GREAT BAY WATCH
A CITIZENS WATER MONITORING PROGRAM

Original
MANUAL
JULY 1990

Revised/Updated March 1998

by
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"Helping You Put Knowledge and Research To Work"

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UNIVERSITY OF NEW HAMPSHIRE COOPERATIVE EXTENSION

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The volunteer monitors in the Great Bay Watch must be recognized and gratefully acknowledged, for it is through their efforts that we all better understand and appreciate the Great Bay Estuary.

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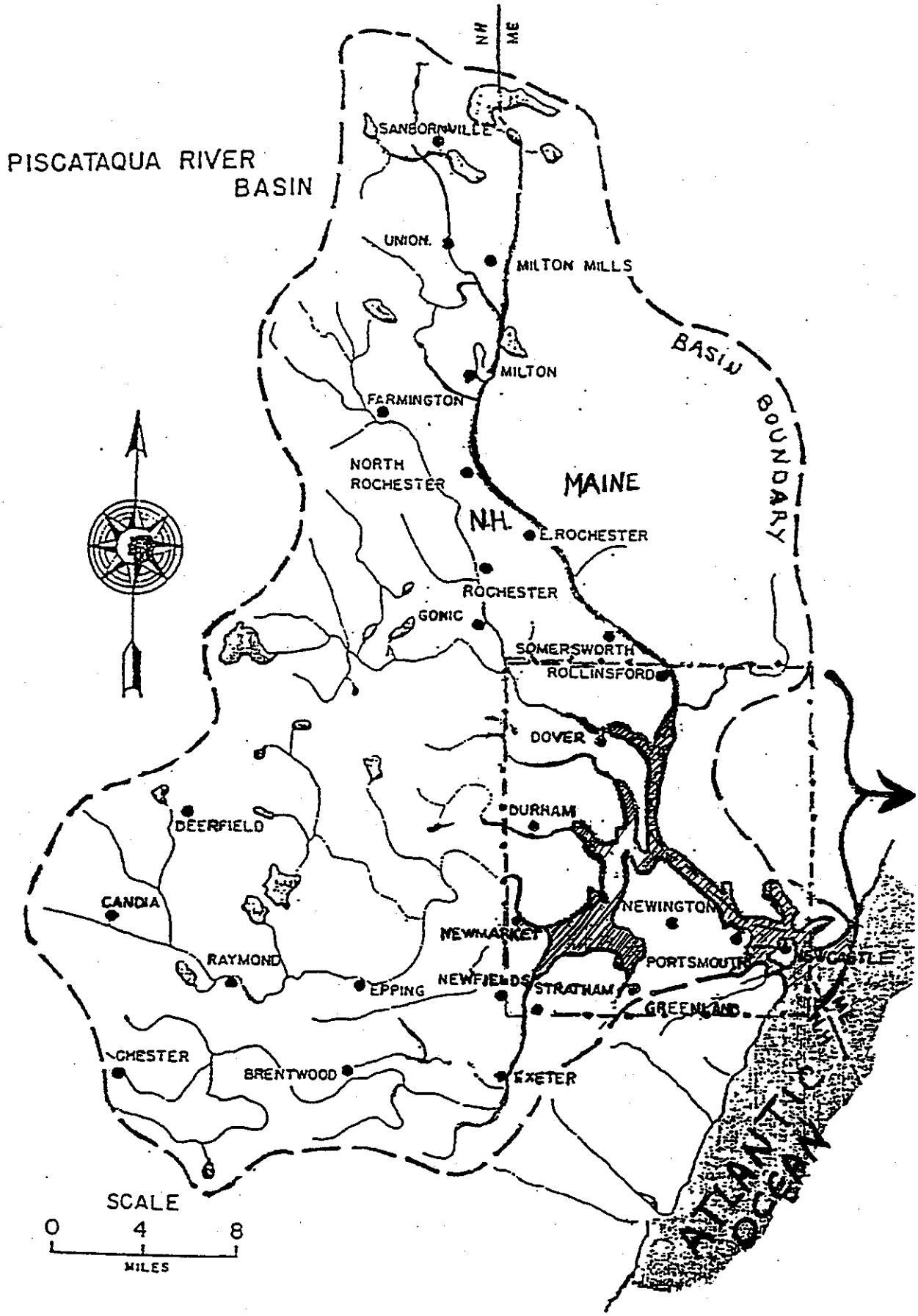
PISCATAQUA RIVER
BASIN
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ROCHESTER
GONIC
SOMERSWORTH
ROLLINSFORD
DOVER
DURHAM
DEERFIELD
CANDIA
RAYMOND
EPPING
NEWMARKET
NEWFIELDS
NEWINGTON
PORTSMOUTH
NEWCASTLE
STRATHAM
GREENLAND
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BRENTWOOD
EXETER
BASIN BOUNDARY
SCALE
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MILES

