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The Distribution of Fecal Coliform Bacteria in Surface Waters of Sengekontacket Pond and Management Implications.

Arthur G. Gaines, Jr. and Andrew R. Solow

Marine Policy Center
Woods Hole Oceanographic Institution
October 14, 1991

INTERIM REPORT # 1
SENGEKONTACKET POND PROJECT

Prepared for:
Friends of Sengekontacket, Inc.
P.O. Box 740
Edgartown, Massachusetts 02539

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EXECUTIVE SUMMARY

Results

1) Fecal coliform bacteria were assayed in Sengekontacket Pond, Massachusetts, to evaluate the present level and potential sources of contamination. 200 surface water samples were analyzed between July and November 1990, using a standard multiple tube fermentation method (medium A-1) for determining fecal coliform bacteria (employed by public health agencies), but incorporating innovative methods for the analysis of results.

2) High bacterial counts occurred only during warm months. Highest bacterial levels were associated with an intense summer rain storm, with 72% of samples (29 out of 40) exceeding state standards for shellfish water quality. These high counts dropped sharply over 24 hours, at which time only 30% (11 of 30 stations) exceeded the standard. Other surveys during the summer showed from 24% to 40% of stations exceeding the standard, while 30% to 50% of assays showed coliform bacteria to be low or absent.

3) Spatially, highest bacterial counts were associated with coves along the southwest margin of the Pond. This distribution corresponds roughly with the distribution of freshwater input and/or lowest salinities. This association could result from bacteria contained in incoming freshwater, from the enhanced survival of coliform bacteria in lower salinity waters, or it could be attributed to reduced flushing associated with these areas. Viewed otherwise, the results indicate **lowest** bacterial counts occur in open water on either side of the main inlet (but not at the inlet itself).

4) No human sources of coliform bacteria were identified. Cruising boats do not use Sengekontacket Pond; sewage treatment plant outfalls do not exist; failing septic systems are not evident; State Title V regulations are enforced as far as is known. Given the ambiguities of the standard methods for assaying fecal coliform bacteria, high counts observed in this study (and by the regulatory agencies) can be attributable to warm-blooded wildlife or to naturally occurring bacteria known to be responsible for "false positive" coliform results.

5) The association of high counts with the July 27, 1990 rainstorm suggests surface runoff from the land could be a significant pathway for these bacteria.

Recommendations

1) A new standard index for bacterial water quality should be adopted by regulatory agencies. An index highly specific for human enteric components is needed. This is largely a political issue since agencies responsible for monitoring water quality have little incentive to change from current practices. Given a more human-specific standard, Sengekontacket Pond would probably not be closed to shellfishing in the future. A letter making these points should be drafted for distribution to Massachusetts representatives in the State and Federal legislatures.

2) Sites of entry for surface runoff around Sengekontacket Pond should be identified and structural diversions installed to prevent direct inflow of surface runoff. Areas marked by very low salinity during the July 27, 1990 rainstorm, documented in this report, represent initial sites to investigate. Incorporation of stormwater leaching beds into road networks and paved surface planning has become widespread among highway departments, zoning authorities, and natural resources management agencies. Friends of Sengekontacket should transmit this recommendation to the Boards of Selectmen of the Towns, and to the Dukes County Commissioners.

3) The common assertion that failing residential septic systems are responsible for high coliform counts in Sengekontacket Pond is challenged in this report and is regarded as a distraction from genuine progress on the issue of shellfish closures here. Individuals making this assertion should be invited to identify specific instances of septic system failure. The Boards of Selectmen or their designates on the Town Boards of Health are responsible for enforcing the State Title V regulations that define the design and operation of acceptable septic systems. Friends of Sengekontacket should press these agencies to clarify the status of septic systems near the Pond.

4) Any project that increases flushing of Sengekontacket Pond, such as certain dredging schemes, could improve bacterial water quality. Whether existing plans for dredging accomplish this objective is beyond the scope of this report. It should be pointed out, however, that increased flushing may have certain deleterious impacts on organisms and habitats that depend upon the existing brackish conditions in Sengekontacket Pond.

5) Although waterfowl are a known source of fecal coliform bacteria, we are not aware of any genuine threat to human health posed by these animals in terms of water quality degradation. Although management of waterfowl concentrations could be a means to reduce coliform bacteria entering Sengekontacket Pond, the compromise posed by aggressively implementing wildlife controls (in terms of lost natural history and nature education assets) suggests it should be regarded as a low priority option.

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INTRODUCTION

Fecal contamination of coastal waters has long been a public health concern, and remains a high priority coastal issue. Despite improved sewage treatment infrastructure, technology alternatives, and vast state, federal, and local expenditures for sewage treatment facilities, coastal waters closed to shellfishing in Massachusetts by the Division of Marine Fisheries (DMF) exceeded 50,000 acres in 1984 and have continued to increase in recent years. The closure of three coastal ponds on Martha's Vineyard to shellfishing in 1988 due to high coliform bacteria counts shocked local residents and visitors alike and gave the problem new local significance. One of those coastal ponds was Sengekontacket Pond (Fig. 1). The purpose of this study, part of a larger Sengekontacket Pond project, is to assess the level and sources of fecal contamination in surface waters of Sengekontacket Pond.

Sengekontacket Pond

Sengekontacket Pond and its drainage basin (and recharge area) lies almost equally in the Towns of Edgartown and Oak Bluffs (Fig. 2). It is a flooded glacial landscape of which parts have been strongly modified by marine erosion and deposition, and by marsh and wetland formation. The Pond is tidal and brackish. Principal human modifications to the geometry of the Pond include creation of an artificial inlet and structuring of the natural one through the barrier beach, and dredging of a channel between the inlets inside the Pond. The shoreline is mostly natural. Because of the remote location of Sengekontacket Pond relative to New England urban centers and regional sources of pollution, significant impacts on water quality are probably a reflection of local uses of the water and adjacent lands.

About half of the Pond contains shallow-water and intertidal flats used for commercial and recreational shellfishing, a use that dominates management priorities for the Pond, and sustains the concern over fecal contamination. The northeast shoreline is defined by a barrier beach, and is currently the site of a primary road between Oak Bluffs and Edgartown. The barrier beach serves as a primary public access for residents and visitors to the Island and the Nantucket Sound side is one of the best known and most heavily used beaches on Martha's Vineyard. About half of the Pond is sufficiently deep for boating, and each year sees increased pressure for mooring and anchoring sites from adjacent landowners and from transient boats. The Pond side of the barrier beach is heavily used for boat storage and launching access.

The remainder of the shores are settled with mostly seasonal residences and a golf course. For landowners in this area, the vista, rural ambience and convenient access to beaches are high priorities. It has been asserted that some of the septic systems serving these residences predate modern design or operation standards, and some concern exists that failing domestic septic systems could be a source of contamination to the Pond.

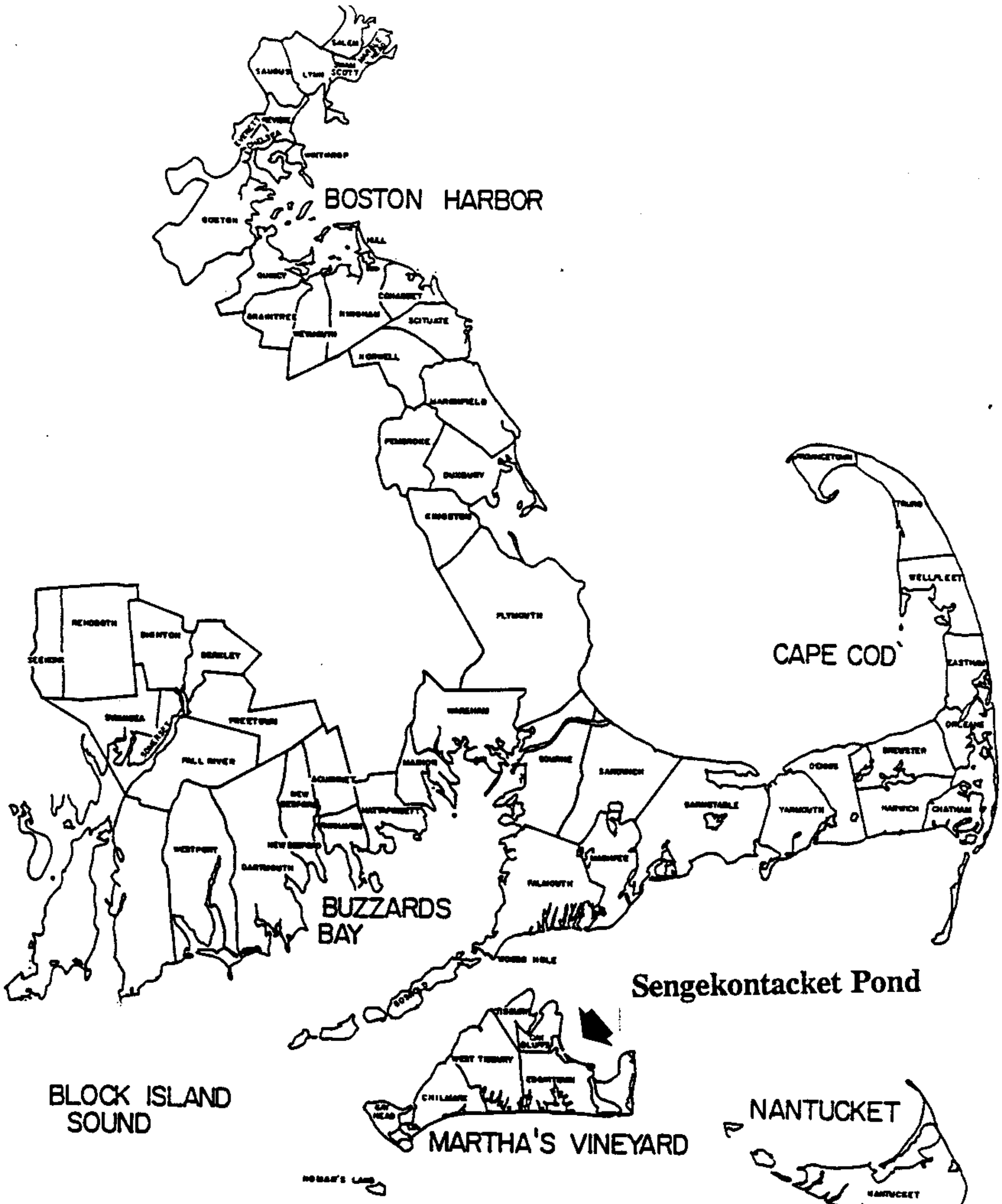

Figure 1. Regional setting of Sengekontacket Pond.

