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WATER QUALITY STUDIES

FOR

PLYMOUTH, MASSACHUSETTS

PART III: FINAL REPORT

SUBMITTED TO

CE MAGUIRE, INC.

31 CANAL STREET

PROVIDENCE, RHODE ISLAND 20903

DECEMBER 20, 1982

Environmental Consulting Services

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1. INTRODUCTION

New England Research, Inc. (NER) previously submitted two technical reports on Water Quality Studies for Plymouth, Massachusetts to CE Maguire, Inc. (CEM). The first report (NER, November 15, 1982) focused on bacterial surveys of Billington Sea and Little Pond conducted by NER in September and October. The second report (NER, November 30, 1982) focused on eutrophication studies of Billington Sea conducted by NER in October and November. These previous reports are included in the Appendices of this Final Report.

This Final Report includes a review and summary of findings of various water quality studies of Billington Sea and Little Pond, and integrates these findings with the water quality studies conducted by NER. Previously conducted studies considered in this report include studies discussed in the following documents which were provided by CEM:

(1) Lyons-Skwarto Associates. 1978. A Study of Billington Sea, Plymouth, Massachusetts with Guidelines for Rehabilitation.

(2) IEP. 1980. Shoreline Water Quality Survey, Billington Sea for Conservation Commission, Plymouth, Massachusetts.

(3) Geoscience. 1981. Groundwater Resource and Lakes Management Study.

2. OBJECTIVES

The objectives of this Final Report are as follows:

(1) to review the findings of previously conducted water quality studies of Billington Sea and Little Pond,

(2) to integrate these findings with the water quality studies conducted by NER in 1982, and

(3) to summarize the results of these studies with respect to the potential role of household septic systems on public health and eutrophication issues in Billington Sea and Little Pond.

3. PREVIOUS WATER QUALITY STUDIES

3.1 Billington Sea

Lyons-Skwarto Associates (1978) analyzed water quality in samples collected at 8 in-lake sampling stations and various output and tributary waters from June through May. Reported data on key water quality parameters may be summarized as follows:

(1) The average concentration of dissolved oxygen (based on 8 in-lake sampling stations) varied from 6.5 mg/1 in June and July to 10 mg/1 in September, October, February and March.

(2) The average temperature varied from 3.3°C in February to 24.4°C in July.

(3) Secchi disc readings varied from 3 feet in June and July to 5 feet in the period October through March.

(4) Individual values of hardness (calcium and magnesium) ranged from 16 mg/1 to 23 mg/1. Among 8 in-lake sampling stations, the range was 16-23 mg/1; among 6 outlet sampling stations, the range was 16-20 mg/1.

(5) Individual values of iron concentration ranged from 0.01 to 0.04 mg/1. Among 8 in-lake sampling stations, the range was 0.01 - 0.04 mg/1; approximately 35% of all samples collected from in-lake sampling stations had concentrations of iron which were ≥ 0.03 mg/1. Among 6 outlet sampling stations, the range was 0.01 - 0.03 mg/1; approximately 19% of all outlet samples had concentrations which were ≥ 0.03 mg/1.

(6) The average concentration of ammonia plus nitrate nitrogen in in-lake samples ranged from 0.02 mg/1 in February and April to 0.3 mg/1 in June. The average concentration in tributary waters varied from 0.04 mg/1 in April to 0.6 mg/1 in June. The average concentration in outlet waters varied from 0.03 mg/1 in April to 0.6 mg/1 in June.

(7) The average concentration of nitrite nitrogen in in-lake, tributary and outlet waters was less than 0.01 mg/1 throughout the study period.

(8) The average concentration of orthophosphate in in-lake samples varied from 0.01 mg/1 in June, November and February to 0.03 mg/1 in August, April and May. In tributary waters, the range was 0.015 (June) -

0.05 mg/l (October). In outlet waters, the range was 0.01 (June, November and February) - 0.03 mg/l (August - October, April and May).

(9) Approximately 8 genera of emersed aquatic plants and 12 genera of submersed aquatic plants were identified. Among the submersed plants, 14 species of Potamogeton (pondweed) were identified. The primary plant infestation was identified as the common Elodea. Moderate to dense infestation was typically noted in the western portion of the lake.

(10) No quantitative data on algae are presented. However, the report states that during the course of this study Billington Sea was susceptible to recurrent algal blooms. Ankistrodesmus falcus and Chlamydomonas polypyrenoideum were identified as key algal species. It is also noted that copper sulfate treatment of the lake was undertaken.

(11) Additional data are presented on heavy metals and the concentrations of various chemicals in the mud. However, sampling locations and frequency of sampling are not indicated.

It should be noted that this report does not specifically identify the depth(s) at which samples were collected for analysis of various water quality parameters. It is also unclear as to whether data presented for orthophosphate are values for the phosphate moiety or for the phosphorus moiety.

IEP (1980) collected 11 water samples from Billington Sea on July 15, 1980. Nine shoreline samples were collected at locations identified as possible plumes of septic leachate by means of a Type 2100 Septic Leachate Detector System. Two samples (background samples) were located at central locations in the lake to provide a baseline for comparison. Water samples were analyzed for Fecal Coliform Bacteria, Fecal Streptococcus Bacteria, ammonia nitrogen, nitrate nitrogen and total phosphorus. Results of these analyses may be summarized as follows:

(1) The density of Fecal Coliform Bacteria in the 11 samples ranged from < 10 to 70 bacteria per 100 ml. The average density in the 9 plume samples was < 28 bacteria per 100 ml; the average density in the 2 background samples was < 50 bacteria per 100 ml.

(2) The density of Fecal Streptococcus Bacteria in the 11 samples ranged from < 10 to 130 bacteria per 100 ml.

The average density in the plume samples was < 40 bacteria per 100 ml; the average density in the background samples was < 50 bacteria per 100 ml. Only one plume sample had a concentration greater than 100 Fecal Streptococcus Bacteria per 100 ml. In this sample, the ratio of Fecal Coliform to Fecal Streptococcus Bacteria (FC/FS ratio) was 0.46. This type of ratio is generally indicative of discharges from animals or stormwater runoff. It is definitely not indicative of domestic waste (APHA, AWWA, WPCF, 1980).

(3) The concentration of ammonia nitrogen in the plume samples ranged from < 0.01 to 0.01 mg/1; in the background samples, the range was < 0.01-0.04 mg/1.

(4) The concentration of nitrate nitrogen in the plume samples ranged from < 0.01 to 0.53 mg/1, for an average of 0.16 mg/1. In the background samples, the range was 0.01 - 0.17 mg/1, for an average of 0.09 mg/1.

(5) The concentration of total phosphorus in the plume samples ranged from 0.01 to 0.05 mg/1, for an average of 0.03 mg/1. In the background samples, the range was 0.02 - 0.05 mg/1, for an average of 0.04 mg/1.

It should be noted that it is unclear if the bacterial analyses performed in this study were conducted by means of the MF (membrane filter) or MPN (most probable number) technique. It should also be noted that some parameters were no different in the plume samples as compared to values obtained from samples taken in the center of the lake.

Geoscience (1981) conducted a series of water quality analyses of surface and groundwater samples collected in Billington Sea and its immediate environs. Surface samples included lake and tributary samples. Groundwater samples included domestic well and new test well samples. Key results of nutrient analyses may be summarized as follows:

(1) The range in concentration of nitrate nitrogen in all surface and groundwater samples was $< 0.01 - 5.5$ mg/1. Of the total of 11 samples having concentrations ≥ 1.0 mg/1, 3 were obtained from tributary surface waters, and 8 were obtained from well samples. The surface water samples having high concentrations were obtained from one tributary stream draining a cranberry bog to the southwest of the lake. Groundwater samples from the center of the lake ranged from 0.07 to 0.35 mg/1, and a surface sample from the lake had a concentration of < 0.01 mg/1.

(2) The range of concentration of total phosphorus in all surface and groundwater samples was < 0.01-2.8 mg/l. Of the total of 16 samples having concentrations ≥ 0.1 mg/l, 2 were tributary surface waters, and 14 were groundwater samples. The higher concentrations in surface waters were observed in tributary waters draining a cranberry bog southwest of the lake. The higher concentrations in groundwaters were typically observed in samples collected southwest of the lake. Concentrations in the surface and groundwater samples in the central portion of the lake ranged from 0.02 to 0.08 mg/l.

(3) The study did not identify consistent sources of nitrogen and phosphorus.

3.2 Little Pond

The three reports cited in Section 3.1 do not include water quality data on Little Pond.

4. WATER QUALITY STUDIES IN 1982

4.1 Billington Sea

Surface water samples (grab samples) were collected at 20 locations in Billington Sea on September 22 and October 13, 1982 (NER, November 15, 1982). Samples were analyzed for Total Coliform, Fecal Coliform and Fecal Streptococcus Bacteria, color and turbidity (Appendix 1).

Additional samples were collected on October 13 for purposes of conducting an algal bioassay to determine the limiting nutrient for a standard algal species. Samples collected on October 13 were also analyzed for a number of physical and chemical parameters. Results of the physical and chemical analyses and the algal bioassay are included in Appendix 2 (NER, November 30, 1982).