GREAT BAY EXTUARINE SYSTEM AND SITE LOCATIONS

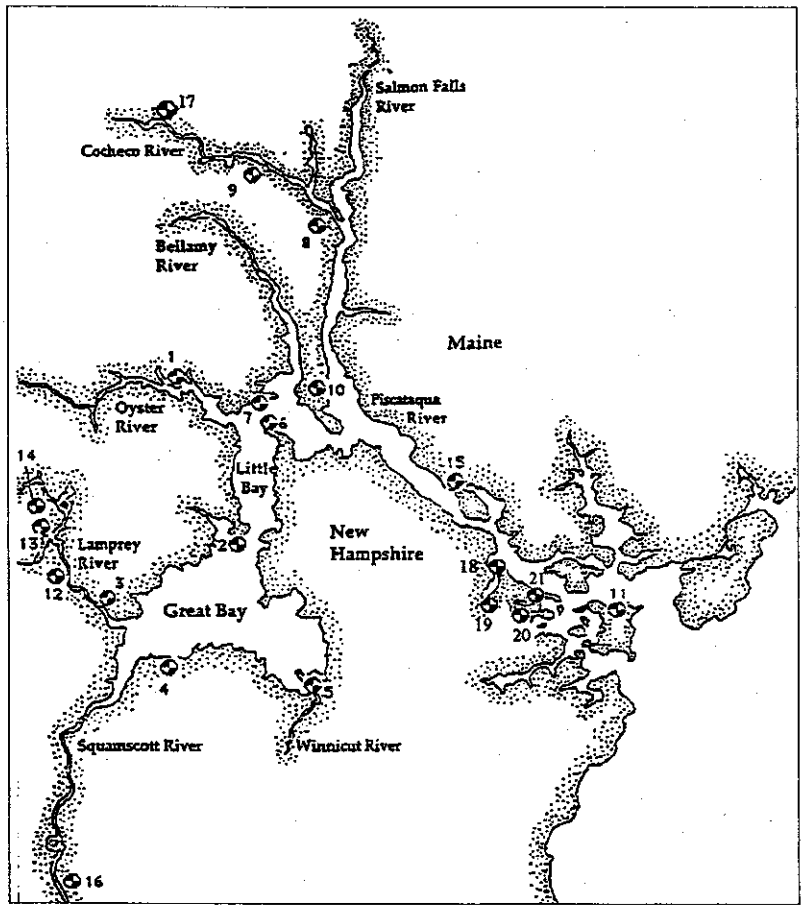


Table of Great Bay Watch Sites, locations, towns and year started

Site Name	Site #	Location	Town	Year Started	Comments
Peninsula (Smith's)	1	Oyster River	Durham	1990	
JEL	2	Great Bay	Durham	1990	
Lamprey River	3	Lamprey River	Newmarket	1990	New dock, Townes' 1997
Depot Road	4	Great Bay	Greenland/ Stratham	1990	High tide only as of 1993
Portsmouth Country Club	5	Winnacut River	Greenland/ Stratham	1990	
Fox Point	6	Little Bay	Newington	1990	
Cedar Point	7	Little Bay	Durham	1990	
Rakoskes'	8	Piscataqua River	Dover	1990	Inactive as of 1992
Neals'/Williams'	9	CochechoRiver	Dover	1990	
Clark's (Dube's)	10	Piscataqua River	Dover	1991	
Coastal Marine Lab	11	Piscataqua River	New Castle	1991	
STP	12	Lamprey River	Newmarket	1992	
Marina Falls Landing	13	Lamprey River	Newmarket	1992	
Fowler's (Essley's)	14	Lamprey River	Newmarket	1992	New owner, Essleys' 1997
Patten Yacht Yard Inc.	15	Piscataqua River	Eliot, Me	1993	
Exeter Town Docks	16	Squamscott River	Exeter	1994	
Dover Foot-Bridge	17	CochechoRiver	Dover	1996	
Maplewood Ave (NMP)	18	North Mill Pond	Portsmouth	1997	
Bartlett Ave. (NMP)	19	North Mill Pond	Portsmouth	1997	
Junkins Ave. (SMP)	20	South Mill Pond	Portsmouth	1997	
Pleasant Ave. (SMP)	21	South Mill Pond	Portsmouth	1997	

The Great Bay Watch Mission Statement

The Great Bay Watch is comprised of citizen volunteers, working within the UNH Cooperative Extension/Sea Grant Program, who are dedicated to monitoring, promoting, and protecting the long term ecological health and natural resources of New Hampshire's coastal waters and estuarine systems through educational programs, stewardship, and community based science activities.

INTRODUCTION

For years, some of us have known the Great Bay Estuary as a place of great beauty and abundant resources. Researchers from the University of New Hampshire and elsewhere utilize it as a "living laboratory." It is an exciting outdoor classroom for University of New Hampshire oceanography and biology classes, and most recently it is an essential part of the Math and Marine Science (M & M) program for high school students. It is being discovered by many who want a "taste of the coast" without braving the crowds at the beach. Sportsmen wait eagerly for the annual fall bird migrations. Now, people are building homes at a rapid rate along the estuary's rivers and bays, increasing pressures on the already strained sewage treatment facilities in the communities around the estuary. This year 65-70% of Great Bay's clam and oyster beds are off-limits due to pollution, this is a slight inprovement in the last three years. In fact, Great Bay Estuary still has the third highest percentage of area closed to shellfishing in New England, a rather dubious distinction.

Still, the estuary is one of the region's most pristine, and the Great Bay proper recently achieved status as a National Estuarine Research Reserve. The Reserve includes 4,471 acres of tidal waters and mudflats and approximately 48 miles of shoreline. The water area includes all of Great Bay, the small channel from the Winnicut River and large ones from the Squamscott and Lamprey Rivers which meet in the center of the Bay to form a channel known as Furber Straits, which connects to Little Bay at Adams Point. Also within the boundary are 800 acres of upland which includes a wide range of environments including salt marshes, tidal creeks, islands, woodlands and open fields.[1]

The U.S. Department of Agriculture has designated portions of the Great Bay Estuary watershed (563,200 acres) as a priority watershed area in the Nonpoint Source Management Plan (in accordance with section 319 of the Clean Water Act). The selected project area encompasses a little less than half the watershed in the Lamprey, Exeter and Oyster River/Great Bay hydrologic units.[2]

The Great Bay Watch, a pilot citizen water monitoring program sponsored by Sea Grant Extension through a grant from the National Oceanic Atmospheric Administration (NOAA) has been formed. Its dual mission is to extend and augment monitoring efforts already underway in the estuary by the University of New Hampshire's Jackson Estuarine Laboratory staff, and to involve interested people in an action-oriented educational program. The data that the group collects will be made available to researchers, town and regional planners, state and local government agencies, and other interested parties.

WHY MONITOR?

Ecological monitoring can be defined as repetitive measurements or observations recorded over time for the purpose of determining a condition or tracking change. A number of scientific studies point to the necessity of doing long-term ecological monitoring before drawing conclusions as to cause and effect of observed changes. Changes are often gradual and subtle. The question is whether they represent trends. For example, is the apparent sea level rise due to warming of earth's atmosphere or just a natural fluctuation? In general, these studies have shown that:

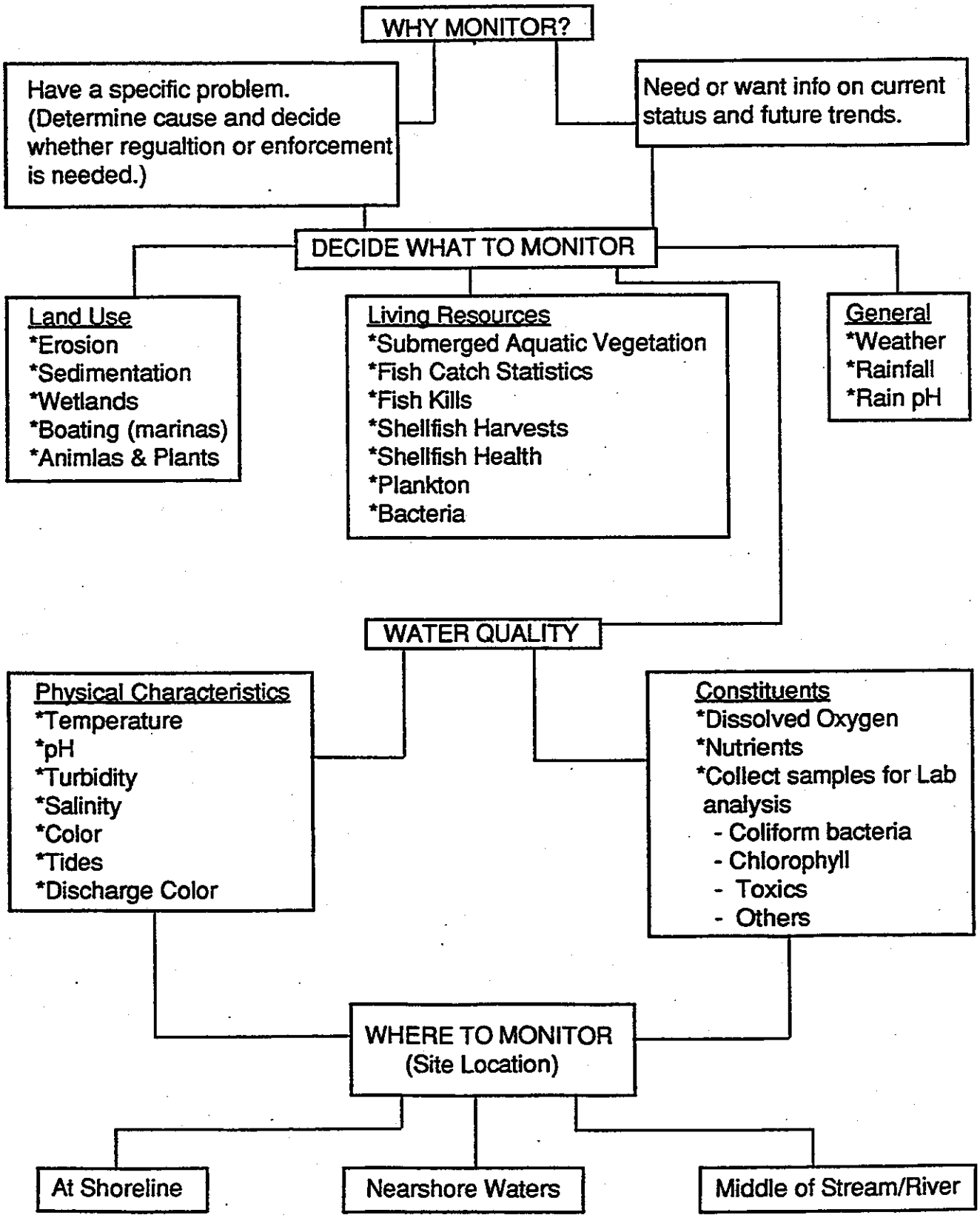
1. complex ecological systems require longterm observation and study for understanding;

2. a sequence of only 2 to 3 years of data can be very misleading about the direction of environmental quality;

3. environments have a "memory" or response time which varies greatly. It takes a certain amount of time to detect a change -- perhaps a decade for lakes, a century for soil.