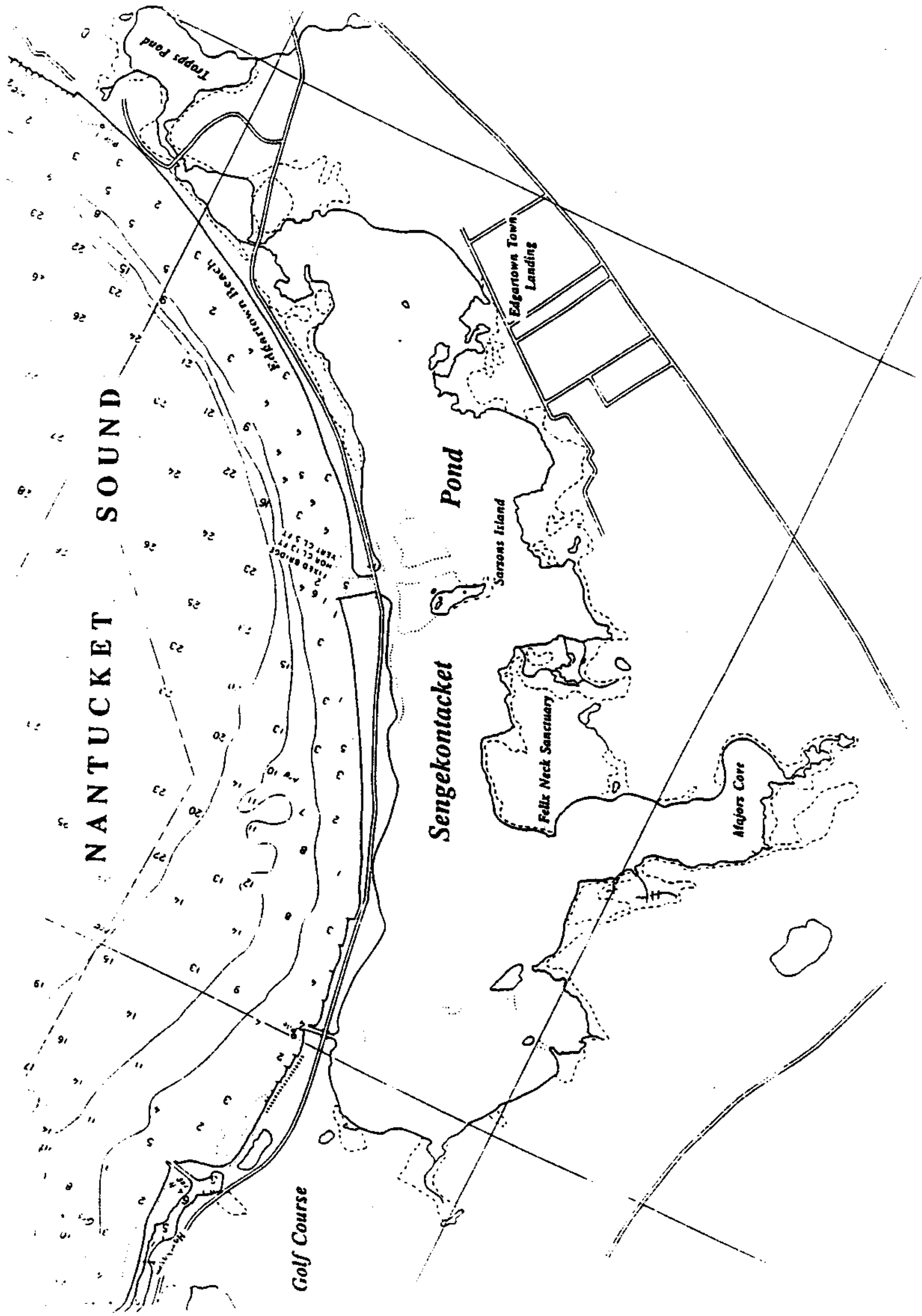

Figure 2. Sengekontacket Pond, Dukes County, Martha's Vineyard, Massachusetts (numbers shown in Nantucket Sound indicate water depth).

Coliform Bacteria and Water Quality Standards

Although State agencies (formerly the Department of Environmental Quality Engineering and more recently DMF) use several techniques to check coastal waters for pollution by sewage (such as shoreline surveys for effluent pipes or evidence of failing shoreline septic systems) the standards for classifying coastal water quality and, ultimately, for closing them to human contact or to shellfishing are based upon the concentration of coliform bacteria.

It is widely recognized that coliform bacteria themselves are seldom agents of disease in humans, although they are abundant in the human intestinal tract. Their use as a tracer is intended to demonstrate direct pathways for fecal material into coastal waters, and because these bacteria die quite quickly in seawater, their presence is regarded as evidence of recent contamination by human feces. Genuine human pathogens are difficult to directly detect in natural waters (see APHA et al, 1985 p. 828). Unfortunately, standard methodologies are not effectively able to distinguish between human sources of coliform bacteria and those derived from other warmblooded animals, such as birds and mammals, including livestock. Faust and Goff (1978) found highest levels of fecal coliform bacteria in arms of their Chesapeake Bay study area receiving runoff from pasture areas. Intermediate coliform contamination was associated with forested regions; and least coliform contamination came from "urbanized" areas.

Another source of potential confusion comes from so-called "false positive" coliform reactions resulting from other bacteria or combinations of bacteria in the environment that can respond like coliforms in assays (Hussong et al., 1980). Sediment and soil bacteria are a particular problem in this regard.

A second inadequacy of the coliform index for human fecal pollution is the rationale of using a bacterial indicator that assumes other bacteria, such as pathogenic ones, will generally behave similarly in the environment as coliforms (e.g., their susceptibility to antibacterial agents). Furthermore, for over 30 years bacterial diseases such as typhoid or cholera have been rare or absent in relation to shellfish consumption in the northeast U.S. (Rippey, 1988). Instead the common shellfish related pathogens have been viruses, such as hepatitis, and norwalk and rotavirus, the latter of which are responsible for a range of ailments known as gastroenteritis. Viruses are much smaller than bacteria, are considerably more mobile in the groundwater, and can have very different susceptibilities to predation or mortality in the environment (e.g., metals, sunlight, osmotic pressure). It may also be true that the concentration of coliform bacteria in shallow coastal waters is affected by such filter feeding organisms as shellfish, which are able to use them as food. In this instance waters overlying productive shellfish beds could be swept clear of the very indicator organism used to establish safeguards to public health surrounding shellfish consumption. As a consequence of the above, many areas of the coast closed for shellfish harvesting probably lack any significant source of human fecal contamination; alternatively, there may be areas with significant human waste inputs that are not recognized as hazardous.

Although alternative indices for detecting fecal pollution have been proposed over the years, coliform and fecal coliform bacterial densities are still regarded as the most practical and useful indicator (APHA 1985, p. 827) and have been used for over half a century. Numerous recent advances in immunological and gene probe methods specific to human enteric materials offer promising alternatives for the future.

In this study, we used the distribution of fecal coliform bacteria as a tool for identifying likely sources of the bacteria, given other information about the likelihood of human sources of contamination. An essential difference between our study and the routine surveys of public health agencies is that we have not assumed, a priori, that humans are the source of contamination. By using other information in interpreting our results we hope to avoid some of the pitfalls associated with the coliform indicator organism.

METHODS

Sampling and sample processing

Bacterial assays were performed using a fecal coliform MPN procedure employing A-1 broth (a lactose-tryptone broth) as described in APHA et al. (1985). Preparation of medium and sterilization of medium and sample bottles was conducted in laboratory facilities at Woods Hole; inoculation and incubation of tubes was done in a mobile field laboratory located adjacent to the Pond. All water samples were collected at about 12 inches (30 cm) depth. For our spatial surveys, samples were collected simultaneously from multiple boats, generally three, at predetermined and mapped locations, to expedite sampling and reduce ambiguities resulting from tidal advection. All samples for each set were collected within a one hour time interval. Samples were stored in insulated chests and processed within 2 to 4 hours of collection. Our facility was equipped to incubate 40 samples (10 assay tubes/sample) simultaneously.

In choosing sampling sites for coliform bacteria, we avoided stations at the immediate shoreline and collected all samples from boats (versus by wading into the Pond). This decision was based on experience at Edgartown, where virtually all high coliform counts occurred a the immediate shoreline, and where high shoreline counts occurred at sites where human sources could not explain them. For example the high counts in and near Cape Poge Pond (Fig. 3) cannot reasonably be attributed to human contamination (see Gaines and Solow, 1989). Rivilla and Gonsalez (1989) also observed high coliform counts in waters surrounded by undeveloped lands, wildlife sanctuaries, and saltmarshes.