The results of all analyses conducted by NER may be summarized as follows:

(1) The range of Total Coliform Bacteria in all samples was 8-1100 bacteria per 100 ml, for an average value of 60 bacteria per 100 ml. Only 1 out of 40 values exceeded 1000 bacteria per 100 ml. The range of Fecal Coliform Bacteria was $\leq$ 0-170 bacteria per 100

ml, for an average value of < 14 bacteria per 100 ml. None of the values of Fecal Coliform Bacteria exceeded the Massachusetts standard for Class B waters (MWRC, 1978). The range of Fecal Streptococcus Bacteria was < 2-1600 bacteria per 100 ml, for an average value of < 119 bacteria per 100 ml. FC/FS ratios were typically indicative of discharge from animals and stormwater runoff, rather than domestic waste runoff.

(2) Values of physical and chemical parameters varied from place to place in Billington Sea, but did not indicate any overall consistent geographical pattern. The September-October range for turbidity was 1.8 - 6.6 J.T.U.; color ranged from 25-40 Pt-Co units. In October, the following ranges were observed:

- pH (6.9 - 7.3 pH Units)
- Sulfate (0.9 - 3.7 mg/1 S)
- Chloride (16.3 - 23 mg/1 Cl)
- Conductivity (76 - 97 umhos/cm)
- Orthophosphorus (< 0.01 - 0.03 mg/1 P)
- Total Phosphorus (0.03 - 0.06 mg/1 P)
- Ammoniacal Nitrogen (0.08 - 0.18 mg/1 N)
- Nitrate plus Nitrite Nitrogen (0.09 - 0.51 mg/1 N) .

(3) The bioassay indicated that phosphorus was a limiting nutrient at the time of the study. The bioassay also indicated that suspended particles are a source of nutrient and may also be a source of an algal growth inhibitor (e.g., copper or some other algicide previously used for algal control). Finally, the bioassay indicated that the bottom muds of Billington Sea may serve as sources of phosphorus and nitrogen nutrients, and may also contain an algal growth inhibitor.

4.2 Little Pond

Surface water samples (grab samples) were collected at 10 locations in Little Pond on September 22 and October 13, 1982 (NER, November 15, 1982; Appendix 1). Samples were analyzed for Total Coliform Bacteria, Fecal Coliform Bacteria, Fecal Streptococcus Bacteria, Staphylococcus aureus, Pseudomonas aeruginosa, turbidity and color. Results of these analyses may be summarized as follows:

(1) Turbidity and color values were typically low and showed little variation among sampling sites. The range of turbidity values was 0.40 - 0.98 J.T.U.; the range for color was 5 - 7.5 Pt-Co Units.

(2) Total Coliform Bacteria ranged from ≥ 2400 to 23 bacteria per 100 ml for an average of ≥ 578 bacteria per 100 ml. Fecal Coliform Bacteria ranged from < 0 to 13 bacteria per 100 ml, for an average of<5 bacteria per 100 ml. Fecal Streptococcus Bacteria ranged from < 0 to 38 bacteria per 100 ml, for an average of<12 bacteria per 100 ml. The density of Staphylococcus aureus populations ranged from 8 - ≥ 2400 bacteria per 100 ml, and the density of Pseudomonas aeruginosa populations ranged from < 2 - 23 bacteria per 100 ml. Since these species were identified only by the presumptive MPN technique, averages are not considered to be significant; the range of densities merely indicates a high probability that these opportunistic pathogens were present.

5. DISCUSSION

Because the various studies have included a diversity of objectives, sampling locations, parameters and/or seasonal constraints, it is important to focus on certain findings which either (a) have been made in several of the studies or (b) are at least consistent from study to study. Such findings may be summarized as follows:

(1) The nutrient data generated in all the studies (e.g., phosphorus and nitrogen nutrients in the epilimnion), and observations of macrophytic growth and algal populations clearly indicate that Billington Sea is eutrophic. As indicated by an inventory of ponds, lakes and reservoirs in the early 1970s (McCann et al., 1972), and which includes data on trophic status, it is evident that Billington Sea has been eutrophic for at least the past decade.

(2) Nutrient parameters, physical parameters and various observations of vegetative growth in a number of studies indicate that the western portion of Billington Sea is probably more biologically productive (or eutrophic) than the eastern portion.

(3) At least two studies indicate that the bottom sediments of Billington Sea are rich in nitrogen and phosphorus nutrients, and one study indicates that these sediments may be a source of an algal growth inhibitor. It is possible that, if such an inhibitor is present, it may have been deposited in the process of treating the lake for excessive algal growth.

(4) On the basis of the results of an algal bioassay, it is apparent that Billington Sea can support large populations of phytoplankton and that the growth of these populations is limited by the availability of phosphorus. This finding is also confirmed by the relative concentrations of nitrogen and phosphorus observed in a number of studies.

(5) Relatively high concentrations of nutrients evidently enter into Billington Sea from some surface water and groundwater sources. It appears that such sources are located at the western portion of the lake, although other potential sources may enter the lake in other areas.

(6) None of the chemical, physical or bacteriological data indicate the presence of gross contamination

from septic effluent along the shoreline of Billington Sea or Little Pond.

(7) None of the studies present any data which can be used to pinpoint the cause of the relatively high concentrations of nutrients observed in some surface and groundwater sources. However, the preponderance of chemical, physical and bacteriological data appear to indicate that the relatively high nutrient concentrations cannot be directly correlated with domestic effluent.

(8) Opportunistic pathogens were observed in Little Pond. Since there are no data which indicate that domestic effluent enters Little Pond, it is likely that these organisms entered the pond via swimmers during the summer.

6. CONCLUSIONS

On the basis of the above findings (Section 5), NER has made the following conclusions:

(1) There is no evidence of gross contamination of Billington Sea by domestic waste effluents along the shoreline, and it is unlikely that any localized effort to alter current domestic waste disposal practices along the shoreline of Billington Sea will have any measurable effect on the lake's trophic status.

(2) There is no evidence that any effort to alter or otherwise control current domestic waste disposal practices beyond the shoreline of Billington Sea will have any measurable effect on the lake's trophic status.

(3) It is highly unlikely that any effort to reverse or substantially reduce the eutrophic conditions of Billington Sea will be successful unless each of the following is accomplished:

    (a) complete control of the watershed and groundwater aquifers so as to reduce the input of nutrients into the lake, and

(b) nutrient rich muds are dredged out or otherwise sealed off from overlying lake waters.

(4) Since there is no evidence of gross contamination of Little Pond by domestic waste effluent, the most probable source of the observed pathogens is the swimmers in the pond. No engineering solution appears appropriate at this time.

7. LITERATURE CITED

American Public Health Association (APHA), American Water Works Association (AWWA), and Water Pollution Control Federation (WPCF). 1980. Standard Methods for the Examination of Water and Wastewater. (15th Edition). American Public Health Association, Washington, D.C.

Commonwealth of Massachusetts, Water Resources Commission (MWRC). 1978. Water Quality Standards. Commonwealth of Massachusetts, Water Resources Commission, Division of Water Pollution Control, Boston, Massachusetts.

Geoscience. 1981. Groundwater Resource and Lakes Management Study. Town of Plymouth, Conservation Commission, Plymouth, Massachusetts.

IEP. 1980. Shoreline Water Quality Survey, Billington Sea, for Conservation Commission, Plymouth, Massachusetts.

Lyons-Skwarto Associates. 1978. A Study of Billington Sea, Plymouth, Massachusetts, with Guidelines for Rehabilitation.

McCann, James A., George E. Wood, and Edward E. Kraus. 1972. An Inventory of the Ponds, Lakes, and Reservoirs of Massachusetts - Plymouth County. Community Resource Development Program, Cooperative Extension Service, University of Massachusetts, Amherst, Massachusetts.

New England Research, Inc. (NER). November 30, 1982. Water Quality Studies for Plymouth, Massachusetts, Part II, Eutrophication Studies of Billington Sea. CE Maguire, Inc.

New England Research, Inc. (NER). November 15, 1982. Water Quality Studies for Plymouth, Massachusetts, Part I, Bacterial Surveys of Billington Sea and Little Pond. CE Maguire, Inc.

APPENDIXES

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WATER QUALITY STUDIES

FOR

PLYMOUTH, MASSACHUSETTS

PART I: BACTERIOLOGICAL SURVEYS

OF BILLINGTON SEA AND LITTLE POND

SUBMITTED TO

CE MAGUIRE, INC.

31 CANAL STREET

PROVIDENCE, RHODE ISLAND 20903

NOVEMBER 15, 1982

Environmental Consulting Services

TABLE OF CONTENTS

1. INTRODUCTION

This is a report on the bacteriological surveys of Billington Sea and Little Pond, Plymouth, Massachusetts conducted by New England Research, Inc. (NER) for CE Maguire, Inc. (CEM). These bacteriological surveys were conducted in September and October 1982 as part of an overall study of public health and environmental issues related to the water quality of Billington Sea and Little Pond. A separate report on eutrophication studies of Billington Sea will be submitted to CEM on November 30, 1982. A Final Integrated Report will be submitted to CEM on December 15, 1982, and will include an integration of the results of the bacteriological surveys and eutrophication studies conducted by NER with other available studies and information.

2. OBJECTIVES

The objectives of the bacteriological studies are as follows:

1. To determine if there is any bacteriological evidence of contamination of Billington Sea and Little Pond by effluents from septic systems, and
2. To determine if there is any evidence that bacteria may have played some role in reported incidents of eye and ear irritations among swimmers in Little Pond.

3. BACTERIOLOGICAL STUDIES

3.1 Methods

Duplicate water samples were collected at 20 locations in Billington Sea and at 10 locations in Little Pond on September 22 and October 13, 1982. Water samples collected for bacteriological analysis were grab samples, using autoclave-sterilized 500 ml polypropylene containers.

