance, buildings are structures.

Solid Wastes: Useless, unwanted, or discarded solid material with insufficient liquid content to be free flowing. This includes but is not limited to rubbish, garbage, scrap materials, junk, refuse, inert fill material and landscape refuse.

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CHAPTER 722

THE COMMONWEALTH OF MASSACHUSETTS -IN THE YEAR
ONE THOUSAND NINE HUNDRED AND SIXTY-NINE

AN ACT RELATIVE TO THE CONTROL OF AQUATIC NUISANCES IN WATERS OF THE COMMONWEALTH BY THE DEPARTMENT OF PUBLIC HEALTH AND AUTHORIZING THE WATER RESOURCES COMMISSION TO ESTABLISH PRIORITIES THEREFOR.

Be it enacted by the Senate and House of Representative in General Court assembled, and by the authority of the same, as follows:

Section 1. Clause (36b) of section 5 of chapter 40 of the General Laws is hereby amended by adding the following two paragraphs:

A city or town may participate in the cost sharing program established by this section for the control of aquatic nuisances in those waters of the commonwealth selected for control by the department of public health under the provisions of section five F of chapter one hundred and eleven.

To participate in such program, a city or town may contribute up to one half of the total cost of the control program but not less than one quarter of the total cost as determined by said department. If a body of water is located in a state park or reservation, or if the body of water is a great pond which said department determines is more heavily used by inhabitants of cities or towns other than the one in which the pond is located, the entire cost of the control may be borne by the commonwealth; provided, however, that if a state agency operates a recreational facility on a body of water the department of public health may authorize the city or town to contribute less than one quarter of the total cost. The department in determining the amount of any such contribution shall consider the following: (1) the economic capabilities of the city or town as determined by the department of corporation and taxation, (2) the use of the waters by the communities outside of the city or town in which the waters are located, and (3) the advantage to the commonwealth of the work. When the body of water is located in more than one city or town, the local contribution shall be apportioned in accordance with the amount of water area in acres lying in each municipality as determined by the department of public health. In instances where a city or town boundary is merely contiguous to the shoreline of the waters but does not encompass any water area, the apportionment of costs shall be made in accordance with the amount of shoreline in linear feet lying in each town as determined by the department of public health. All city and town funds to be used in the cost sharing program for the control of aquatic nuisances shall be paid to the state treasurer and may be expended by the department of public health for said purposes.

Section 2. Chapter 111 of the General Laws is hereby amended by striking out section 5F, inserted by section 1 of chapter 498 of the acts of 1961, and inserting in place thereof the following section:

Section 5F. The department shall undertake the control of algae, weeds and other aquatic nuisances in waters within the commonwealth in accordance with priorities established under this section; provided, however, no funds of the commonwealth shall be expended for a control program in waters to which there is no public access. In undertaking such control work the department shall consider the public health implications as they relate to public and private water supply uses, bathing and industrial process uses.

The department shall receive requests from any person or agency of the commonwealth to consider waters for control and shall submit to the water resources commission all such requests which it approves. The water resources commission shall review such requests and establish priorities for control, considering public accessibility, recreational and agricultural uses, the general public advantage, the importance to commercial, agricultural or other interests, the local interest therein as manifested by municipal or other contributions therefor, and other considerations affecting the feasibility, necessity or advantage of the proposed work. The water resources commission shall forward the results of its review to the department within a period of sixty days, and if such review is not completed within sixty days or within such further time as may be mutually agreed upon, the department shall establish priorities.

No work authorized under this section shall be begun until the department conducts bioengineering surveys to determine the types and extent of nuisance aquatic growth, evaluates water usages, establishes restrictions where necessary to protect the public health, safety and property, as well as fish and other animal life, and develops estimates with the amount of shoreline in linear feet lying in each town as determined by the department of public health. All city and town funds to be used in the cost sharing program for the control of aquatic nuisances shall be paid to the state treasurer and may be expended by the department of public health for said purposes.

Section 2. Chapter 111 of the General Laws is hereby amended by striking out section 5F, inserted by section 1 of chapter 498 of the acts of 1961, and inserting in place thereof the following section:

Section 5F. The department shall undertake the control of algae, weeds and other aquatic nuisances in waters within the commonwealth in accordance with priorities established under this section; provided, however, no funds of the commonwealth shall be expended for a control program in waters to which there is no public access. In undertaking such control work the department shall consider the public health implications as they relate to public and private water supply uses, bathing and industrial process uses.

The department shall receive requests from any person or agency of the commonwealth to consider waters for control and shall submit to the water resources commission all such requests which it approves. The water resources commission shall review such requests and establish priorities for control, considering public accessibility, recreational and agricultural uses, the general public advantage, the importance to commercial, agricultural or other interests, the local interest therein as manifested by municipal or other contributions therefor, and other considerations affecting the feasibility, necessity or advantage of the proposed work. The water resources commission shall forward the results of its review to the department within a period of sixty days, and if such review is not completed within sixty days or within such further time as may be mutually agreed upon, the department shall establish priorities.

No work authorized under this section shall be begun until the department conducts bioengineering surveys to determine the types and extent of nuisance aquatic growth, evaluates water usages, establishes restrictions where necessary to protect the public health, safety and property, as well as fish and other animal life, and develops estimates of costs. Personnel of the department of public health in the performance of their duties under this section may enter upon, pass through or over private lands or property whether or not covered by water.

Division of Environmental Health
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