Incubation temperatures (35° C and 44.5° C, +/- 0.5° C) were maintained in circulating water baths. Because of our special objective in this study (to assay large numbers of samples for presence of low bacterial densities) we did not process serial dilutions of our samples. Ten ml aliquots of undiluted sample from each station were inoculated into 10 tubes containing 10 ml double strength A-1 medium, as prescribed by the method. After incubation, fermentation tubes were examined for production of gas. Gas production in a fermentation tube within 24 hours or less is considered a positive reaction indicating coliforms of fecal origin.

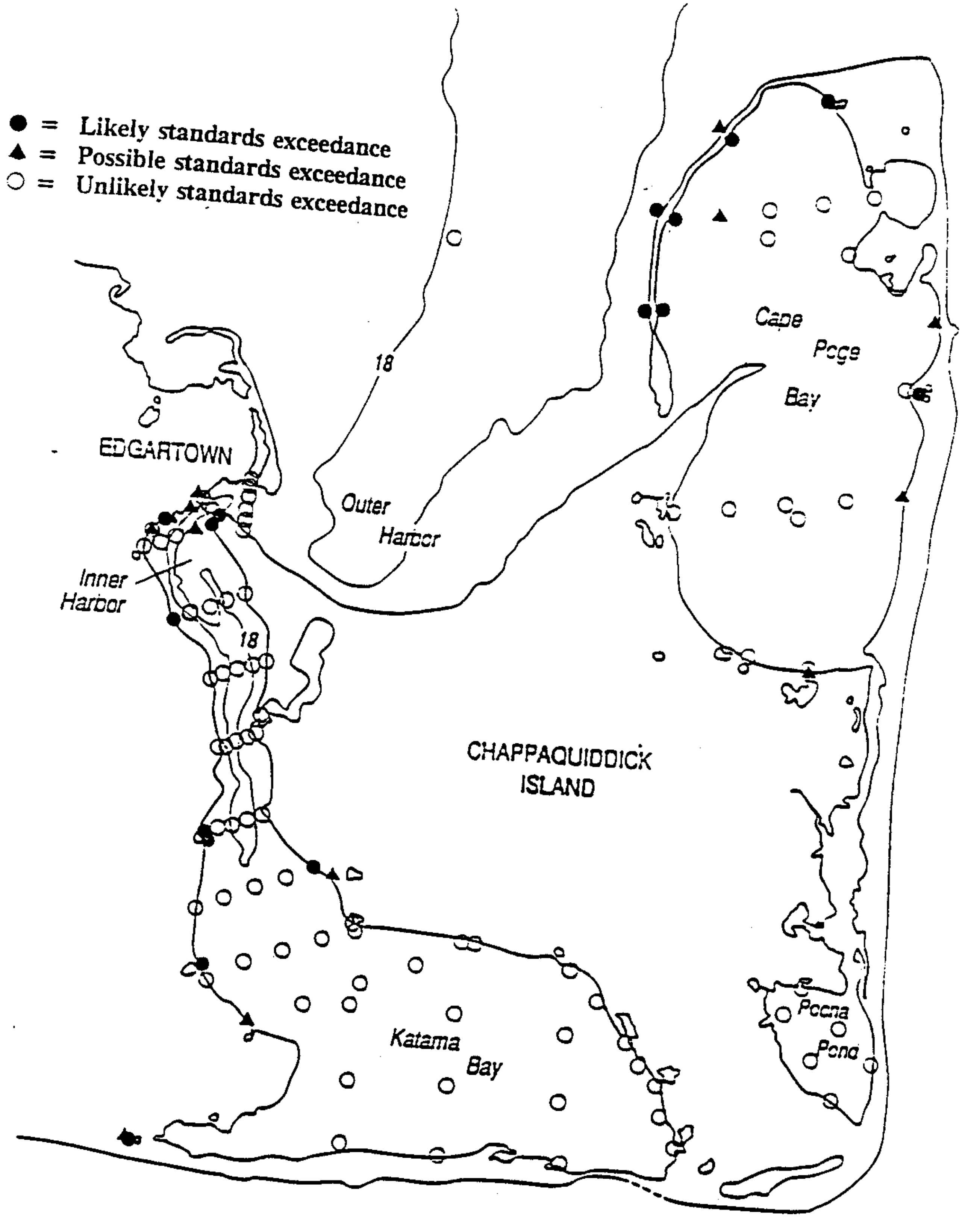

Figure 3. Distribution of fecal coliform bacteria in the Edgartown Harbor complex, summer and autumn 1988.

Interpretation of positive reactions

The standard interpretation of data obtained in the manner described above is to arrive at a point estimate using statistical tables of "most probable number" (APHA et al., 1985; Table 1, column A, this report). Using this approach the standard interpretation would be that 7 or 8 positive tubes indicate the exceedance level. There is large uncertainty associated with this approach, however. For example 7 positive reactions actually represents a range in point estimate of 4.3 to 27.1/100 ml at the 95% level of confidence. The likelihood that 14/100 ml would produce exactly 7 or 8 positive reactions is only 25% and 28%, respectively (Table 1, column B). Therefore, we used different approaches employing hypothesis testing, as outlined below (we also present results in terms of "number of positive responses" to allow the traditional interpretation.)

To interpret spatial survey results, we let each assay test the null hypothesis that the fecal coliform count did not exceed 14 per 100 ml of sample (the Massachusetts standard above which waters can be closed to shellfishing). As indicated in Table 1, column C, 10 positive reactions would indicate that the hypothesis should be rejected at the 95% confidence level, i.e., that the fecal coliform bacterial count most likely exceeded the standard, but that one sample in twenty would lead us falsely to this conclusion. Likely errors associated with fewer than 10 positive reactions were unsatisfactory (too high) for our purposes in this study. For some of the data we have also used a statistical approach called "local scoring" to estimate the spatial distribution of mean density at a set of point locations (Solow and Gaines, accepted).

Supplementary data

To aid in identifying sources of contamination the salinity of each sample was measured, using an Autosal 6000' salinometer which is accurate to better than +/- 0.01 o/oo. Fecal pollution from failing domestic septic systems, storm runoff or other sources associated with freshwater could be accompanied by a freshwater signal. Contamination from wildlife or in some cases false-positives would lack a freshwater signal. The salinity data also support other objectives of the Project, such as our flushing calculations.

RESULTS AND DISCUSSION

Freshwater Input and Tidal Flushing

The distribution of salinities, a reflection of tidal flushing and freshwater input, are given in Plates I through III. Data for only three of the five field coliform field assays are available. These results illustrate the comparatively strong impact of a rain storm event preceding the July 27, 1990 field assay (Table 2), although the average for the Pond as a whole was not strongly affected (Table 3). The storm event effect shows up as depressed salinities along the shoreline, especially in Major's Cove, Trapps Pond, and at the Town Landing in Edgartown. In comparison, salinities are more uniform and are higher on other survey dates.

Table 1. Interpretations of multiple tube assay statistics for single trial combinations of positive and negative results when 10 ml sample portions are used. A) Most probable number (MPN), and range at the 95% confidence limit; B) probability of exactly 14/100 ml; C) probability of error in concluding bacterial concentration value exceeds 14/100 ml.

# positive reactions	A: MPN	A: 95% Limits (approx.) lower	A: 95% Limits (approx.) Higher	B: p	C: p
0	>1.1	0	3.0	0.0	0.9999
1	1.1	0.03	5.9	0.0	0.9999
2	2.2	0.26	8.1	0.0004	0.9999
3	3.6	0.69	10.6	0.0031	0.9996
4	5.1	1.3	13.4	0.0162	0.9965
5	6.9	2.1	16.8	0.0584	0.9803
6	9.2	3.1	21.1	0.1460	0.9219
7	12.0	4.3	27.1	0.2503	0.7759
8	16.1	5.9	36.8	0.2816	0.5256
9	23.0	8.1	59.5	0.1877	0.2440
10	>23.0	13.5	infin.	0.0563	0.0563

Table 2. Rainfall data for periods surrounding coliform sampling in Sengekontacket Pond. Rainfall data (inches) recorded in Edgartown, Massachusetts (1990 data from Mr. Mark Lovewell, personal communication).

July		**August**		**November**	
	ppt		ppt		ppt
24	t	12	0.01		
25	0.13	13	t	26	t
26	0.39	14	0.0	27	0
27*	1.26	15*	0.0	28	t
28*	0.43	16*	0.0	29*	

* Indicates survey of fecal coliform bacteria in Pond.
t = trace

Table 3. Summary of salinity results for Sengekontacket Pond, July and November, 1990

Date	**Ocean Salinity** (o/oo)	**Pond Salinity** Average (o/oo)	Extreme (o/oo)
7/27/90	31.3	29.1[a]	22.2 (21.8)[d] - 31.3
7/28/90	31.2	29.3[b]	20.2 - 31.2
11/30/90	32.6	31.8[c]	27.5 - 32.6

a/ Average of 40 measurements
b/ Average of 38 measurements
c/ Average of 37 measurements
d/ Observed in Trapps Pond