While those involved in citizen monitoring efforts are usually not trained scientists, they can with relatively little training and simple equipment, collect information that will contribute to an ecological study of the site they are investigating. When the data collected at the Great Bay Watch sites are put together, they will become part of the ecological picture of the Great Bay Estuary.

SO YOU THINK YOU WANT TO MONITOR?



SAFTEY FIRST

General Precautions

Read all instructions to familiarize yourself with the test procedures before you begin. Note any precautions in the instructions.

For your safety and good data recording, work with at least one partner.

Keep all equipment and reagent chemicals out of the reach of small children and animals. SOME OF THE REAGENTS ARE CAUSTIC.

In the event of an accident or suspected poisoning, immediately call 1-800-562-8236, the Poison Control Center – New Hampshire. If a reagent should get into your eye or on your skin, irrigate the area immediately with fresh water. We have the details on the reagents we are using. See Appendix V, pages 88-91 for Material Safety Data Sheets. Call Ann (749-3880) or Sharon (659-5411) at home or at the office (749-1565)

PROTECT YOURSELF AND YOUR EQUIPTMENT: Use proper analytical technique.

1. Avoid contact between reagent chemicals and skin, eyes, nose, or mouth.

2. Wear safety goggles or glasses when handling the reagents.

3. Use stoppers, not your fingers to cover the bottles during shaking or mixing.

4. Rinse and wipe up any reagent chemical spills, liquid or powder as they occur.

5. Thoroughly rinse jars and bottles before and after each use. Dry your hands and the outside of the bottles.

6. Avoid prolonged exposure of equipment and reagents to direct sunlight. Keep regents in a dark location, protected from extremes in temperature.

WASH EVERYTHING THAT WAS IN CONTACT WITH CHEMICALS OR SALT WATER AFTER EVERY TEST. DRY EVERYTHING THOUTROUGHLY, INCLUDING THE INSIDE OF THE BUCKET.

EQUIPMENT LIST SITE #_____ SITE NAME_____

_____ Tool Box #_____

TEMPERATURE

_____ Air thermometer with string

_____ Armored (water) thermometer # _____

SALINITY

_____ Hydrometer with case and stopper #_____ (inside paper on hydrometer stem)

_____ Hydrometer jar (plastic 500ml cylinder)

pH

_____ pH meter #_____

_____ Small brown bottles with caps: ____ (count)

_____ Small white bottle for extra buffer

DISSOLVED OXYGEN

_____ Graduated buret (2)

_____ Glass rods (2)

_____ BOD bottle (glass) and stopper (2)

_____ 100ml graduated cylinder

_____ Plastic beaker

_____ 1 box manganese sulfate pillows Count_____

_____ 1 box iodide-azide pillows Count_____

_____ 1 box sulfamic acid pillows Count_____

_____ 1 bottle starch solution

_____ 1 bottle of sodium thiosulfate

_____ 1 scissors

_____ 2 glass marbles

COLIFORM

_____ Collecting tongs

_____ Whirl pak bags (sterilized) _____ (count)

_____ Permanent marker

_____ Ice pack

_____ Cooler container for samples

SAFETY ITEMS

_____ Container with sticker/emergency numbers

_____ Bandaids

_____ Antiseptic

_____ Protective glasses

TRANSPARENCY

_____ Secchi disk with measure line attached

MISCELLANEOUS

_____ Clipboard

_____ #2 pencil

_____ Eyewash (tap water for flushing out eyes)

_____ 1 waste container (1 gallon plastic detergent container)

_____ Plastic container for purified water (pH test and clean-up)

_____ Clean cloth for drying equipment

_____ GBW badge

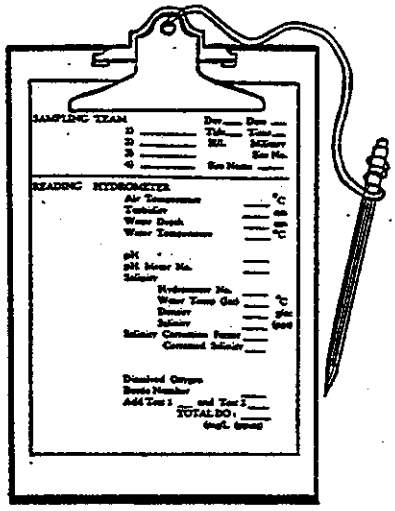
_____ GBW Manual (notebook and data sheets)

_____ Water sample collection container with rope, tubing, clamp and spigot attached

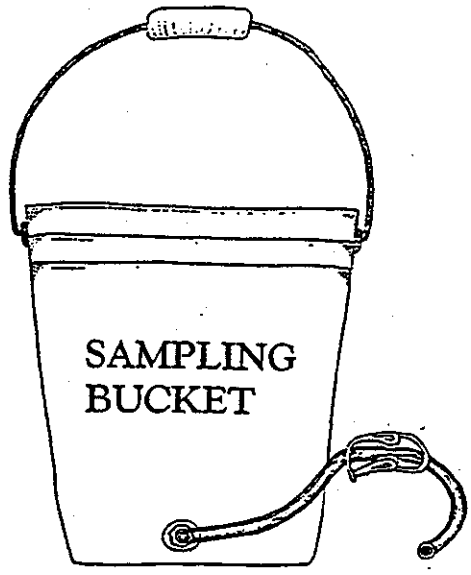
_____ Journal

_____ Data Sheets **DATE** _____ **SIGNATURE** _____

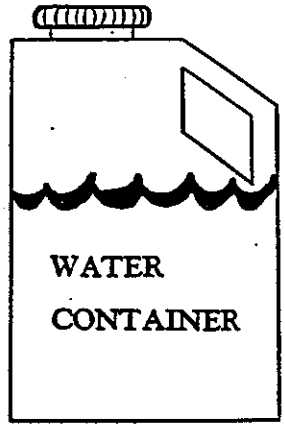
MISCELLANEOUS (ADMINISTRATIVE EQUIPMENT)



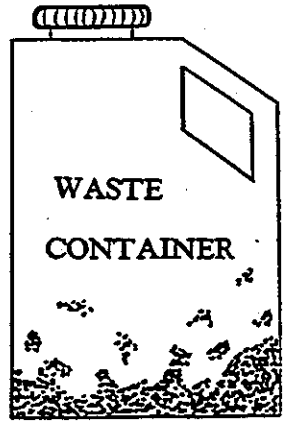
CLIPBOARD (with No. 2 Pencil attached)



G.B.W. OFFICIAL BADGE



G.B.W. MANUAL



CLEAN CLOTH (for drying equipment with)

SAMPLING PROCEDURE SUMMARY

Procedure at the water's edge:

1. Bring instruction manual.
2. Fill out data sheet heading completely.
3. Put air thermometer in place, (we suggest hanging it in a nearby bush out of the sun.) Record temperature after 3-5 minutes.
4. Do secchi depth reading. Record.
5. Take water depth measurement. Record.
6. Take water sample with bucket.
7. Immediately immerse armored thermometer to measure water temperature. (Read after 3-5 minutes -- no later.) Record.
8. While you are waiting for the temperature reading, draw off water for dissolved oxygen test into your BOD bottle, do steps 1-4 of the D.O. procedure.
9. Take sample of water in sterile bag for coliform test and place in cooler.

Procedure in laboratory: (These may be done at water's edge or site lab.)