Water sampling locations in Billington Sea (Figure 1) were determined on the basis of housing-density along the shoreline; in Little Pond (Figure 1), sampling locations were determined on the basis of bathing beach location. In both ponds, samples were collected approximately 10 meters from the shoreline. Also, some samples were collected at central pond locations in both ponds.

Upon collection, all samples were labeled, iced and transported to NER for analysis. Each label included a Sample Number selected by CEM field personnel.

All water samples were processed by NER laboratory personnel within 12 hours of collection. Records of analysis used by NER laboratory personnel were based on the Sample Number

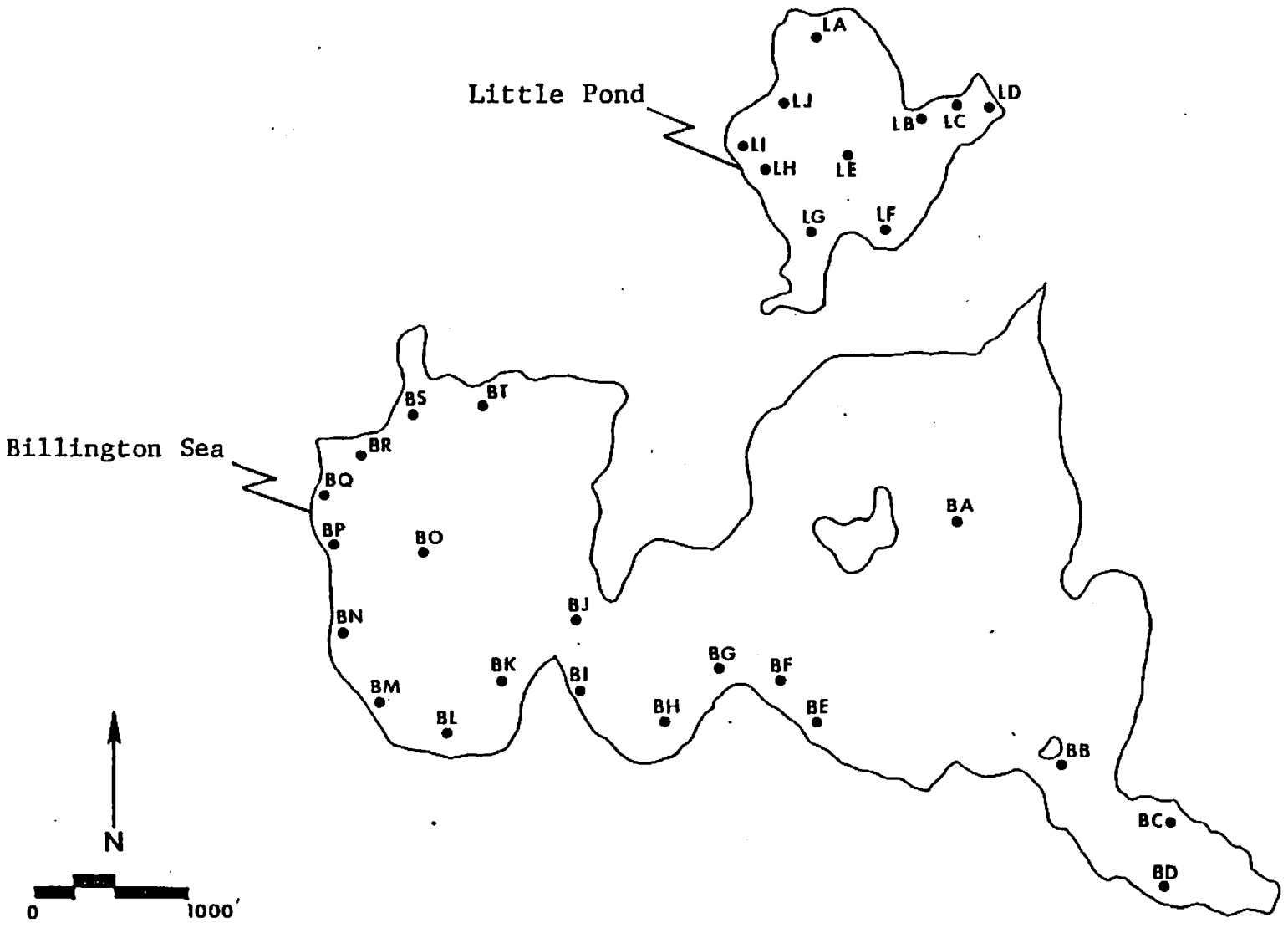

Figure 1.

Water Sampling Locations, Billington Sea and Little Pond.

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included on the sample label; NER personnel did not know the specific location of samples, but did know if a sample was collected from Billington Sea or from Little Pond.

Analysis of turbidity and color was performed on one of each duplicate water samples. These analyses were performed in order to determine if the MPN (Most Probable Number) or the MF (Membrane Filter) technique for bacteriological analysis should be used. On the basis of the analyses of turbidity and color for Billington Sea (see Appendices) it was determined that turbidity and color might interfere with the MF technique for bacteriological analysis (Russomanno, 1974, p. 12-5; Bordner, Robert and John Winter, 1978, p. 71; MDEQE, 1977, 1978, p. 31; APHA, AWWA, WPCF, 1980, p. 806). Therefore, the MPN technique was used for all bacteriological analyses in both Billington Sea and Little Pond.

Bacteriological analyses of samples collected from Billington Sea to determine the potential presence of septic effluent consisted of the following determinations:

- total colofirm bacteria
- fecal coliform bacteria
- fecal streptococcus

Bacteriological analyses of samples collected from Little Pond to determine the potential presence of septic effluent consisted of the same determinations as in Billington Sea. In addition, the following determinations were made in order to determine the potential role of bacteria in reported incidents of eye and ear irritations among swimmers in Little Pond:

- Staphylococcus aureus
- Pseudomonas aeruginosa

All bacteriological analyses were performed utilizing the 5-tube (4-dilution) MPN Technique for estimating bacterial density (APHA, AWWA, WPCF, 1980, pp. 794-805, 819-821, 873, 875-876). Analyses of total coliform bacteria, fecal coliform bacteria, and fecal streptococcus included the presumptive and confirmed test. Analyses of Staphylococcus aureus and Pseudomonas aeruginosa included only the presumptive test.

3.2 Results

The results of the bacteriological analyses of water samples collected from Billington Sea and Little Pond are included in Tables 1, 2, 3, and 4. These data are arranged by location in Billington Sea and in Little Pond. Locations for each Sample Number were identified by CEM personnel subsequent to the laboratory analyses performed by NER.

PLYMOUTH ROADS ADVISORY COMMITTEE
THURSDAY, MARCH 3, 2011 AT 6:30 PM
MANOMET BRANCH – PLYMOUTH PUBLIC LIBRARY

MEETING AGENDA

Items on the meeting agenda include, but are not limited to, the following:

Old Business:

1) Approval of meeting minutes of February 3, 2011 meeting

2) Election of new Clerk

3) Status of proposed legislation

New Business:

4) FY 2011 DPW road improvement program

5) Snow plowing requests

6) Next meeting date

Public Comment:

Meeting Adjournment

Sample Location*	Sample No.	MPN INDEX: NUMBER/100 ML		
		Total Coliform[1]	Fecal Coliform[1]	Fecal Streptococcus[1]
BA	BS-47	17	9	8
BB	BS-40	11	2	23
BC	BS-43	49	13	23
BD	BS-28	17	2	13
BE	BS-57	79	8	22
BF	BS-55	49	8	8
BG	BS-26	33	<0	8
BH	BS-53	8	2	8
BI	BS-54	13	<0	23
BJ	BS-44	23	<0	17
BK	BS-56	33	8	14
BL	BS-42	1100	170	1400
BM	BS-58	49	17	79
BN	BS-33	33	5	33
BO	BS-51	17	<0	5
BP	BS-45	46	2	5
BQ	BS-59	33	11	79
BR	BS-35	49	2	23
BS	BS-34	46	5	23
BT	BS-46	33	8	49

Table 1. Bacteriological Analyses, Billington Sea, September 22, 1982.

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* See Figure 1

[1] Confirmed Test

Sample Location*	Sample No.	MPN INDEX: NUMBER/100 ML		
		Total Coliform[1]	Fecal Coliform[1]	Fecal Streptococcus[1]
BA	BS-102	17	11	2
BB	BS-108	49	49	20
BC	BS-114	170	22	37
BD	BS-105	33	8	10
BE	BS-107	17	13	22
BF	BS-112	33	13	20
BG	BS-109	49	8	1600
BH	BS-104	17	7	17
BI	BS-120	12	4	6
BJ	BS-117	79	49	22
BK	BS-113	17	5	7
BL	BS-101	79	23	110
BM	BS-106	8	5	12
BN	BS-111	13	2	5
BO	BS-110	23	2	2
BP	BS-103	11	2	34
BQ	BS-115	33	23	920
BR	BS-118	13	8	46
BS	BS-119	49	11	12
BT	BS-116	14	4	< 2

Table 2. Bacteriological Analyses, Billington Sea, October 13, 1982.