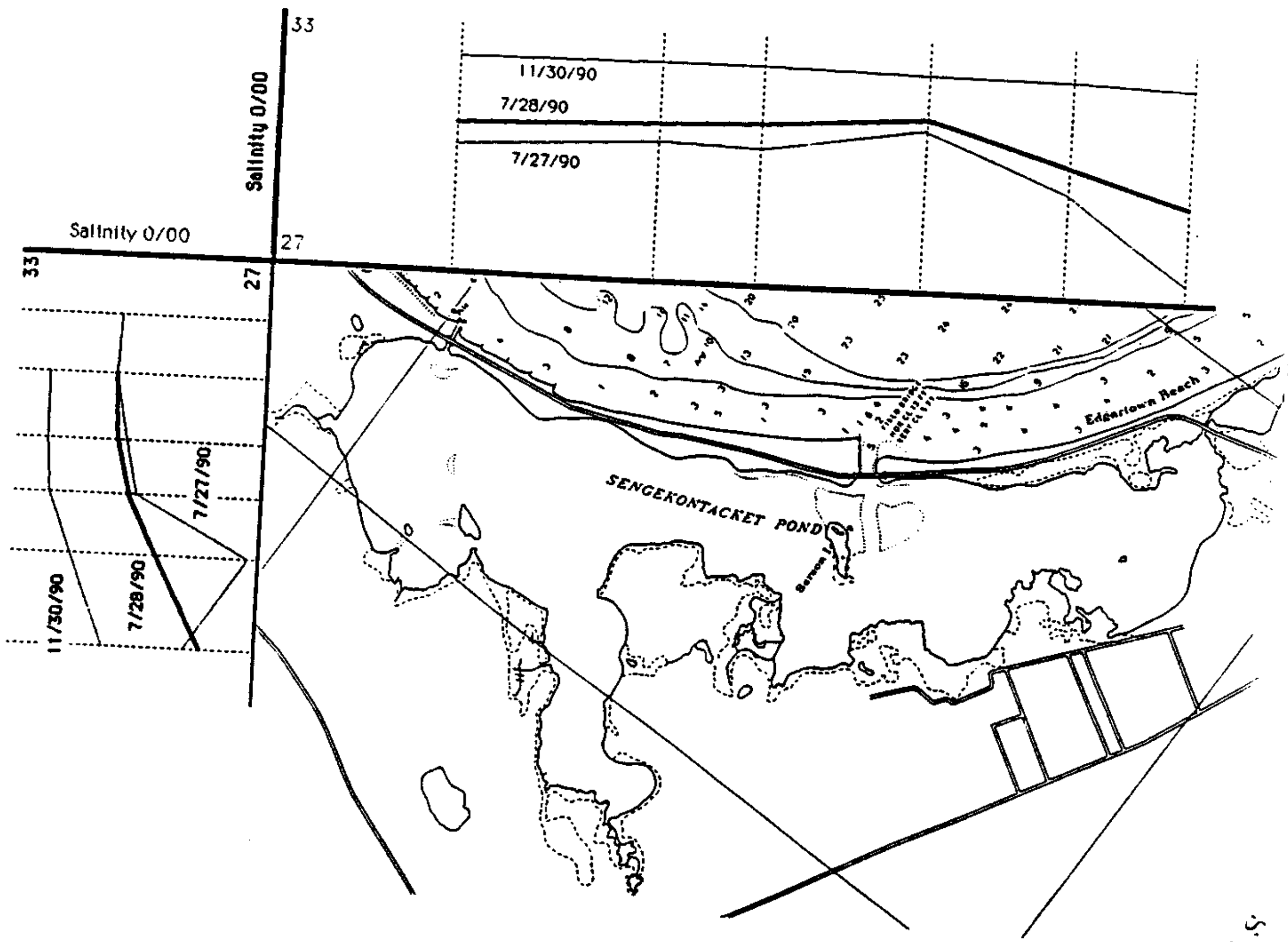

Figure 4. Salinity trends in Sengekontacket Pond, July and November 1990.

The salinity results show general distribution trends (Table 4), a result of the distribution of freshwater input and the exchange with Nantucket Sound. These trends, determined by averaging salinities along transects following the long axis of the Pond versus the short axis of the Pond, differ in magnitude but were the same on all dates (Fig. 4). Salinity was highest near the primary tidal inlet and decreased in either direction away from the inlet. Lowest salinities occurred at the Edgartown end of the Pond, while a less pronounced decrease in occurred toward the Oak Bluffs end, where a secondary inlet exists.

The decline in salinity also occurs with increasing distance from the barrier beach. In this instance lowest salinities occur along the southwest margin of the Pond, with lowest values evident in the Major's Cove. Data from the July 27 rain storm event strongly indicate storm water entering the long southwestern shoreline of the Pond. Consistent low salinities in Major's Cove suggest a significant freshwater source in that area.

Distribution of Coliform Bacteria

Results of spatial coliform surveys of the Pond (Plates IV to VII) are presented as follows:

No. positive reactions	Interpretation	figure symbol
0-6	**Unlikely standards exceedance,** low or undetectable fecal coliform contamination	○
7-9	**Possible standards exceedance, marginal** likelihood of shellfish water quality standard exceedance	▲
10	**Likely standards exceedance, high** likelihood (95%) of water quality standard exceedance	●

Salient results are the frequent likely standards exceedances during the summer and a strong seasonal decline in the colder month of November, when no likely exceedances occurred (PLATES IV-VIII). This result is consistent with past experience in temperate climates where strong point sources of fecal contamination are absent.

A second prominent result is the impact of the July 27 rain storm event, during which over 1/2 inch of precipitation fell in the 24 hours prior to field sampling. On this date 72% of samples assayed probably exceeded the standard while only 16% most likely did not. On this date nearly twice as many high values were observed as on the next most frequent instance, which was on August 15. The rain effect was especially pronounced in coves and ponds

Table 4. Salinity trends along and across Sengekontacket Pond, July and November 1990

Along Pond (Long axis)

	Northwest to Southeast					
7/27/90	30.1	30.4	30.3	30.9	29.5	27.5
7/28/90	30.6	30.8	30.9	31.1	30.2	29.3
11/30/90	32.2	32.3	32.3	32.2	32.2	32.0

Across Pond (Short axis)

	Northeast to Southwest					
7/27/90	30.6	30.7	30.3	30.1	27.5	28.7
7/28/90	-	30.7	30.6	30.2	-	28.4
11/30/90	-	32.2	32.2	32.1	-	30.8

Table 5. Summary of fecal coliform assay results for Sengekontacket Pond, July, August, and November 1990.

		State Shellfish Standard Exceedance:		
	n[a/]	Likely	Possible	Unlikely
July 27, 1990	40	29 (72%)	5 (12%)	6 (16%)
July 28, 1990	38	11 (30%)	8 (20%)	19 (50%)
August 15, 1990	38	15 (40%)	11 (30%)	12 (30%)
August 16, 1990	38	9 (24%)	10 (26%)	19 (50%)
November 30, 1990	37	0 (0%)	3 (8%)	34 (92%)

a/ Number of samples assayed in Pond (generally 2 samples of Nantucket Sound water was assayed for comparative purposes.

surrounding Sengekontacket Pond. All stations in Major's Cove showed likely exceedance values.

Equally prominent was the rapid decline in coliform levels within one day. By July 28, the number of exceedance values had dropped to less than half the preceding day's, and half of samples assayed were free of significant contamination. Highest levels remained in coves along the landward margin of the Pond; 83% of all exceedance values observed in Sengekontacket Pond were in Major's Cove.

The distribution of coliform levels for July 28 was also mapped incorporating a statistical procedure known as "local scoring". This method uses the overall distribution of observed levels to generate an estimated spatial distribution for the density of bacteria (see Solow and Gaines, accepted). The results (Table 5) indicate the 90% tolerance limits on the probable distribution of coliform bacteria on this date. This presentation emphasizes the predominance of high values in the coves along the southwest, landward, margin of the Pond, especially in the cove areas. The recurring nature of this pattern in our results suggests that it reflects a correct and consistent distribution of coliform bacteria in Sengekontacket Pond.

On most occasions we included two assays of water from Nantucket Sound, over 1/2 mile from shore. Generally these samples showed very low levels of coliform bacteria. On August 15, however, a possible exceedance value was observed (Plate VI). This can be explained in two ways: it could represent a genuinely high value associated with wildlife or with humans using the public beach; or it could be an error associated with normal probabilities associated with the quantal assay methodology.

Sources of Coliform Bacteria

Given the distribution of coliform bacteria as illustrated in Fig. 5, it is possible to seek potential sources of these bacteria. The possibilities along this portion of the Sengekontacket Pond shoreline include: stormwater runoff, failing residential septic systems, natural or artificial concentrations of wildlife, and other bacteria that falsely react as fecal coliform bacteria. Swimmers are also known to be a source of coliform contamination, but the distribution of counts does not support a significant source outside the inlet where most human exposure to the water occurs. Cruising boats that pump wastes over the side are not a possible source in Sengekontacket Pond (as they are in Edgartown Harbor) since boats of this kind cannot pass beneath the bridges crossing the two inlets to the Pond.

Stormwater runoff is believed to be a significant pathway for entrance of coliform bacteria to the Pond, based on the strong signal observed following rainfall on July 27. This, however, does not identify the actual source of the bacteria.

Although failing septic systems are commonly mentioned as a suspected source of human waste contamination, we are aware of no instances involving this source of contamination to Sengekontacket Pond, and the distribution of fecal coliform counts do not suggest any point source. Coliform contamination from failing septic systems can only occur if the system is overflowing across the surface of the ground; old systems or those that have not been maintained regularly do not contaminate adjacent waters with bacteria unless they are actually overflowing. This is a condition that is readily observed. No specific instance of overflowing septic systems has been observed by us or reported to us. In the event of such a septic system failure, the Town Boards of Selectmen or their designates in the Boards of Health are empowered to take corrective action to enforce state laws contained in Title V, applying to proper design and operation of on site septic systems.