10. Determine pH; (remember to discard tap water, sample water, and old buffer.)
11. Fill Hydrometer jar, immerse both the armored thermometer and the hydrometer in the jar. Read the thermometer after 3-5 minutes. Record. Then read the hydrometer. Record.
12. Determine salinity, using the tables in your book.
13. Complete the dissolved oxygen (protocol) titration (steps 5-12).
14. **WASH EVERYTHING THAT WAS IN CONTACT WITH CHEMICALS OR SALT WATER AFTER EVERY TEST. DRY EVERYTHING THOROUGHLY, INCLUDING THE INSIDE OF THE BUCKET.** This will help maintain the life of the equipment.
15. Complete data sheet (sample page 10-11) : Weather, Water, Activity, and VERY IMPORTANT - Observation Narrative. Write in time spent and **have data sheet signed by a member of the site team who has successfully completed a QA/QC session, this signature makes the sampling data valid, thus is very important.**
16. Bring water sample for coliform testing (before 5 p.m.) to Kingman Farm (House) 749-1565.

GREAT BAY WATCH FIELD DATA SHEET

Sampling Team (First, last and mid. in.)

1)_____

2)_____

3)_____

Day_____Date_____

Tide_____Time_____

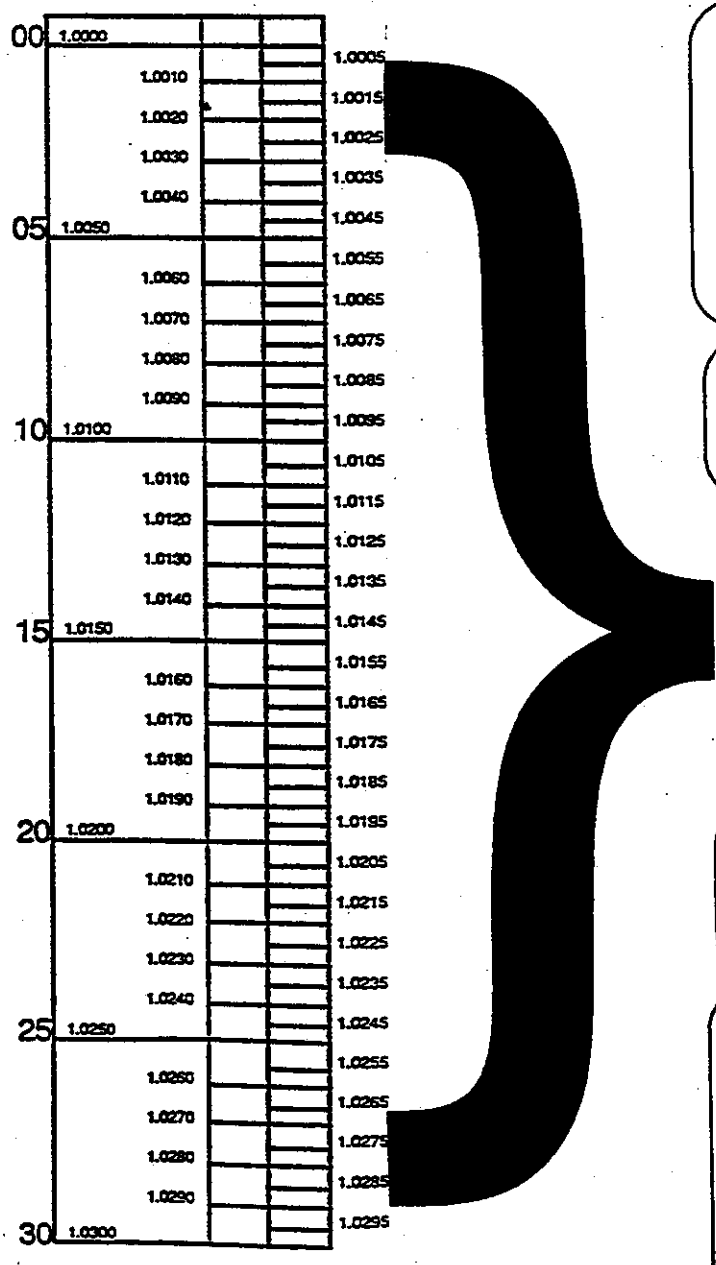
(H/L) (Military)

Site Number:_____

Site Name:_____

Air Temperature _____ C

Reading the Hydrometer



Turbidity

_____cm_____cm_____cm

disappear appear average

Water Depth _____ cm

Water Temperature _____°C

Thermometer # _____

Salinity

Hydrometer # _____

Water Temp (Jar) _____°C

Density _____ g/cc

Salinity _____ ppt (from chart)

pH pH meter # Reading

_____ _____

Dissolved Oxygen

Bottle # _____

Add Test 1_____ and Test 2_____

Test 3 if difference is >0.3ml_____

TOTAL D.O.:_____

mg/L (ppm)

Revised 3/6/97 (OVER)

Great Bay Watch Cumulative Data and Site Sheet

Site Name :_____ Site Number :_____

Sample Date	Tide	12-May	10-Jun	9-Jul	10-Aug	9-Sep	7-Oct	5-Nov
Air Temperature (°C)	Low							
	High							
Water Temperature (°C)	Low							
	High							
Secchi (cm)	Low							
	High							
Water Depth (cm)	Low							
	High							
pH	Low							
	High							
Salinity (ppt)	Low							
	High							
Dissovled Oxygen (Mg/L)	Low							
	High							
Percent Saturation	Low							
	High							
Samplers Names	Low							
	High							
Fecal Coliform	Low							
	High							
Water	Low							
	High							
Weather	Low							
	High							
Activities	Low							
	High							

Additional Observation Narrative by Date	
5/12/97	
6/10/97	
7/9/97	
8/10/97	
9/9/97	
10/7/97	
11/5/97	

TIME AND MILEAGE SHEET

NAME_____

PHONE_____

DATE	TASK	MILEAGE	HOURS
Example 3/5/97	Annual Meeting	10	3

Revised 3/3/97

Signature_____

TEMPERATURE

Discussion

Although temperature is one of the easiest measurements to perform, it is probably one of the most important parameters to be considered. It dramatically affects the rates of chemical and biochemical reactions within the water. Many biological, physical, and chemical principles are temperature dependent. Among the most common of these are the solubility of compounds in sea water, distribution and abundance of organisms living in the estuary, rates of chemical reactions, density, inversions and mixing, and current movements. Because the Bay and its tributaries are so shallow, their capacity to store heat over time is relatively small. As a result, water temperature fluctuates considerably.

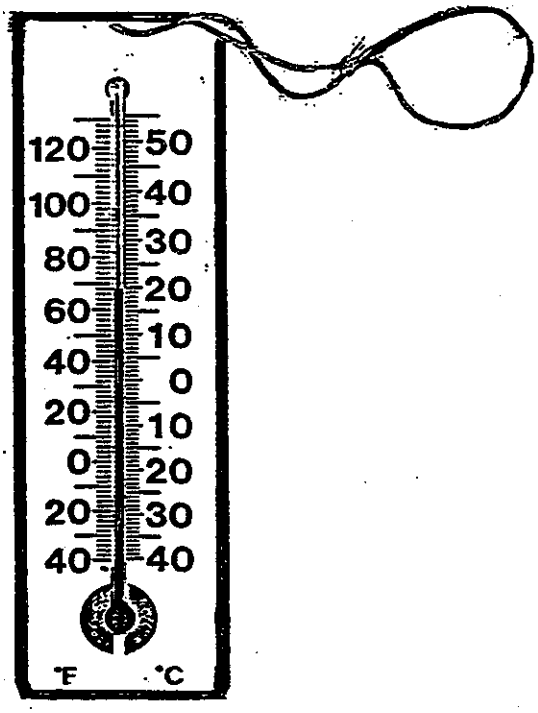
The temperatures of surface and subsurface water usually differ. With increase in depth the water generally becomes colder. This results in thermal stratification of deeper water and can lead to density differences. Vertical temperature profiles are fairly predictable. During the spring and summer months, the surface waters are warmer than the deeper waters, due to the warmth of the sun. In the fall, the warming radiation of the sun begins to diminish. As the surface water cools, it increases in density, becoming heavier. Once the surface water becomes colder and denser than the waters toward the bottom, it begins to sink and vertical mixing occurs. Wind and tide may speed up the process. This mixing action can bring nutrients up from the bottom into higher water where more plants and organisms may use it to their advantage. During the winter, the water temperature becomes relatively constant from surface to bottom until March, when the process of surface warming begins again.