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* See Figure 1

[1] Confirmed Test

Sample Location *	Sample No.	MPN INDEX: NUMBER/100 ML				
		Total Coliform[1]	Fecal Coliform[1]	Fecal Streptococcus[1]	Staphylococcus aureus[2]	Pseudomonas aeruginosa[2]
LA	LP-21	≥2400	<0	7	130	23
LB	LP-3	42	5	17	17	23
LC	LP-2	350	8	11	49	23
LD	LP-22	1600	2	5	49	23
LE	LP-14	350	2	<0	14	23
LF	LP-5	920	<0	5	9	23
LG	LP-1	≥2400	<0	2	8	23
LH	LP-17	40	<0	2	49	23
LI	LP-31	59	<0	13	79	23
LJ	LP-9	44	<0	2	79	13

* See Figure 1

[1] Confirmed Test

[2] Presumptive Test

Table 3. Bacteriological Analyses, Little Pond, September 22, 1982.

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Sample Location*	Sample No.	MPN INDEX: NUMBER/100 ML Total Coliform[1]	Fecal Coliform[1]	Fecal Streptococcus[1]	Staphylococcus aureus[2]	Pseudomonas aeruginosa[2]
LA	LP-204	1600	8	17	280	< 2
LB	LP-207	280	5	4	123	< 2
LC	LP-203	40	7	19	≥ 2400	< 2
LD	LP-205	26	5	12	220	< 2
LE	LP-206	140	13	38	920	< 2
LF	LP-208	63	13	20	123	< 2
LG	LP-210	920	13	< 0	47	< 2
LH	LP-209	34	4	33	1600	< 2
LI	LP-202	23	5	14	≥ 2400	< 2
LJ	LP-201	220	2	17	≥ 2400	< 2

* See Figure 1

[1] Confirmed Test

[2] Presumptive Test

Table 4. Bacteriological Analyses, Little Pond, October 13, 1982.

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4. DISCUSSION OF RESULTS

As indicated in Tables 1-4, the population density of fecal coliform bacteria in all water samples collected from Billington Sea and Little Pond are well within the Massachusetts Water Quality Standards for Class B (primary and secondary contact recreation) waters (MWRC, 1978, p. 11).

With respect to total coliform bacteria, only one sample from Billington Sea (out of a total of 40 samples) showed a density of greater than 1000 bacteria per 100 ml; four samples from Little Pond (out of a total of 20 samples) showed a density of greater than 1000 bacteria per 100 ml. A density of 1000 total coliforms per 100 ml has often been used as an upper limit for primary contact recreation. A density of 240-2,400 total coliforms per 100 ml has often been used to characterize normal total coliform densities for agricultural drainage or runoff from forest and other wildlife areas (New Hampshire Water Supply and Pollution Control Commission, 1964).

Fecal coliform:fecal streptococcus ratios (FC:FS) of 4.0 or higher typically indicate domestic waste while ratios of 0.6 or lower are common to discharges from farm animals or stormwater runoff. However, when the density of fecal

streptococcus is below 100 organisms per 100 ml, the sanitary significance of the FC:FS ratio is questionable (APHA, AWWA, WPCF, 1980, p. 874). In the Billington Sea samples (Tables 1 and 2), the density of fecal streptococcus was greater than 100 per 100 ml in 4 samples (sample locations BL, BG, and BQ). The FC:FS ratios in these samples range from 0.005 to 0.21. None of the samples from Little Pond (Tables 3 and 4) showed fecal streptococcus densities greater than 38 organisms per 100 ml. However, the density of fecal streptococcus was greater than the density of fecal coliforms in 17 out of a total of 20 samples.

As shown in Tables 3 and 4, Staphylococcus aureus and Pseudomonas aeruginosa were present (on the basis of the presumptive test) in all samples collected from Little Pond in September. Staphylococcus aureus was also present in all samples collected in October. It appears that the density of Staphylococcus aureus increased in Little Pond from September to October, and that the density of Pseudomonas aeruginosa decreased in the same period. Specific causes for these apparent changes in population density cannot be determined at this time. However, it is possible that temperature and pH may have influenced the die-off rate and/or growth rate of these bacterial species. Both species of bacteria are

opportunistic pathogens which can be transmitted to and/or by humans (APHA, AWWA, WPCF, 1980, p. 873).

It is not possible to discern any precise pattern to the distribution of the various bacterial densities within Billington Sea or Little Pond. A comparison of all the data obtained on the two different dates suggests that the highest densities of bacteria tend to occur in the western portion of Billington Sea, and in the northern, southern and eastern extremes of Little Pond.

5. SUMMARY OF RESULTS

The results of the bacteriological studies conducted by NER in September and October 1982 may be summarized as follows:

1. The observed densities of total coliform and fecal coliform bacteria in Billington Sea and in Little Pond are low and are generally indicative of normal runoff from agricultural lands, forest land and wildlife areas.

2. The observed densities of fecal coliform bacteria and fecal streptococcus are typical of non-domestic waste (e.g., farm animals, stormwater, etc.).

3. The observed densities of Staphylococcus aureus and Pseudomonas aeruginosa in September and October indicate that these opportunistic pathogens were present after the swimming season and may have been transmitted to or by swimmers in Little Pond during the summer swimming season.

On the basis of these findings, NER concludes that there is no bacteriological evidence in these studies that Billington Sea or Little Pond receives effluent from surrounding septic systems. NER also concludes that reported eye and ear irritations among swimmers in Little Pond may be due to opportunistic pathogens introduced into Little Pond by swimmers.

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7. APPENDICES

Results of Analyses of Turbidity and Color, Billington Sea and Little Pond

Sample Location*	Sample No.	Turbidity (J.T.U.)	Color (Pt-Co Units)
BA	BS-4	4.5	35
BB	BS-18	4.5	35
BC	BS-25	4.2	35
BD	BS-38	5.5	35
BE	BS-20	6.6	40
BF	BS-48	5.0	35
BG	BS-60	4.9	35
BH	BS-11	4.0	35
BI	BS-52	4.4	35
BJ	BS-23	4.0	30
BK	BS-32	5.0	30
BL	BS-49	4.9	30
BM	BS-13	4.5	30
BN	BS-15	4.8	25
BO	BS-27	4.5	30
BP	BS-6	3.9	25
BQ	BS-29	3.9	25
BR	BS-50	4.9	30
BS	BS-39	4.8	30
BT	BS-41	5.0	25

* See Figure No. 1

Appendix 1. Results of Analyses, Billington Sea, September 22, 1982.

NEW ENGLAND RESEARCH, INC.
WORCESTER, MASSACHUSETTS

Sample Location*	Sample No.	Turbidity (J.T.U.)	Color (Pt-Co Units)
BA	BS-122	3.4	25
BB	BS-128	3.0	25
BC	BS-133	3.3	25
BD	BS-129	3.2	25
BE	BS-134	2.8	25
BF	BS-125	3.6	25
BG	BS-136	3.6	25
BH	BS-130	3.4	25
BI	BS-140	2.6	25
BJ	BS-124	2.7	25
BK	BS-126	2.8	25
BL	BS-127	1.8	25
BM	BS-121	2.5	25
BN	BS-135	2.5	25
BO	BS-138	2.6	25
BP	BS-123	2.9	25
BQ	BS-132	2.2	25
BR	BS-131	2.4	25
BS	BS-139	2.5	25
BT	BS-137	2.9	25

* See Figure No. 1

Appendix 2. Results of Analyses, Billington Sea, October 13, 1982.

NEW ENGLAND RESEARCH, INC.
WORCESTER, MASSACHUSETTS

Sample Location*	Sample No.	Turbidity (J.T.U.)	Color (Pt-Co Units)
LA	LP-37	0.50	5
LB	LP-8	0.40	5
LC	LP-16	0.65	5
LD	LP-7	0.42	5
LE	LP-36	0.42	5
LF	LP-30	0.53	5
LG	LP-12	0.50	5
LH	LP-19	0.49	5
LI	LP-10	0.55	5
LJ	LP-24	0.67	5

* See Figure No. 1

Appendix 3. Results of Analyses, Little Pond, September 22, 1982.

NEW ENGLAND RESEARCH, INC.
WORCESTER, MASSACHUSETTS

Sample Location*	Sample No.	Turbidity (J.T.U.)	Color (Pt-Co Units)
LA	LP-216	0.65	5
LB	LP-218	0.82	7.5
LC	LP-217	0.60	5
LD	LP-214	0.58	7.5
LE	LP-220	0.38	7.5
LF	LP-211	0.62	5
LG	LP-212	0.45	5
LH	LP-213	0.42	7.5
LI	LP-219	0.98	7.5
LJ	LP-215	0.65	7.5

* See Figure No. 1

Appendix 4. Results of Analyses, Little Pond, October 13, 1982.

NEW ENGLAND RESEARCH, INC.
WORCESTER, MASSACHUSETTS

APPENDIX 2.

NEW ENGLAND RESEARCH, INC.
15 SAGAMORE ROAD
WORCESTER, MASSACHUSETTS 01605
TELEPHONE: (617) 752-0346

WATER QUALITY STUDIES

FOR

PLYMOUTH, MASSACHUSETTS

PART II: EUTROPHICATION STUDIES

OF BILLINGTON SEA

SUBMITTED TO

CE MAGUIRE, INC.

31 CANAL STREET

PROVIDENCE, RHODE ISLAND 20903

NOVEMBER 30, 1982

Environmental Consulting Services

TABLE OF CONTENTS

1. INTRODUCTION

This is a report on the eutrophication studies of Billington Sea, Plymouth, Massachusetts conducted by New England Research, Inc. (NER) for CE Maguire, Inc. (CEM). These eutrophication studies were conducted in October and November 1982 as part of an overall study of public health and environmental issues related to the water quality of Billington Sea. A report on bacteriological surveys of Billington Sea was submitted to CEM on November 15, 1982. A Final Integrated Report will be submitted to CEM on December 30, 1982, and will include an integration of the results of the bacteriological surveys and eutrophication studies conducted by NER with other available studies and information.