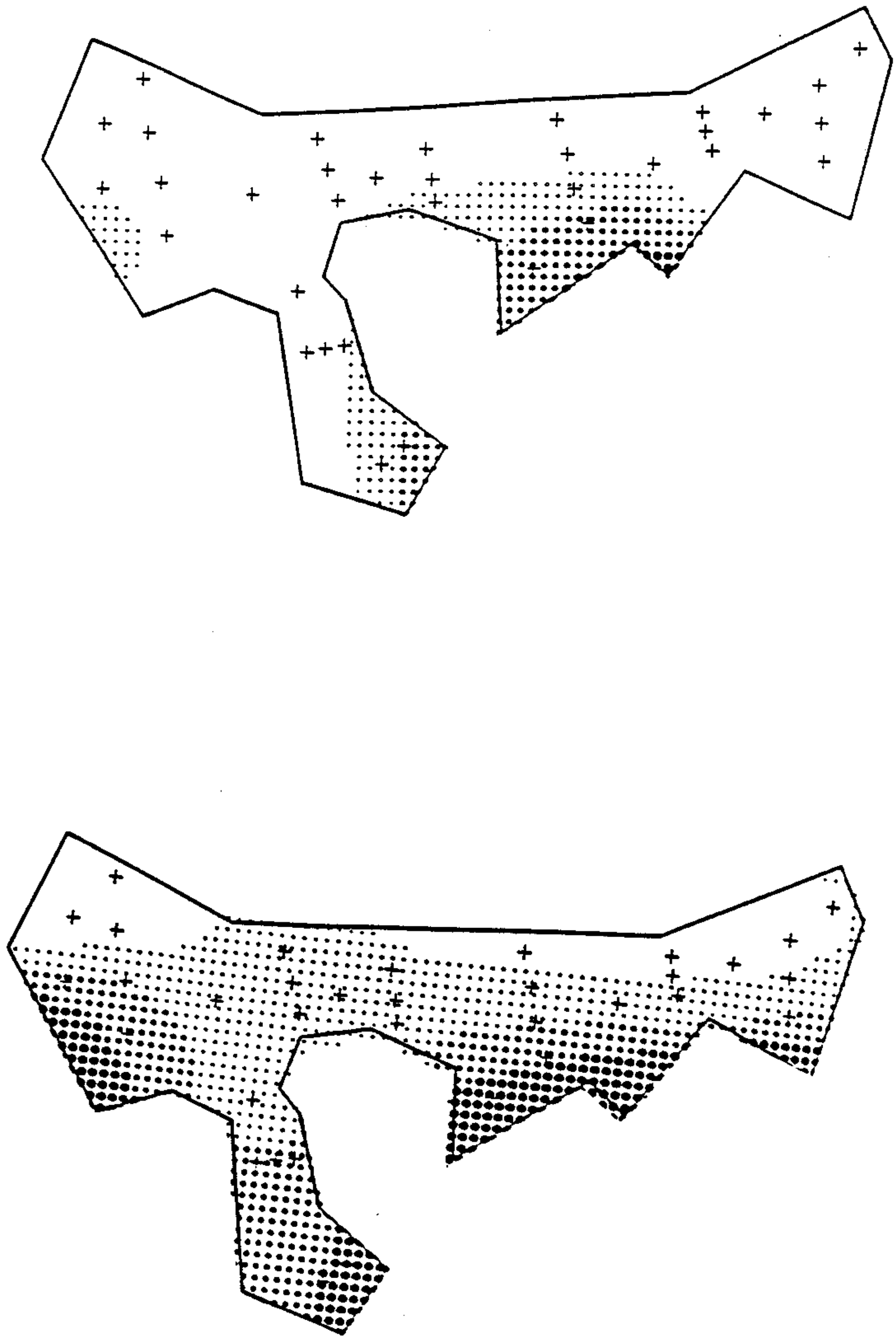

Figure 5. Lower and upper boundaries of approximate 0.90 confidence interval for the spatial distribution of fecal coliform bacteria. Density of stippling corresponds approximately to the three classes of coliform concentration described in the text.

Concentrations of wildlife occur in at least three places in the area of concern in Sengekontacket Pond, although wildlife is ubiquitous. Natural populations of seabirds, including many cormorants, concentrate on Sarson Island near the main inlet. This is an area where high coliform counts were commonly observed. In the same vicinity, at the Felix Neck Wildlife Sanctuary, there are also concentrations of birds, including waterfowl. Although there is no direct evidence that these animals contribute coliforms to Sengekontacket, it is possible that they are partly responsible for the observed distribution of bacteria. A third site of bird concentrations appears to be in Majors Cove, again where high bacterial counts were found.

Although measures are possible to reduce wildlife concentrations, it would seem to be an unfortunate approach to meeting a standard intended for other purposes. We are aware of no genuine threat to human health resulting from the presence of birds in shellfishing areas. Given the high value attributed to birds and other wildlife it would seem misdirected to compromise the wildlife asset in order to comply with a defective agency standard.

False-positive bacteria are believed to be an additional source of high coliform counts in Sengekontacket Pond. These result from non-fecal bacteria which alone or acting in concert can produce a positive reaction in the assay medium. Very commonly bacteria capable of producing false positive results occur in organic soils and sediments. In Sengekontacket Pond, the organic sediments are particularly common in the areas where we find high coliform counts, as opposed to the loose, inorganic sands associated with the barrier beach side of the Pond. There is little that can be done to eliminate false-positive bacteria, other than to adopt a methodology that does not respond to their presence.

ACKNOWLEDGEMENT

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Glossary

Bacterial assay - An analysis to determine the presence or quantity of bacteria in a sample.

Brackish - Containing salt, but not much. Used in the context of coastal oceanography, brackish water is diluted seawater.

Coliform bacteria - A large and somewhat ecologically diverse group of bacteria sharing similarities in size, appearance, and certain growth capabilities. Commonly associated with the human gut, these bacteria also inhabit the gut of other animals, soils, marine sediments, and plant materials. Their wide and longstanding application to sanitary analysis standards, therefore, represents an ambiguous index of human contamination.

Drainage basin - The area of land in which precipitation will flow to a common depression, stream, or water body. A drainage basin is usually defined by connecting the highest points of land around a river or pond.

Fecal coliform bacteria - A subset of the coliform group, including those species requiring or tolerant of high temperature during growth. While this group excludes many species of coliforms, it still includes many species besides those found in the human gut. As an indicator of human contamination of natural waters, therefore, it remains ambiguous.

Flushing - Replacement of water in a waterbody, from an external source. Flushing can result from tidal exchange, wind forced circulation, and density driven flow between waters of different salinity or temperature.

Human enteric components - Ingredients of the human digestive tract, used in this report to refer to substances or items that might be used to trace sources of human fecal contamination into a natural water body.

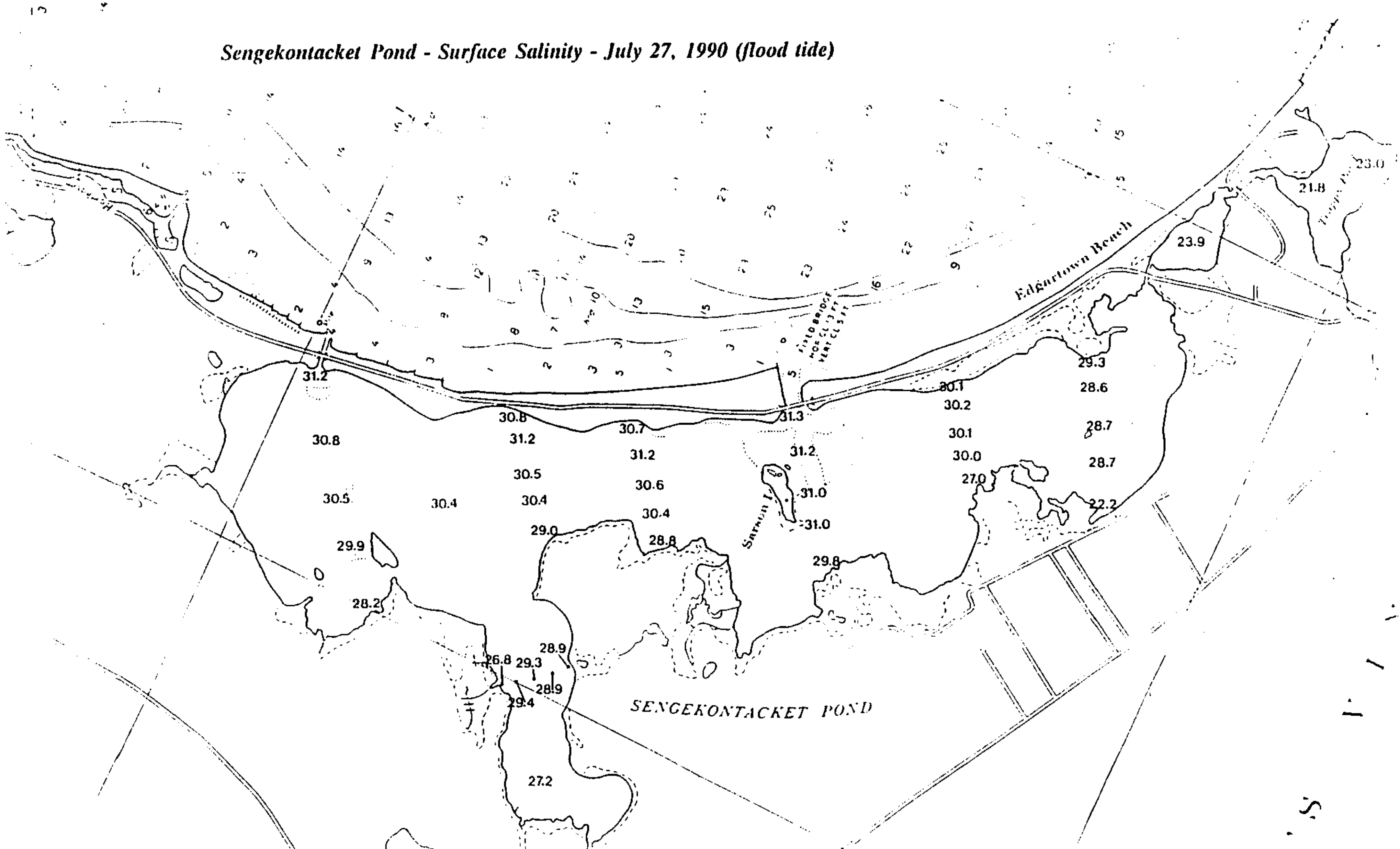
Salinity - The salt content of seawater or diluted seawater, normally expressed as "parts per thousand" (ppt or °/oo). Undiluted water from Nantucket Sound has a salinity of about 33 °/oo (which equals 3.3 percent). Freshwater has a salinity of about 0 °/oo.