Temperature is reported in degrees Celsius. You can make conversions either way using the following formulas:

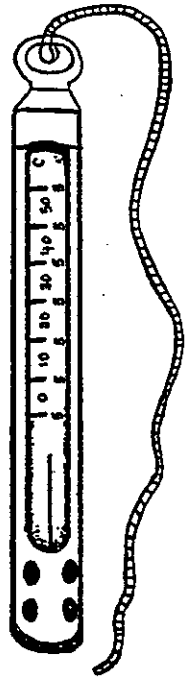
Fahrenheit to Centigrade: subtract 32 degrees from F. temperature; divide by 9; multiply by 5.

Centigrade to Fahrenheit: divide Centigrade temperature by 5; multiply by 9; add 32.

Equipment: armored thermometer (for water); air thermometer.



AIR THERMOMETER



WATER THERMOMETER (ARMORED)

Temperature Procedure:

1. Check thermometers for continuous fluid - no breaks.
2. Hang the air thermometer in a nearby bush, out of the sun.
3. Rinse sampling bucket twice by filling it halfway and disposing of contents in an area away **from the sampling spot**. Let water flow through the tube and then clamp tube shut.
4. Take water sample with bucket, hang armored thermometer in bucket and record reading after 3-5 minutes.
5. Record air temperature making sure to use Celsius scale.

WATER CLARITY (TRANSPARENCY) - SECCHI DISK

Discussion

Transparency of water is a quick and easy measurement that integrates many important features of an aquatic system. Algae, microscopic animals, eroded soil, and resuspended bottom sediment contained in the water column interfere with light penetration and lessen the transparency of the water. In late spring and early fall, transparency is usually less because of plankton and algal blooms, and in the early spring, the water may become more turbid with silt being carried into the estuary with spring run-off. Since the sunlight is the basic energy source for all life, the degree of water transparency of the water has an important effect.

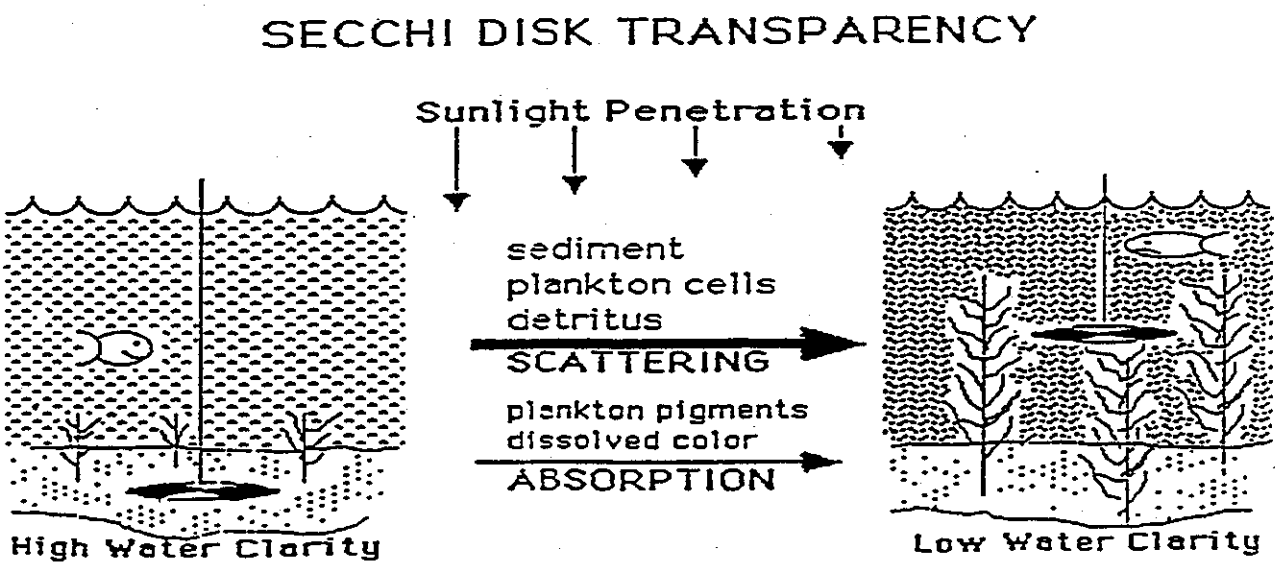
Transparency affects fish and other aquatic life by:

1. limiting photosynthetic processes and increasing respiration, oxygen use and the amount of carbon dioxide produced.

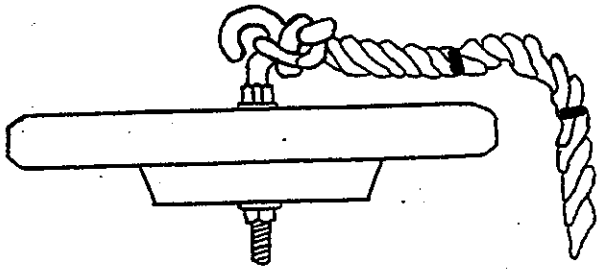
2. clogging of fish gills by suspended particles.

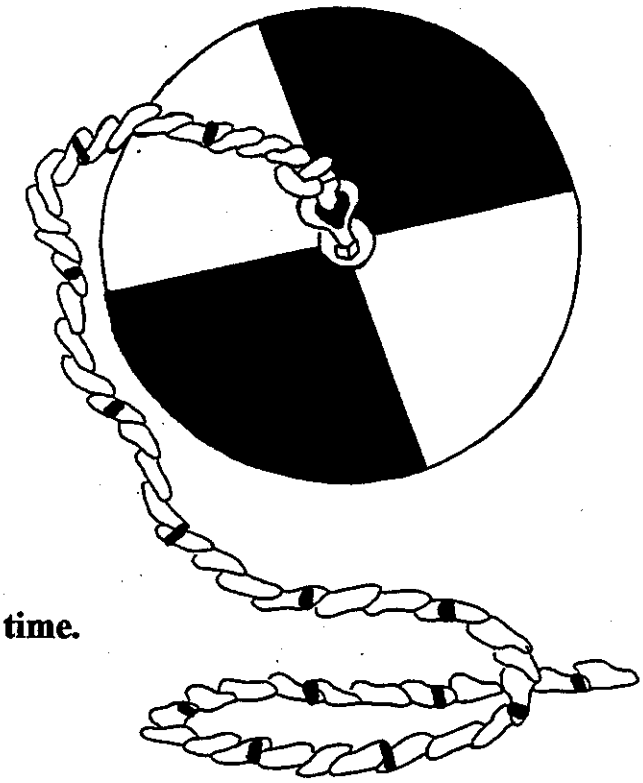
3. obscuring vision of fish and shellfish as they hunt food.

Water color indicates content, to a degree, and it is useful to record the color, also.



Equipment: Secchi disk, with line marked every 5 centimeters.





Secchi disk Procedure:

Note: Take these reading at the same spot each time.
Do these tests after sunrise!

Water Transparency

1. Lower the Secchi disk into the water (in the shade of your body as you stand with your back to the sun, if possible), until it just goes out of sight. Note depth to the closest 5 centimeters then raise secchi disk until it just reappears and note the depth to the closest 5 centimeters. Record the average of the two depths. If the disk is resting on the bottom and is still visible, please record "BSV" (Bottom Still Visible).