The eutrophication studies included in this report include (1) a water quality survey of Billington Sea, and (2) a laboratory bioassay utilizing water collected from Billington Sea.

2. OBJECTIVES

The objectives of the Water Quality Survey (Section 3) are as follows:

1. To determine if there is any chemical evidence of gross contamination of Billington Sea by effluents from septic systems, and
2. To provide baseline data on nutrients in Billington Sea.

The objectives of the Bioassay (Section 4) are as follows:

1. To determine the limiting nutrient(s) in Billington Sea,
2. To determine the potential role of suspended particulates in nutrient limitation in Billington Sea, and
3. To assess the potential role of bottom muds in the eutrophication of Billington Sea.

3. WATER QUALITY SURVEY

3.1 Methods

Water samples were collected at 20 locations in Billington Sea (Figure 1) on October 13, 1982. Water samples were grab samples, using acid-cleaned, 500 ml polypropylene containers.

Water sampling locations in Billington Sea were identical to locations utilized in the previously reported bacteriological surveys (NER, 1982). All shoreline samples were collected approximately 10 meters from the shoreline.

Upon collection, all samples were labeled, iced and transported to NER for analysis. Each label included a Sample Number selected by CEM field personnel.

All water samples were processed by NER laboratory personnel using standard analytical procedures (APHA, AWWA, WPCF, 1980). Records of analysis used by NER laboratory personnel were based on the Sample Number included on the sample label; NER personnel did not know the specific location of the samples.

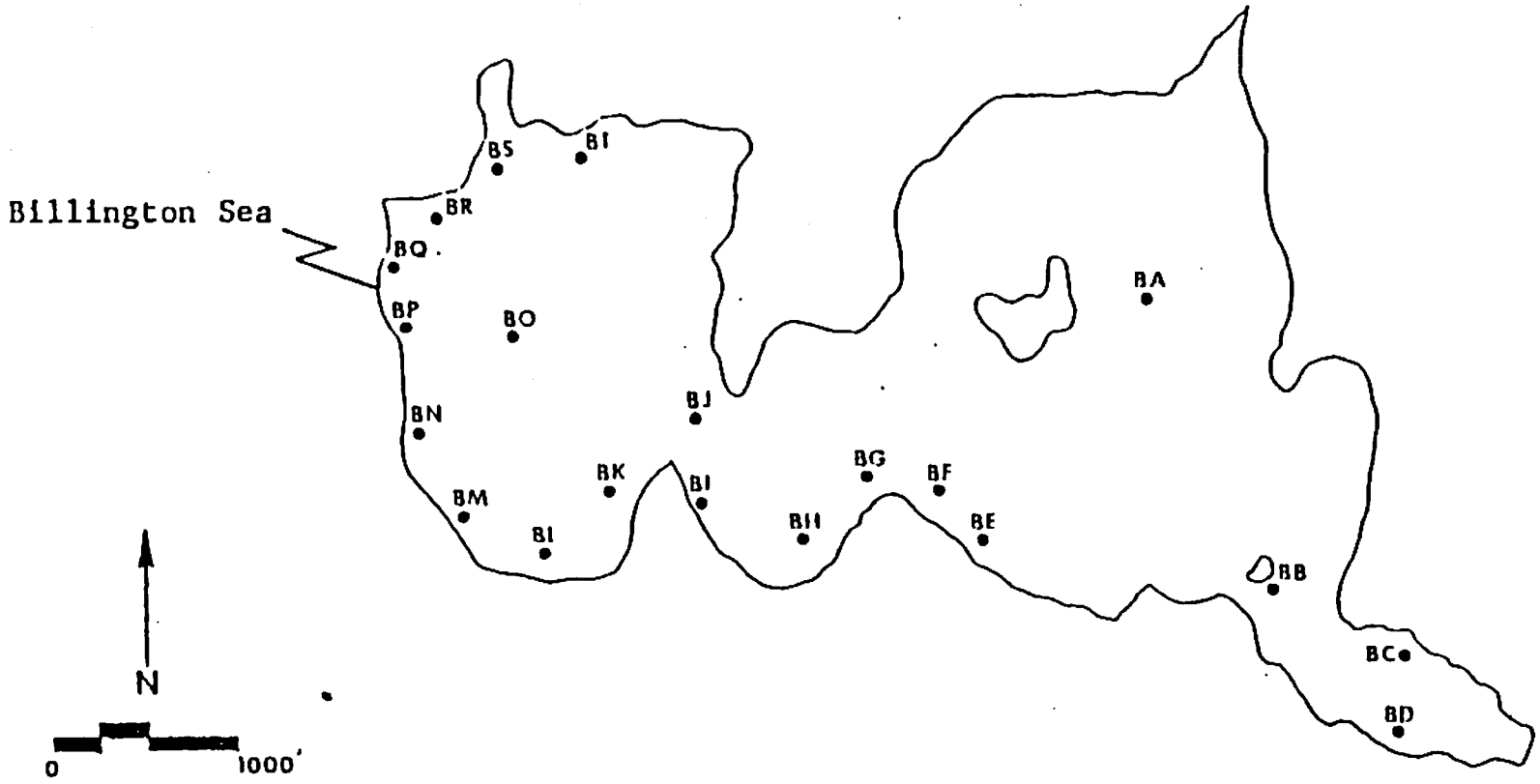

Figure 1.	Location of Sampling Locations, Water Quality Survey, October 13, 1982.	NEW ENGLAND RESEARCH, INC. WORCESTER, MASSACHUSETTS

3.2 Results

Results of analyses of turbidity and color were previously reported in NER's report on bacterial surveys of Billington Sea (NER, 1982). Results of analyses of other water quality parameters are included in Table 1.

3.3 Discussion

As in the bacteriological surveys of Billington Sea (NER, 1982) there is no overall geographical pattern to the water quality data included in Table 1.

The average concentration of NO_3+NO_2-N is 0.27 mg/1; the average concentration of NH_3-N is 0.12 mg/1; the average concentration of total phosphorus (P) is 0.05 mg/1. Thus, the ratio of total available nitrogen (NO_3+NO_2+NH_3 nitrogen) to total phosphorus is on the order of 8:1. The ratio of total available nitrogen (NO_3+NO_2+NH_3 nitrogen) to orthophosphorus is on the order of 26:1. Since orthophosphorus is the more readily available form of phosphorus for algae, the total available nitrogen-orthophosphorus ratio suggests that Billington Sea is phosphorus limited. However, the total available nitrogen - total phosphorus ratio suggests that much of the phosphorus is in an organic form and must be recycled

Parameter	Unit	Sample Number and Location*									
		#122 BA	#128 BB	#133 BC	#129 BD	#134 BE	#125 BF	#136 BG	#130 BH	#140 BI	#124 BJ
pH	pH Units	7.2	7.1	7.0	7.1	7.2	7.3	7.1	7.3	7.1	7.2
Sulfate	mg/l S	1.6	3.6	2.8	3.7	2.1	2.8	0.9	2.5	3.1	3.1
Chloride	mg/l Cl	17.9	17.9	23.0	17.9	12.8	17.9	17.9	18.4	18.4	16.3
Conductivity	umhos /cm	84	86	90	76	88	89	90	86	85	86
Ortho Phosphorus	mg/l P	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.03
Hydrolyzable Phosphorus	mg/l P	0.02	0.02	0.03	0.02	0.03	0.03	0.03	0.02	0.03	0.02
Total Phosphorus	mg/l P	0.04	0.04	0.05	0.04	0.05	0.06	0.06	0.06	0.05	0.05
Ammoniacal Nitrogen	mg/l N	0.21	0.12	0.12	0.12	0.12	0.14	0.12	0.14	0.12	0.18
Nitrate Plus Nitrite Nitrogen	mg/l N	0.18	0.33	0.17	0.09	0.19	0.10	0.13	0.12	0.29	0.14

*See Figure 1

Table 1. Water Quality Analyses, Billington Sea, October 1982.

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WORCESTER, MASSACHUSETTS

Parameter	Unit	Sample Number and Location*									
		#126 BK	#127 BL	#121 BM	#135 BN	#138 BO	#123 BP	#132 BQ	#131 BR	#139 BS	#137 BT
pH	pH Units	7.2	7.0	6.9	6.9	7.2	6.9	6.9	7.0	7.2	7.2
Sulfate	mg/l S	1.5	2.5	1.9	2.4	3.1	2.5	2.8	3.1	3.1	2.0
Chloride	mg/l Cl	23.0	17.9	17.9	17.9	17.9	18.4	18.4	18.9	18.8	17.9
Conductivity	umhos /cm	86	87	94	89	84	90	92	97	94	87
Ortho Phosphorus	mg/l P	<0.01	0.01	0.01	0.01	0.02	<0.01	0.01	<0.01	0.01	0.02
Hydrolyzable Phosphorus	mg/l P	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.03	0.03
Total Phosphorus	mg/l P	0.04	0.04	0.05	0.04	0.05	0.04	0.04	0.03	0.05	0.05
Ammoniacal Nitrogen	mg/l N	0.11	0.10	0.21	0.08	0.12	0.12	0.08	0.08	0.08	0.11
Nitrate Plus Nitrite Nitrogen	mg/l N	0.24	0.37	0.37	0.51	0.15	0.39	0.46	0.51	0.36	0.23

*See Figure 1

Table 1. (Cont.) Water Quality Analyses, Billington Sea, October 1982.