Spatial distribution - The distribution of a variable, such as bacteria or salinity, horizontally or vertically, as opposed to the distribution over changes in time (temporal distribution).

Stormwater leaching bed - A natural or engineered, depression in the land that serves to trap rainwater, particularly under conditions of excessive surface runoff such as during storms, in order to prevent flooding elsewhere, erosion, and/or direct entry of contaminated runoff into natural water bodies.

Surface runoff - Water that flows across the surface of land following rainfall, as opposed to water that enters the ground, becoming groundwater.

Sengekontacket Pond - Surface Salinity - July 27, 1990 (flood tide)



Sengekontacket Pond - Surface Salinity - July 28, 1990 (flood tide)

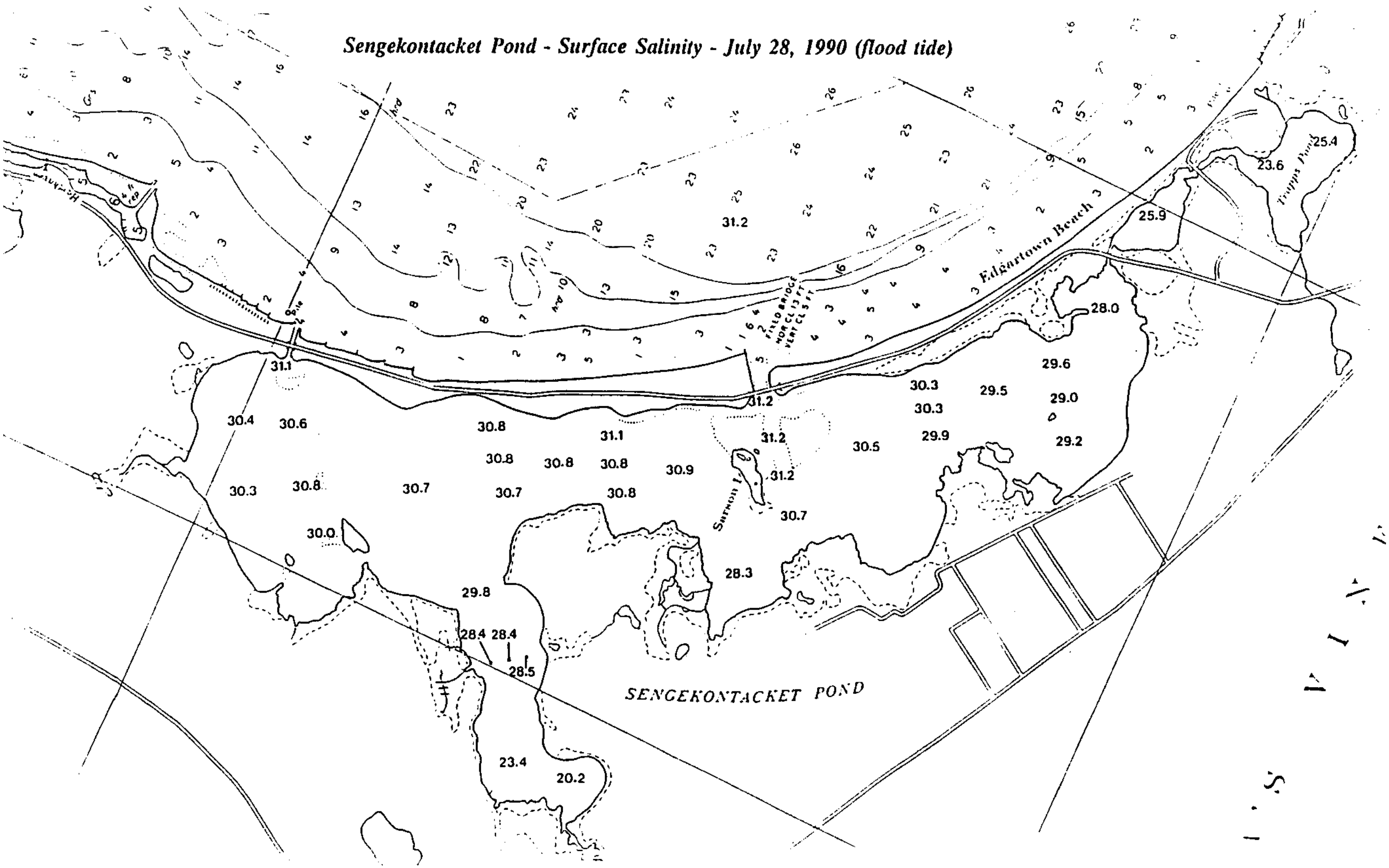


Plate II

Sengekontacket Pond - Surface Salinity - November 30, 1990 (ebb tide)

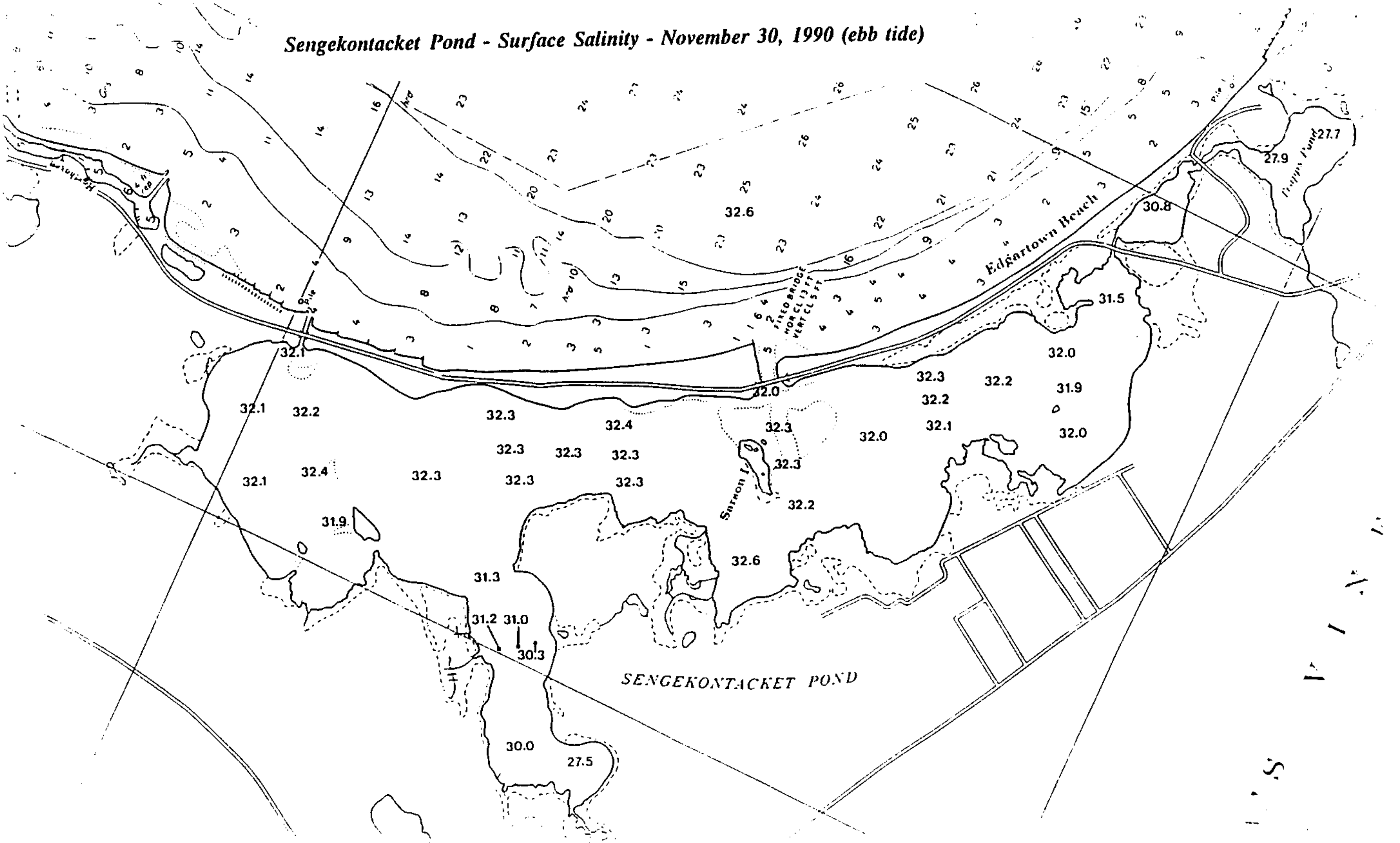


Plate III

Sengekontacket Pond - Fecal Coliform Counts - July 27, 1990 (flood tide)