Water Depth

2. Lower the Secchi disk into the water (in the shade of you body as you stand with your back to the sun), until you feel or see the Secchi disk on the bottom. Record the water depth to the closest 5 centimeters.

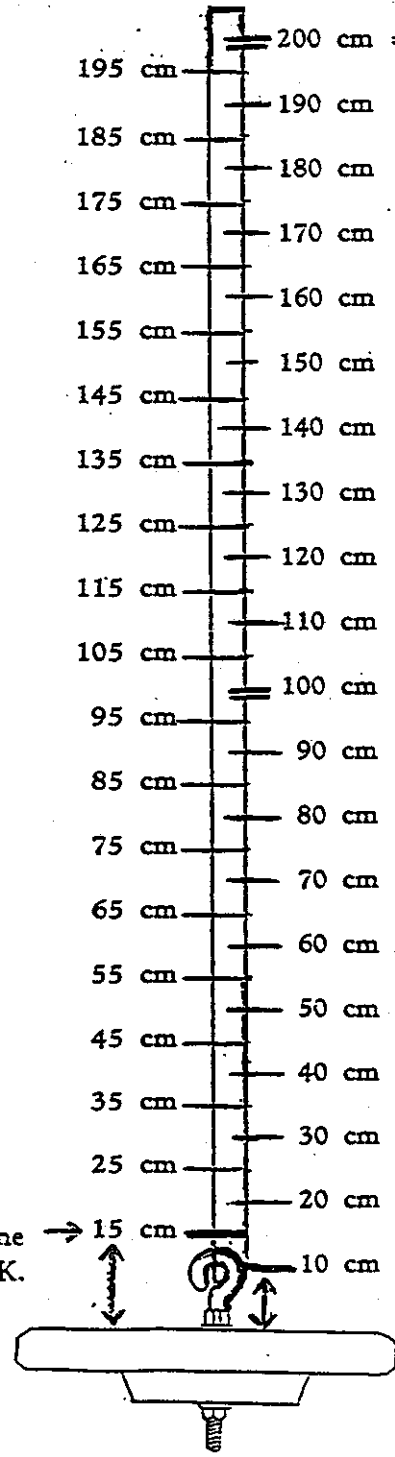
HOW TO READ THE SECCHI DISK

IMPORTANT:

Please start counting from the "surface" of the secchi disk. From the "surface" up to the BLUE line is 10 cm.

Each RED line represents 5 cm each.

When you have counted 10 BLUE lines you have reached the 1 METER line (this is represented by 2 BLACK lines).



= This is the first RED line from the surface of DISK.

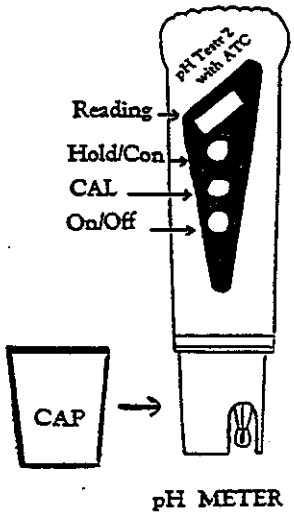
= The first BLUE line you see from the surface of DISK.

pH PROTOCOL

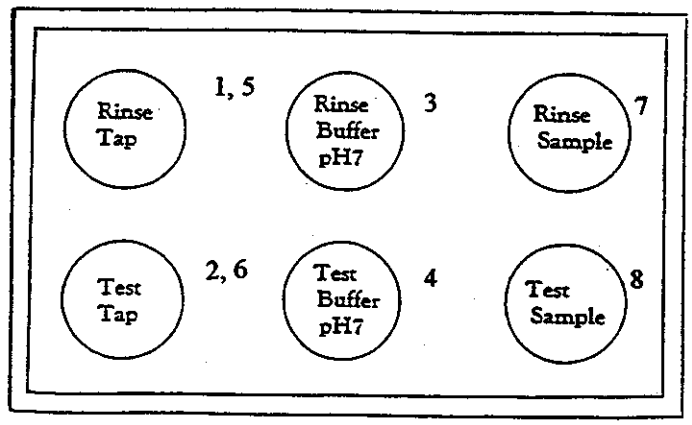
Discussion

pH is the measure of alkalinity/acidity. The pH scale runs from zero to fourteen, acidic to basic, with 7.0 being neutral. The scale is logarithmic, which means that increases are in powers of 10. At a pH of 4 there are 10 times as many hydrogen ions as there are at a pH of 5, and so on. The pH of ocean water is slightly basic, usually at 8.0 to 8.4. In estuaries, the pH varies more, usually from 7.0 to 8.6, but can vary even more widely at times of extreme influx of fresh water or a high degree of biologic activity. Water dissolves the mineral substances it contacts, picks up aerosols and dust from the air, receives wastes, and supports photosynthetic organisms, all of which affect pH. Water has a buffering capacity which helps it resist pH change, but some change does occur. Generally aquatic life can exist between pH of 9.0 and 5.0.

Equipment: pH pocket meter, 7.0 buffer solution, six bottles and tray.



pH METER



BUFFER pH7

pH Procedure :

NOTE: **BE SURE TO IMMERSE THE PROBE IN TAP WATER TO THE BLACK LINE FOR AN HOUR. BEFORE SAMPLING BE SURE TO SEE IF pH METER IS FUNCTIONING.**

I. Collection: Obtain a sample of estuarine water from your sampling bucket and pour into bottles marked "rinse sample" and "test sample."

- **Caution!** Only immerse pH meter to black line and keep meter in dry area of the kit.

II. Calibration and Measurement of pH: (pH is temperature dependent. Calibration liquid must be near your sample temperature or vise-versa.) If your meter doesn't calibrate, check the batteries. Change them if necessary and attempt calibration again. If it still doesn't calibrate correctly, the solution could be weak, or something else could be wrong. Don't take the reading -- bring the meter to the office. (749-1565)

Calibration and Measurement Procedure for pH:

STEP 1. Fill two small brown bottles labeled "rinse tap" and "test tap" and with tap water.

STEP 2. Check 2 small bottles of pH 7 buffer -- bottle marked "rinse buffer" should contain the older, used buffer and bottle marked "test" should contain the fresher, newer buffer.

STEP 3. Remove protector cap from pH probe.

STEP 4. Turn on meter (Press on/off button).

STEP 5. Rinse probe in bottles marked "rinse tap" and "test tap" by stirring gently. No need to take pH readings.

STEP 6. Rinse probe in small bottle of buffer solution marked "rinse pH 7", then immerse in "test pH 7." Press the "cal" button to enter calibration mode (you will see CA in window). Stir gently and wait for the displayed value to stabilize. Press "hold/con" (you will see CO in window) to complete calibration.

STEP 7. Rinse the probe in tap water, first the "rinse tap" then the "test tap." Don't record any numbers.

STEP 8. Rinse probe in small bottle of "rinse sample," then immerse in "test sample". Stir once and allow reading to stabilize . (ATC will correct for temperature changes.)

STEP 9. Read pH in the display window.