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to support current phytoplanktonic and/or other microbial populations. Since these samples were taken in October, it is probable that organic phosphorus will become available in the spring (after winter decomposition of organelles) and will support populations of phytoplankton that are characteristic of eutrophic waters.

Finally, the observed values of pH, sulfate, chloride, conductivity and of the nutrient parameters are well within the normal range of surface waters within reasonably protected watersheds. None of these data demonstrate gross contamination of Billington Sea by septic effluent from surrounding areas.

4. BIOASSAY

4.1 Methods

Water was collected from Billington Sea by CEM personnel on October 13, 1982 in two 1-gallon glass (brown) containers that had been previously acid washed and sterilized. CEM also collected a sample of bottom sediment in a plastic container. Water and sediment samples were iced and transported to NER.

Within 6 hours of collection, one gallon of the collected water was first autoclaved and then filtered, and one gallon was first filtered and then autoclaved. Both the autoclaved/filtered and filtered/autoclaved waters were stored in the dark for subsequent use in the bioassay. The sediment sample was refrigerated upon arrival at NER. Subsequently, a small aliquot of the sediment was autoclaved and filtered, and the filtrate stored in the dark.

The design of the bioassay was based on the Selenastrum capricornutum Printz Algal Assay Bottle Test developed by the U.S. EPA (Miller, et al., 1978). Stock cultures of Selenastrum capricornutum were obtained from a commercial biological supply house.

The bioassay required the preparation of triplicate flasks for each of nine cultures as follows:

- Test Water (from Billington Sea)
- Test Water plus Phosphorus Spike
- Test Water Plus Nitrogen Spike
- Test Water Plus Phosphorus Plus Nitrogen Spike
- Test Water Plus EDTA Spike
- Test Water Plus Phosphorus Plus EDTA Spike
- Test Water Plus Nitrogen Plus EDTA Spike
- Test Water Plus Nitrogen Plus Phosphorus Plus EDTA Spike
- Test Water Plus Sediment Extract (From Billington Sea).

For purposes of this study, two bioassays were performed. The test water (see above) for one bioassay was the Billington Sea water which was first autoclaved and then filtered. The test water for the second bioassay was the Billington Sea water which was first filtered and then autoclaved. The various additions to the culture flasks for the autoclaved/filtered test water (Cultures A through I) and for the filtered/autoclaved test water (Cultures J through R) are summarized in Tables 2 and 3.

Results of chemical analyses of the autoclaved/filtered and filtered/autoclaved test waters and the sediment extract

PROTOCOL								
Culture*	Additions							
	Autoclaved, Filtered Water (1)	Filtered, Autoclaved Water	Algal Innoculum (2)	Distilled Water (3)	Nitrogen (N) (4)	Phosphorus (P) (4)	EDTA (4)	Sediment Extract (5)
A	+	-	+	+	-	-	-	-
B	+	-	+	-	-	+	-	-
C	+	-	+	-	+	-	-	-
D	+	-	+	-	+	+	-	-
E	+	-	+	-	-	-	+	-
F	+	-	+	-	-	+	+	-
G	+	-	+	-	+	-	+	-
H	+	-	+	-	+	+	+	-
I	+	-	+	-	-	-	-	+

* Each culture includes triplicate flasks, each having a total culture volume of 50 ml
(1) 48.9 ml of test water in each flask
(2) 1.0 ml of algal innoculum in each flask
(3) 0.1 ml of distilled water
(4) Appropriate additions to achieve U.S. EPA recommended concentrations
(5) 0.1 ml of sediment extract

Table 2.	Summary of Additions (+) to Each Culture (Autoclaved/Filtered Test Water).	NEW ENGLAND RESEARCH, INC. WORCESTER, MASSACHUSETTS

Sid Kashi

From: Greg Vita [greg@superiorsealcoat.com]
Sent: Friday, February 25, 2011 1:01 PM
To: Sid Kashi
Subject: Parking lot crackseal

Hello Sid:

I left a message today about a small balance remaining on the parking lots invoice #210408 dated 10-18-10.

Our original invoice #210408 dated 10-18-10 was in the amount $45,061.00 and we received payment in the amount of $25,061.00 (check #56955) in December, leaving a remaining balance of $20,000.

Perhaps you can look into when the remaining balance will be processed for payment.

I will try to reach you next week, and I hope all is well.

Thanks Again,
Greg

are included in Table 4. The final concentrations of key parameters in each culture are included in Table 5.

All flasks were prepared and innoculated with Selenastrum capricornutum on November 2. Growth was monitored daily through turbidimetric readings in one flask of each culture (Appendix 1). Cell counts were obtained at various portions of the growth curve (Appendix 2) by means of direct microscopic counting using a Palmer-Maloney Nannoplankton Cell (Weber, 1973). The bioassays were terminated on November 17, 15 days after innoculation.

4.2 Results

Examples of the growth curves of selected cultures in the Billington Sea bioassays are included in Figure 2. These curves and the data included in Appendix 1 and Appendix 2 demonstrate that the cultures had reached the stationary phase of growth two weeks after innoculation. Final cell counts (Appendix 2) for each flask for each culture were obtained on the 15th day after innoculation. Final cell counts are included in Table 6.

Parameter	Unit	Billington Sea Sample		
		Autoclaved, Filtered Water	Filtered, Autoclaved Water	Sediment Extract
pH	pH Units	5.9	7.0	5.3
Sulfate	mg/l S	5.0	1.5	8.7
Chloride	mg/l Cl	20.1	18.1	89.3
Conductivity	umhos/cm	68	90	45
Ortho Phosphorus	mg/l P	< 0.01	0.01	0.1
Hydrolyzable Phosphorus	mg/l P	0.02	0.01	0.46
Total Phosphorus	mg/l P	0.03	0.02	1.3
Ammoniacal Nitrogen	mg/l N	0.51	0.36	4.41
Nitrate Plus Nitrite Nitrogen	mg/l N	0.31	0.31	0.18

Table 4. Results of Chemical Analyses, Billington Sea Bioassay.

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WORCESTER, MASSACHUSETTS

Culture*	Nitrate Plus Nitrite Nitrogen (mg/l)	Ammoniacal Nitrogen (mg/l)	Total Phosphorus (mg/l)
A	0.30	0.50	0.03
B	0.30	0.50	0.08
C	1.3	0.50	0.03
D	1.3	0.50	0.08
E	0.30	0.50	0.03
F	0.30	0.50	0.08
G	1.3	0.50	0.03
H	1.3	0.50	0.08
I**	0.30	0.51	0.03
J	0.30	0.35	0.02
K	0.30	0.35	0.07
L	1.3	0.35	0.02
M	1.3	0.35	0.07
N	0.30	0.35	0.02
O	0.30	0.35	0.07
P	1.3	0.35	0.02
Q	1.3	0.35	0.07
R**	0.30	0.36	0.02

* The total volume of each culture is 50 ml, of which 48.9 ml are the test water.

** 0.1 ml of the mud extract were added to the culture flasks.

Table 5. Final Concentrations of Nutrients, Billington Sea Bioassay.