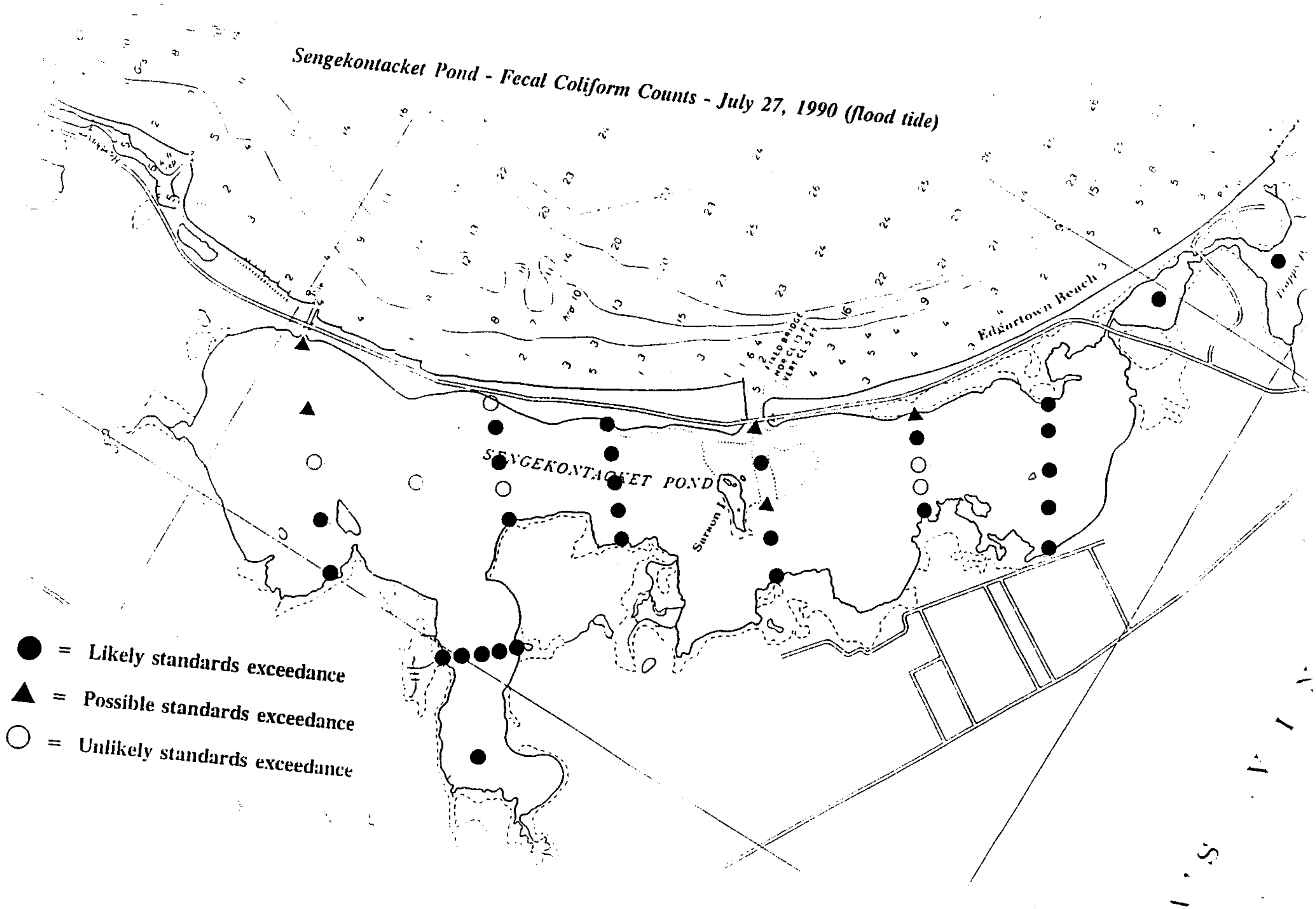


Plate IV

Sengekontacket Pond - Fecal Coliform Counts - July 28, 1990 (flood tide)