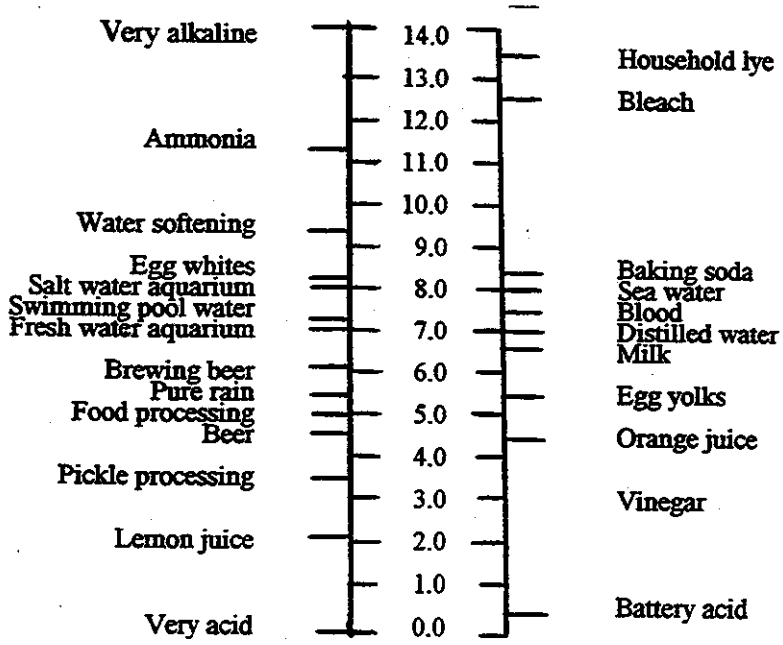
STEP 10. Press on/off button to shut off pH meter.

III. Cleanup: Rinse probe again in two tap bottles, shake off excess water, and replace cap. Rinse sample bottles and tap water bottles in fresh water and dry. Old buffer can be disposed of by pouring down any drain or into waste jug.* Store meter in toolbox near bottles and in a dry section.

Note: At the end of the sampling day, throw out the **rinse** buffer, wash and dry the bottle, and wash the cap. Take the used test buffer and pour it in rinse buffer bottle. Wash "test buffer" bottle and fill with new test buffer solution from extra buffer solution bottle before next sampling day.

Caution: To avoid cross contamination between samples, never immerse the electrode above color band!

pH scale showing the pH of some common substances



SALINITY - HYDROMETER, THERMOMETER

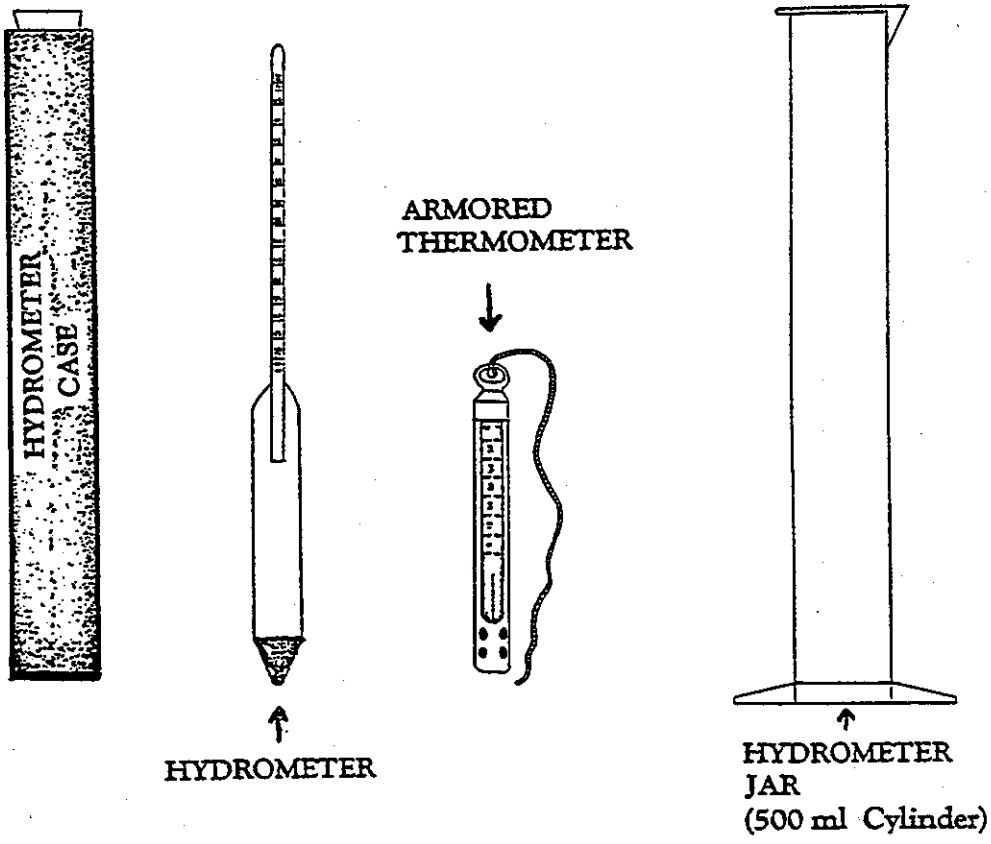
Discussion

Salinity is total amount of dissolved solids in the water and is made up of all known elements. The salinity of the open ocean is approximately 35 parts per thousand (o/oo), but in the Gulf of Maine, salinity is slightly lower at about 32 or 33 o/oo due to river influx and run-off. In the Great Bay Estuary, seven rivers bring fresh water into embayment, and during the spring run-off, levels of salinity have been recorded as low as 0 o/oo. Salinity may also range as high as 30 o/oo. Tolerance of wide-ranging and sometimes rapidly changing salinity determines, more than any other single factor, which species of plants and animals can survive in an estuary. Although salinity levels are higher at the mouth of the Piscataqua River, and generally become progressively lower as we move into the Great Bay proper, winds and tides cause Little Bay and Great Bay to be well-mixed. Mixing also occurs top to bottom, blending the warmer, fresher water which tends to float on top with the cooler, more dense salt water brought in by the tides.

Temperature in the Great Bay estuary has a marked pattern of seasonal variation from a winter low of -1.9 degrees Celsius to 28-30 degrees C. in the summer. Great Bay itself is quite shallow, averaging about 8 feet, which allows for rapid warming and cooling as the seasons change. From 1973 to 1982, time series analyses of hydrographic trends in the estuary by Professor Ted Loder, UNH, and others showed that water temperature decreased 0.17 degrees C. per year while salinity rose (at Dover Point) 0.34 o/oo per year. These trends to colder, saltier water may indicate either local river-flow changes or regional trends affecting the Gulf of Maine.[4]

There are several ways of determining salinity, most of them requiring the use of expensive equipment. However, we will use a hydrometer, an instrument which measures the density of a fluid, making use of Archimedes' Principle, which states that "a floating body will displace a volume of water, the mass of which is equal to its own mass." The mass of a hydrometer is fixed so that it floats in pure, distilled water at 1.00 grams per cubic centimeter. Salinity is also related to temperature, which we will measure. Then we will use conversion tables to relate the two measurements and extrapolate our salinity reading in parts per thousand (o/oo).

Equipment: armored thermometer, hydrometer, 500 ml cylinder.

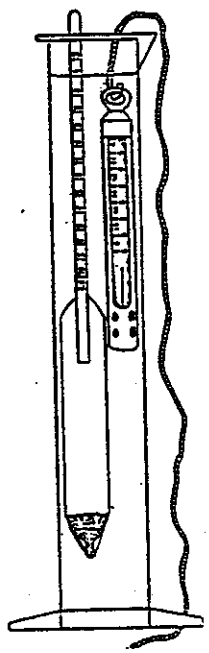


Salinity Procedure :

STEP 1. Fill the 500 ml cylinder 3/4 full below spout with water taken from the bucket.

STEP 2. Hang the armored thermometer in the jar.

STEP 3. **Immediately** insert the hydrometer with a twisting motion (this removes any air bubbles), carefully -- don't just drop it because it might hit the bottom too hard and break.