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WORCESTER, MASSACHUSETTS

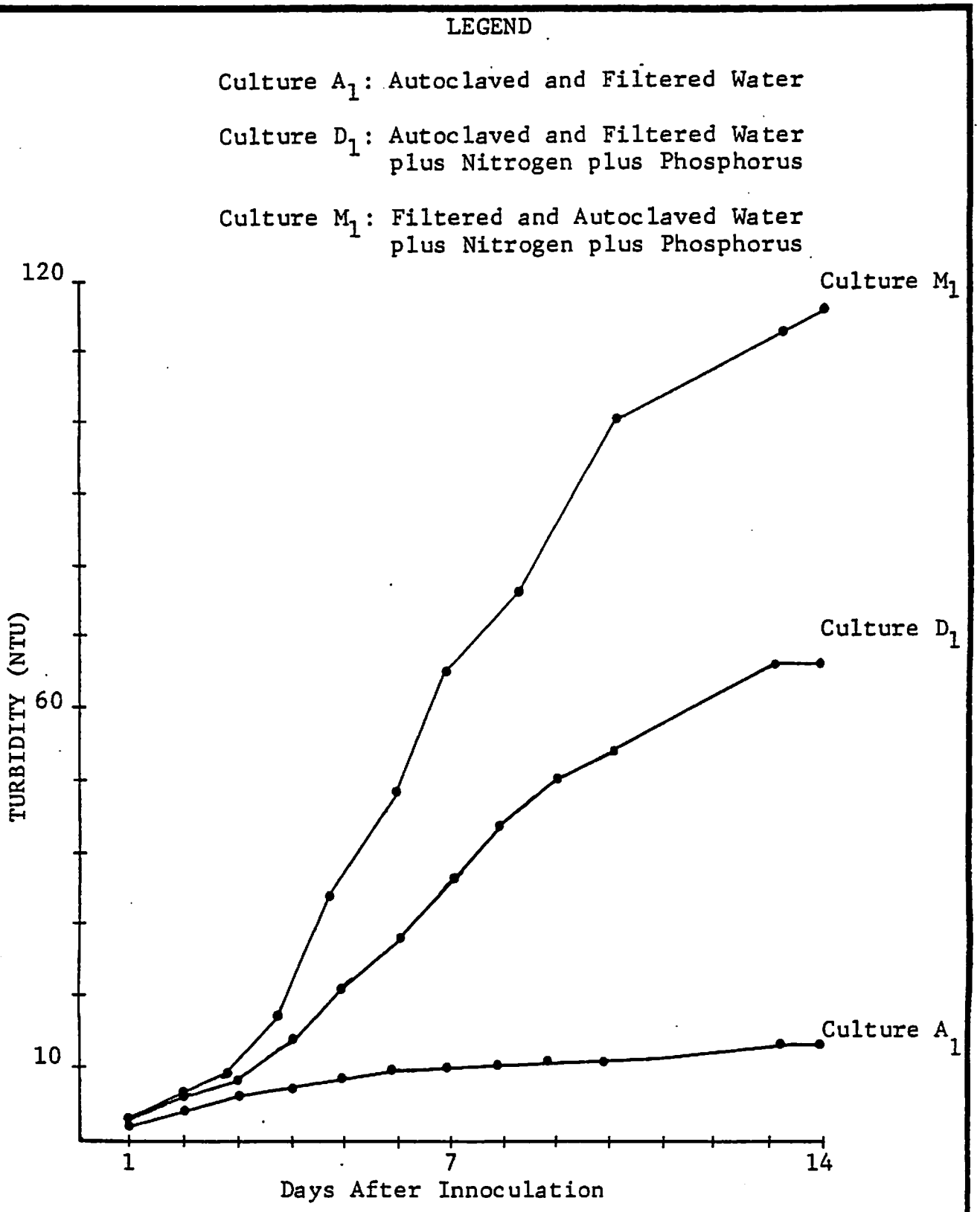

Figure 2. Examples of Growth Curves in Billington Sea Bioassays.

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WORCESTER, MASSACHUSETTS

Culture	Final Cell Counts[1] per ml X 10^{-3}		
	Mean*	Standard Deviation	95% Confidence Interval
A	53	10	33 - 73
J	12	5	2 - 22
B	211	104	3 - 419
K	490	125	240 - 740
C	23	3	17 - 29
L	7	4	<1 - 15
D	1014	228	558 - 1470
M	1546	392	762 - 2330
E	66	17	32 - 100
N	12	3	6 - 18
F	138	66	6 - 270
O	455	136	183 - 727
G	31	6	19 - 43
P	16	3	10 - 22
H	472	75	322 - 622
Q	594	101	392 - 796
I	9	3	3 - 15
R	9	2	5 - 13

* mean of triplicate values

1 cell counts presented in format recommended by U.S. EPA (Miller, et al., 1978).

Table 6. Final Cell Counts (15 Days After Innoculation).

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WORCESTER, MASSACHUSETTS

4.3 Discussion

Final cell counts for both bioassays are arrayed graphically in Figures 3 and 4.

In the bioassay for the test water which was first autoclaved and then filtered (Figure 3), it is clear that the cultures which were spiked with phosphorus (Cultures B, D, F and H) supported larger populations of the bioassay alga than did the test water (Culture A) or any of the other cultures spiked with only nitrogen and/or EDTA. This is a classic example of phosphorus limitation. The addition of EDTA did not appear to have any significant effect on algal growth. Finally, the addition of sediment extract (Culture I) resulted in significantly reduced growth of the bioassay alga when compared to the control (Culture A). Since the nutrient concentrations of Cultures A and I are essentially identical (see Table 5, Section 4.1), it is possible that the sediment extract contained a growth inhibitor.

In the bioassay for the test water which was first filtered and then autoclaved (Figure 4) the phosphorus limitation is even more pronounced. Again, the addition of EDTA did not appear to have any significant impact on algal growth. It should also be noted that, unlike the bioassay using autoclaved/

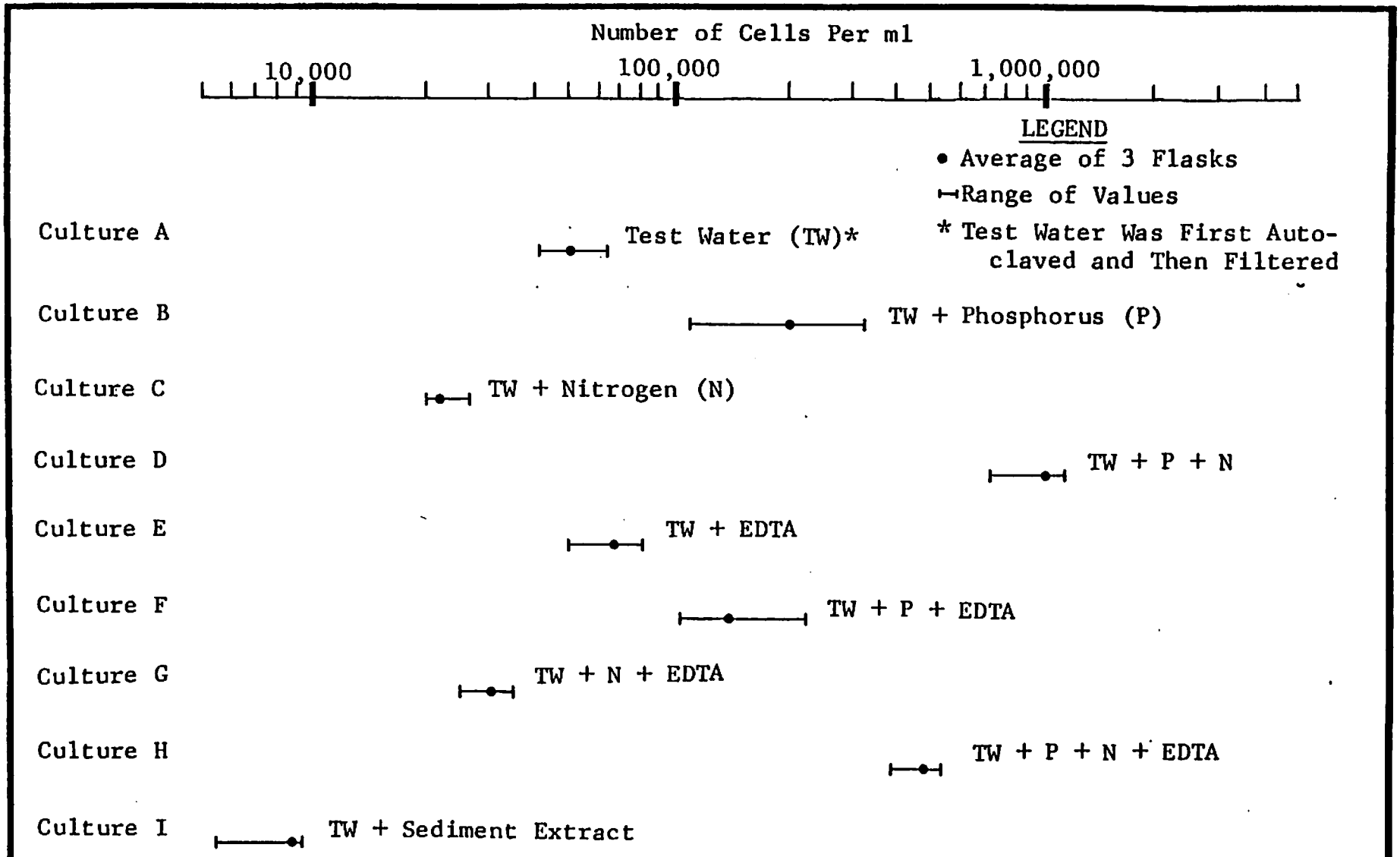

Figure 3.	Comparison of Cell Counts, Autoclaved/Filtered Test Water.	NEW ENGLAND RESEARCH, INC. WORCESTER, MASSACHUSETTS