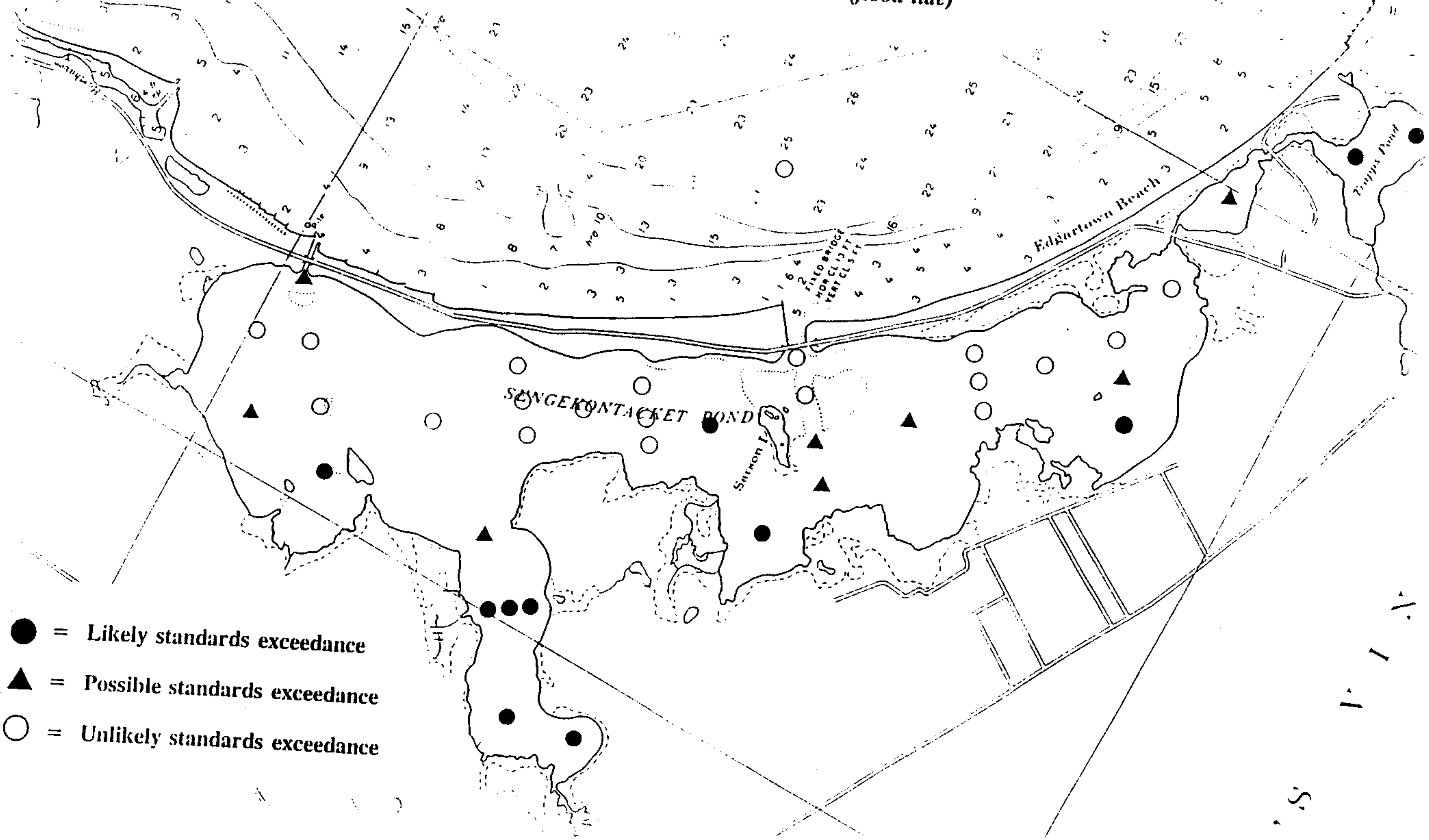


Plate V

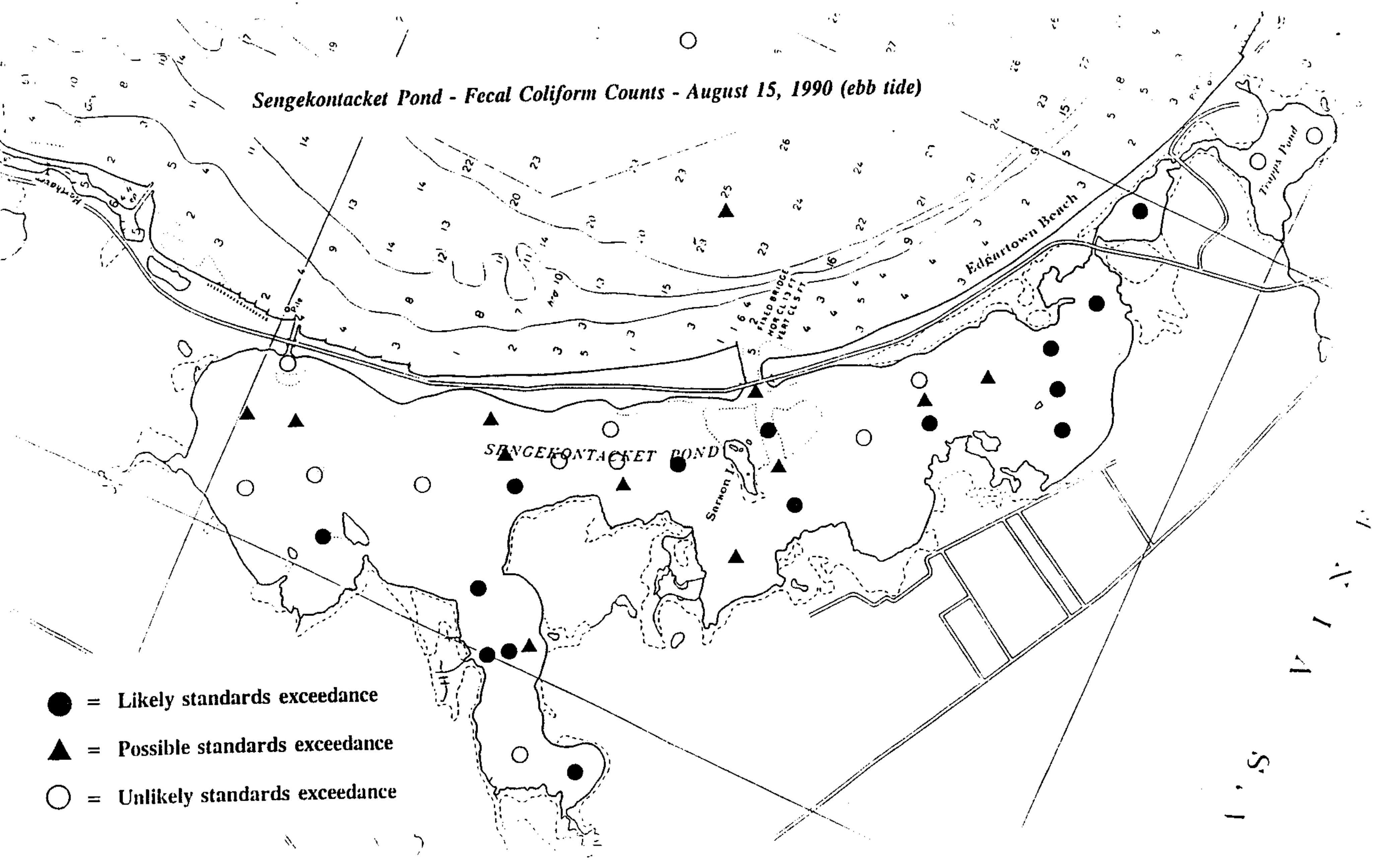

Sengekontacket Pond - Fecal Coliform Counts - August 15, 1990 (ebb tide)
SENGEKONTACKET POND
Sarson I.
Edgartown Beach
Trapps Pond
FIXED BRIDGE
HOR CL 13 FT
VERT CL 5 FT
● = Likely standards exceedance
▲ = Possible standards exceedance
○ = Unlikely standards exceedance

Plate VI

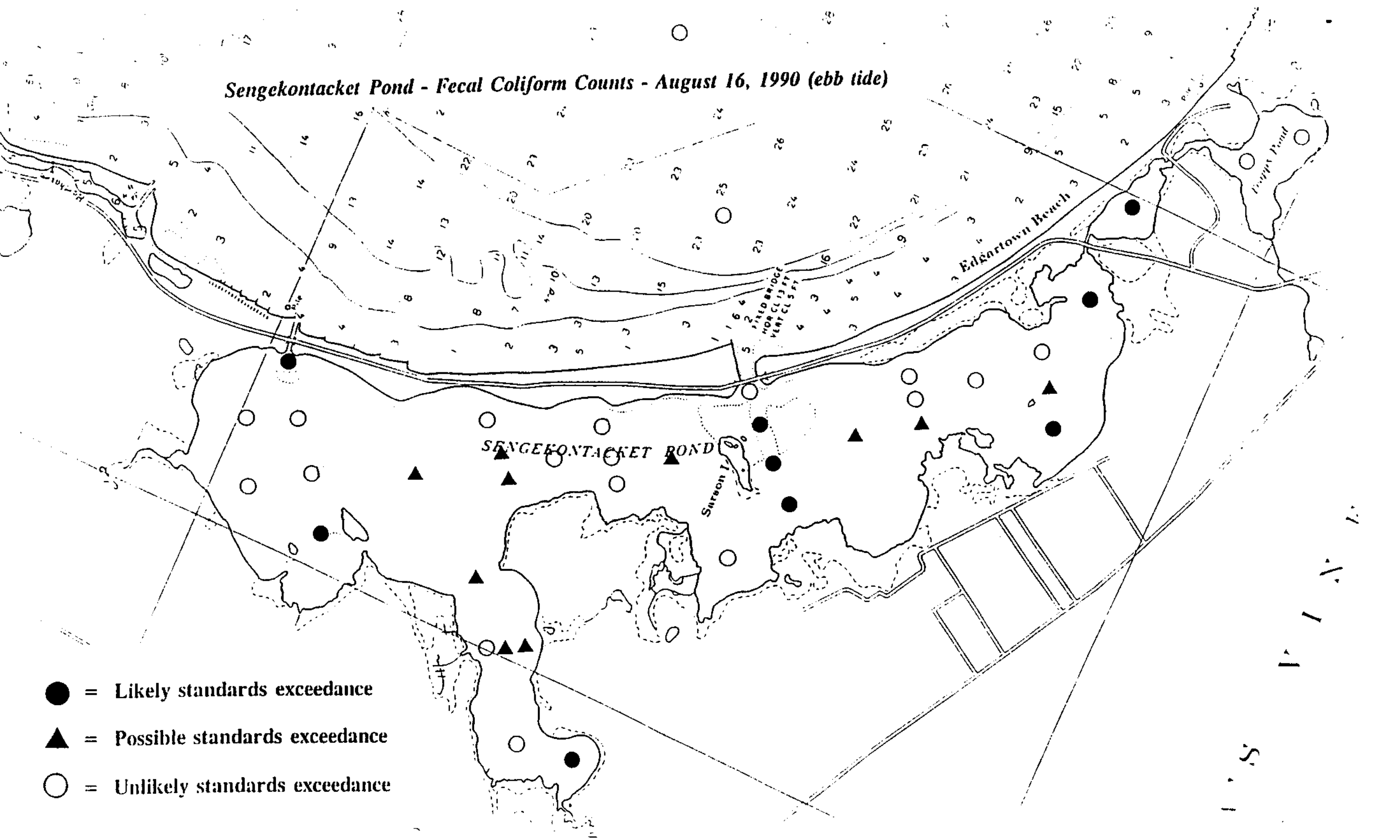

Sengekontacket Pond - Fecal Coliform Counts - August 16, 1990 (ebb tide)
SENGEKONTACKET POND
Sarson I.
Edgartown Beach
Trapps Pond
FIXED BRIDGE
HOR CL 13 FT
VERT CL 5 FT
● = Likely standards exceedance
▲ = Possible standards exceedance
○ = Unlikely standards exceedance

Plate VII

Sengekontacket Pond - Fecal Coliform Counts - November 30, 1990 (ebb tide)

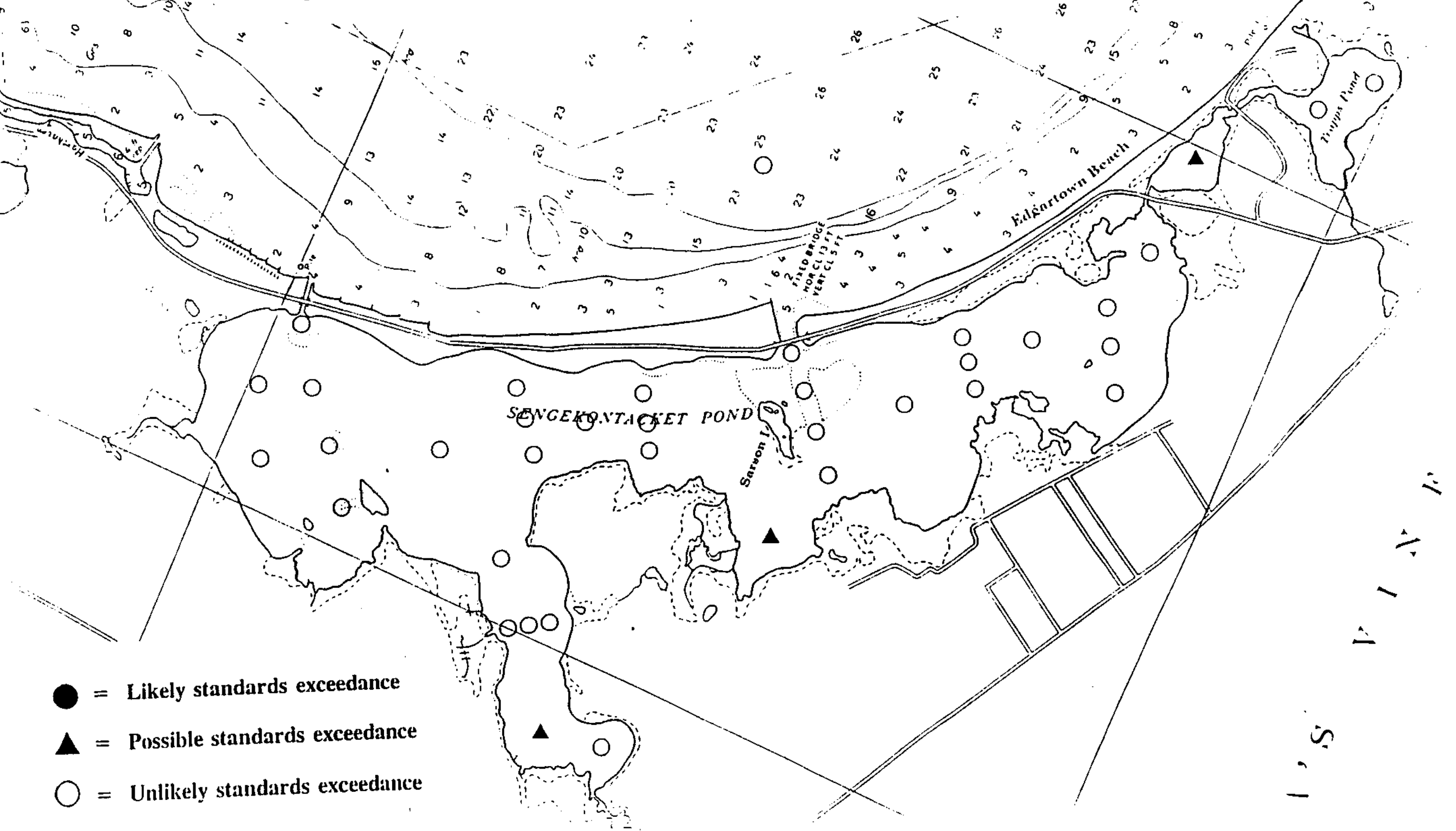


Plate VIII