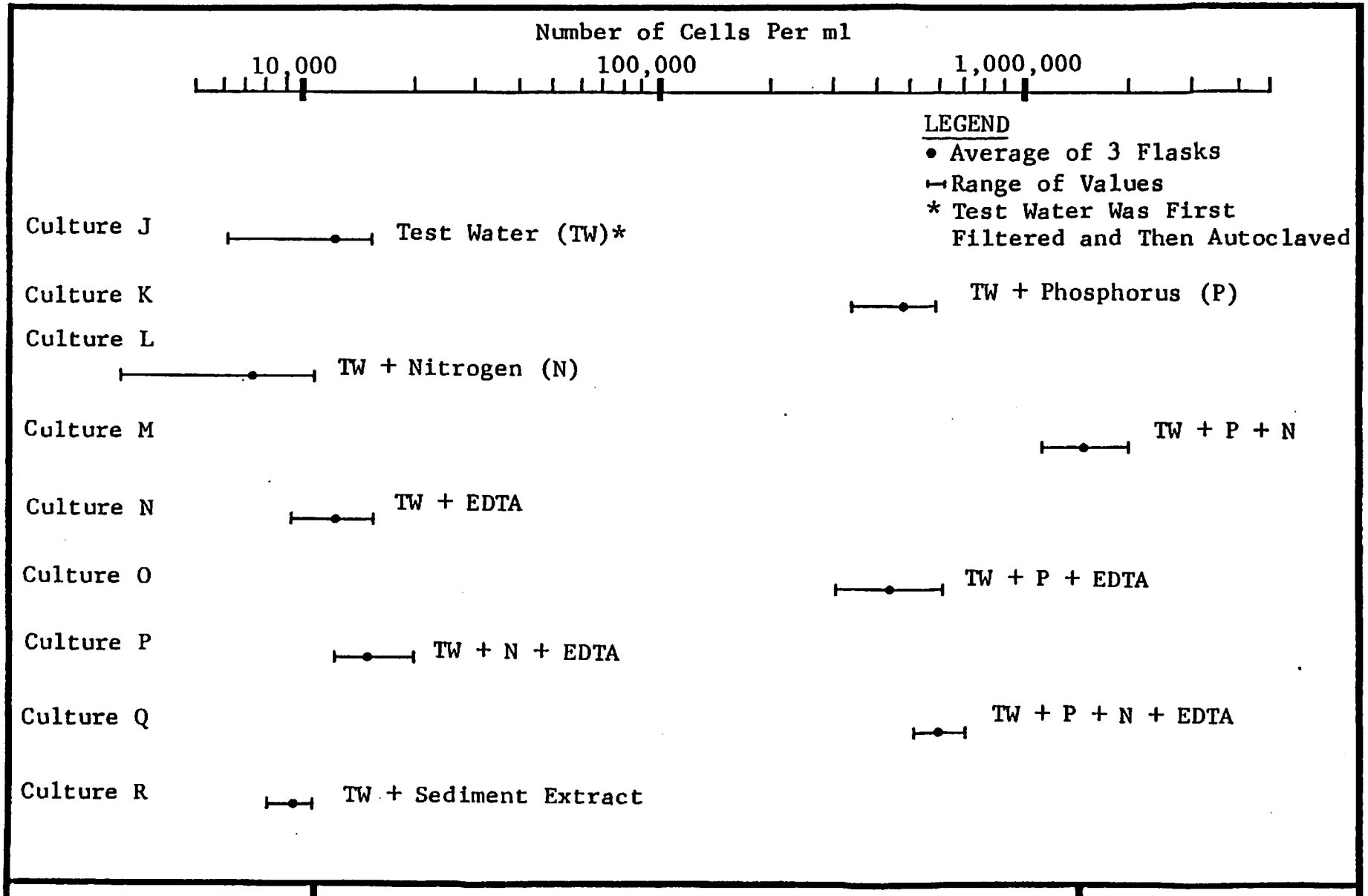

Figure 4.	Comparison of Cell Counts, Filtered/Autoclaved Test Water.	NEW ENGLAND RESEARCH, INC. WORCESTER, MASSACHUSETTS

filtered test water, the addition of sediment extract in this bioassay (Culture R) did not appear to have any significant effect on algal growth when compared to the control (Culture J).

The phosphorus limitation demonstrated by both bioassays is consistent with the finding that algal growth was greater in certain cultures containing autoclaved/filtered test water (Cultures A, C, E, and G) than in comparable cultures containing filtered/autoclaved test water (Cultures J, L, N and P). This is because the initial autoclaving procedure may have released hydrolyzable phosphorus, resulting in a higher total phosphorus concentration in the autoclaved/filtered water than in the filtered/autoclaved water (see Table 4, Section 4.1).

Finally, algal growth was greater in those cultures containing filtered/autoclaved water plus phosphorus additions (Cultures K, M, O, and Q) than in cultures containing autoclaved/filtered water plus phosphorus additions (Cultures B, D, F and H). Since Cultures K, M, O, and Q had lower total phosphorus concentrations than Cultures B, D, F, and H, it is possible that the initial filtration of the filtered/autoclaved water removed a growth inhibitor associated with suspended particles.

5. SUMMARY OF RESULTS

1. There is no chemical evidence of gross contamination of Billington Sea by effluents from septic systems.

2. The concentrations of nutrients in Billington Sea are sufficient to support densities of phytoplankton usually associated with eutrophic waters.

3. The bioassay indicates that phosphorus was a limiting nutrient at the time of the study.

4. Suspended particles in Billington Sea are a source of phosphorus.

5. Suspended particles in Billington Sea may also be a source of an algal growth inhibitor.

6. The bottom muds of Billington Sea contain high concentrations of phosphorus and nitrogen which may serve as potential nutrients for phytoplankton.

7. The bottom muds of Billington Sea may also contain an algal growth inhibitor.

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7. APPENDICES

Culture *	Turbidity (NTU)					
	Nov. 3 Day 1	Nov. 4 Day 2	Nov. 5 Day 3	Nov. 6 Day 4	Nov. 7 Day 5	Nov. 8 Day 6
A1	1.6	3.2	5.6	6.4	6.0	8.0
B1	1.6	4.0	4.8	8.0	8.0	10
C1	1.6	4.0	4.8	4.8	5.0	7.0
D1	1.6	4.0	5.6	12.8	22	28
E1	2.4	3.2	4.0	4.0	7.0	6.0
F1	2.4	4.0	4.8	4.8	8.0	7.0
G1	2.4	2.4	4.8	4.8	5.0	6.0
H1	2.4	4.0	4.8	7.2	14	15
I1	5.6	5.6	4.8	4.0	5.0	4.0
J1	1.6	2.4	3.2	2.4	4.0	4.0
K1	2.4	3.2	4.8	9.6	14	16
L1	4.0	3.2	2.4	3.2	3.0	3.0
M1	3.2	3.2	5.6	16	32	44
N1	3.2	4.0	3.2	1.6	3.0	2.0
O1	4.8	3.2	4.8	9.6	14	22
P1	1.6	3.2	2.4	3.2	3.0	3.0
Q1	2.4	3.2	3.2	8.0	11	12
R1	4.0	3.2	2.4	3.2	2.0	2.0

* One flask of each culture

Appendix 1. Turbidity Values

NEW ENGLAND RESEARCH, INC.
WORCESTER, MASSACHUSETTS

Culture*	Turbidity (NTU)					
	Nov. 9 Day 7	Nov. 10 Day 8	Nov. 11 Day 9	Nov. 12 Day 10	Nov. 15 Day 13	Nov. 16 Day 14
A1	8.0	8.0	10	9.6	12	12
B1	12	12	13	14	16	16
C1	6.0	7.0	7.0	6.9	9.2	9.0
D1	36	43	48	51	67	66
E1	7.0	6.0	8.0	6.0	9.2	8.0
F1	8.0	8.0	10	11	12	12
G1	6.0	6.0	6.0	6.9	9.2	10
H1	22	24	26	33	40	43
I1	6.0	5.0	5.0	6.9	6.3	6.0
J1	4.0	4.0	4.0	5.5	8.1	5.0
K1	22	20	22	25	28	32
L1	7.0	3.0	4.0	5.5	6.9	7.0
M1	66	74	83	98	110	116
N1	4.0	2.0	5.0	4.1	5.0	4.0
O1	30	24	26	28	35	34
P1	4.0	2.0	3.0	2.8	5.0	4.0
Q1	24	22	26	29	37	36
R1	6.0	4.0	4.0	4.1	5.0	6.0

* One flask of each culture

Appendix 1 (Continued) Turbidity Values

NEW ENGLAND RESEARCH, INC.
WORCESTER, MASSACHUSETTS

Culture	Flask No.	Cells per milliliter X 10^{-3}			
		Nov. 2 Day 0	Nov. 8 Day 6	Nov. 12 Day 10	Nov. 17 Day 15
A	1	2.2	50.3	44.0	42.5
	2	2.2	-	-	53.5
	3	2.2	-	-	62.9
B	1	2.2	66.0	113.2	114.8
	2	2.2	-	-	196.5
	3	2.2	-	-	320.8
C	1	2.2	15.7	18.9	22.0
	2	2.2	-	-	20.4
	3	2.2	-	-	26.7
D	1	2.2	264.1	628.0	750.0
	2	2.2	-	-	1150.9
	3	2.2	-	-	1139.9
E	1	2.2	28.3	50.3	50.3
	2	2.2	-	-	83.3
	3	2.2	-	-	64.5
F	1	2.2	59.7	113.2	100.6
	2	2.2	-	-	213.8
	3	2.2	-	-	99.1
G	1	2.2	34.6	47.2	36.2
	2	2.2	-	-	25.2
	3	2.2	-	-	33.0
H	1	2.2	210.7	462.3	533.0
	2	2.2	-	-	388.4
	3	2.2	-	-	493.7
I	1	2.2	18.9	12.6	11.0
	2	2.2	-	-	6.3
	3	2.2	-	-	11.0
J	1	2.2	12.6	22.0	15.7
	2	2.2	-	-	14.2
	3	2.2	-	-	6.3

Appendix 2. Cell Counts

NEW ENGLAND RESEARCH, INC.
WORCESTER, MASSACHUSETTS

Culture	Flask No.	Cells per milliliter X 10^{-3}			
		Nov. 2 Day 0	Nov. 8 Day 6	Nov. 12 Day 10	Nov. 17 Day 15
K	1	2.2	195.0	267.3	345.9
	2	2.2	-	-	570.8
	3	2.2	-	-	551.9
L	1	2.2	12.6	3.1	3.1
	2	2.2	-	-	11.0
	3	2.2	-	-	7.9
M	1	2.2	569.2	1647.8	1677.7
	2	2.2	-	-	1105.3
	3	2.2	-	-	1855.3
N	1	2.2	12.6	25.2	9.4
	2	2.2	-	-	15.7
	3	2.2	-	-	11.0
O	1	2.2	132.1	411.9	460.7
	2	2.2	-	-	316.0
	3	2.2	-	-	588.0
P	1	2.2	12.6	9.4	18.9
	2	2.2	-	-	15.7
	3	2.2	-	-	12.6
Q	1	2.2	317.6	474.8	495.3
	2	2.2	-	-	696.5
	3	2.2	-	-	591.3
R	1	2.2	22.0	6.3	9.4
	2	2.2	-	-	7.9
	3	2.2	-	-	11.0

Appendix 2 (Continued) Cell Counts

NEW ENGLAND RESEARCH, INC.
WORCESTER, MASSACHUSETTS