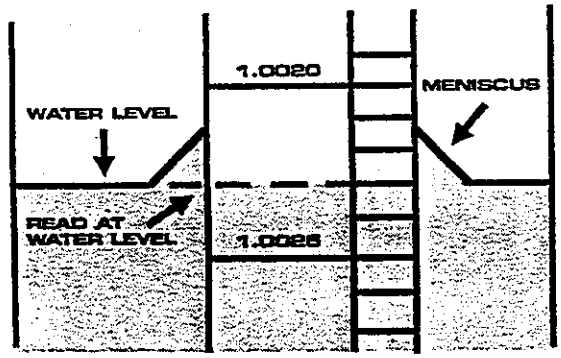


STEP 4. Level the cylinder so hydrometer is level and not touching the sides (try to keep it out of the wind).

STEP 5. After 3-5 minutes, read the thermometer to the **nearest 0.5** degrees C. and record.

Remove the thermometer.

STEP 6. Read the density, taking care to read at the bottom of the curve formed when the water adheres and rises slightly where it touches the sides of the hydrometer. (a magnifying glass may be helpful) This curve is called the meniscus. On your data sheet, show where the meniscus is by marking the "**READING THE HYDROMETER**" diagram. Record your density reading on your data sheet.



STEP 7. To determine the salinity use the five pages of Table I (pp.25-29). Salinity is in parts per thousand. (ppt) Locate the density in the left hand column and the correct temperature in the jar across the top of the page (1 of 5 pages). Then, read down to the appropriate salinity.

NOTE: If you find a reading to be at a density number ending in "5" five, you will need to interpolate the result on the table. This is done by taking the average of the points above and below the value. For example, if the hydrometer read 1.0135, you would then take the values for 1.0140 and 1.0130 and average them.

Table 1. Salinity in parts per thousand (ppt)
NOTE: This table is designed for use with 60°/60°F hydrometer.

Observed	Temperature of Water in Graduated Cylinder (°C)									
Reading	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0
0.9990							0.0	0.1	0.2	0.3
1.0000	0.5	0.6	0.7	0.8	1.0	1.1	1.2	1.4	1.5	1.6
1.0010	1.8	1.9	2.0	2.1	2.3	2.4	2.5	2.5	2.7	2.8
1.0020	3.1	3.2	3.3	3.4	3.6	3.7	3.8	4.0	4.1	4.2
1.0030	4.4	4.5	4.6	4.8	4.9	5.0	5.1	5.3	5.4	5.5
1.0040	5.7	5.8	5.9	6.1	6.2	6.3	6.4	6.6	6.7	7.0
1.0050	7.1	7.1	7.2	7.4	7.5	7.6	7.7	7.9	8.1	8.3
1.0060	8.4	8.5	8.7	8.8	8.9	9.1	9.2	9.3	9.4	9.6
1.0070	9.7	9.8	10.0	10.1	10.2	10.4	10.5	10.6	10.7	10.9
1.0080	11.0	11.1	11.3	11.4	11.5	11.7	11.8	11.9	12.0	12.2
1.0090	12.3	12.4	12.6	12.7	12.8	13.0	13.1	13.2	13.4	13.6
1.0100	13.6	13.7	13.9	14.0	14.1	14.3	14.4	14.5	14.8	14.9
1.0110	14.9	15.0	15.2	15.3	15.4	15.6	15.7	16.0	16.1	16.2
1.0120	16.2	16.3	16.5	16.6	16.7	17.0	17.1	17.3	17.4	17.5
1.0130	17.5	17.7	17.8	17.9	18.0	18.3	18.4	18.6	18.7	18.8
1.0140	18.8	19.0	19.1	19.3	19.5	19.6	19.7	19.9	20.0	20.1
1.0150	20.1	20.4	20.5	20.6	20.8	20.9	21.0	21.2	21.3	21.6
1.0160	21.4	21.7	21.8	22.0	22.1	22.2	22.3	22.5	22.7	22.9
1.0170	22.9	23.0	23.1	23.3	23.4	23.5	23.6	23.8	24.0	24.2
1.0180	24.2	24.3	24.4	24.6	24.7	24.8	24.9	25.2	25.3	25.5
1.0190	25.5	25.6	25.7	25.9	26.0	26.1	26.4	26.5	26.6	26.8
1.0200	26.8	26.9	27.0	27.2	27.3	27.4	27.7	27.8	27.9	28.2
1.0210	28.1	28.2	28.3	28.5	28.6	28.9	29.0	29.1	29.2	29.5
1.0220	29.4	29.5	29.6	29.8	30.0	30.2	30.3	30.4	30.7	30.8
1.0230	30.7	30.8	30.9	31.2	31.3	31.5	31.6	31.7	32.0	32.1
1.0240	32.0	32.1	32.2	32.5	32.6	32.8	32.9	33.2	33.3	33.4
1.0250	33.3	33.4	33.7	33.8	33.9	34.1	34.2	34.5	34.6	34.7
1.0260	34.6	34.7	35.0	35.1	35.2	35.4	35.6	35.8	35.9	36.0
1.0270	35.9	36.2	36.3	36.4	36.5	36.7	36.9	37.1	37.2	37.5
1.0280	37.2	37.5	37.6	37.7	37.8	38.1	38.2	38.4	38.5	38.8
1.0290	38.6	38.8	38.9	39.0	39.1	39.4	39.5	39.7	39.9	40.1
1.0300	39.9	40.1	40.2	40.3	40.6	40.7	40.8	41.0	41.2	41.4
1.0310	41.2	41.4	41.5	41.8	41.9	42.0	42.1	42.3	42.5	

STEP 8. Record the number of your hydrometer on the data sheet. It's found near the neck on white paper inside the stem.

Table 1. Salinity in parts per thousand (ppt)

NOTE: This table is designed for use with 60°/60°F hydrometer.

Observed	Temperature of Water in Graduated Cylinder (°C)									
Reading	-1.0	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
1.0000										
1.0010	0.6	0.6	0.5	0.5	0.2	0.2	0.2	0.2	0.2	0.2
1.0020	1.9	1.9	1.8	1.6	1.6	1.6	1.5	1.5	1.6	1.6
1.0030	3.2	3.1	2.9	2.9	2.8	2.8	2.8	2.8	2.8	2.9
1.0040	4.4	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.2
1.0050	5.7	5.5	5.4	5.4	5.4	5.3	5.3	5.4	5.4	5.4
1.0060	6.8	6.8	6.7	6.6	6.6	6.6	6.6	6.6	6.7	6.7
1.0070	8.1	8.0	7.9	7.9	7.9	7.9	7.9	7.9	7.9	8.0
1.0080	9.3	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.3
1.0090	10.5	10.5	10.4	10.4	10.4	10.4	10.4	10.5	10.5	10.6
1.0100	11.8	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.8	11.8
1.0110	13.0	13.0	12.8	12.8	12.8	12.8	13.0	13.0	13.1	13.1
1.0120	14.3	14.1	14.1	14.1	14.1	14.1	14.1	14.3	14.3	14.4
1.0130	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.6	15.7
1.0140	16.7	16.6	16.6	16.6	16.6	16.6	16.7	16.7	16.9	17.0
1.0150	17.9	17.9	17.9	17.9	17.9	17.9	17.9	18.0	18.0	18.2
1.0160	19.2	19.1	19.1	19.1	19.1	19.2	19.2	19.3	19.3	19.5
1.0170	20.4	20.4	20.4	20.4	20.4	20.4	20.5	20.5	20.6	20.8
1.0180	21.7	21.7	21.6	21.6	21.7	21.7	21.7	21.8	22.0	22.1
1.0190	22.9	22.9	22.9	22.9	22.9	23.0	23.0	23.1	23.3	23.4
1.0200	24.2	24.2	24.0	24.2	24.2	24.2	24.3	24.3	24.4	24.6
1.0210	25.3	25.3	25.3	25.3	25.5	25.5	25.6	25.6	25.7	25.9
1.0220	26.6	26.6	26.6	26.6	26.6	26.8	26.8	26.9	27.0	27.2
1.0230	27.8	27.8	27.8	27.8	27.9	27.9	28.1	28.2	28.3	28.5
1.0240	29.1	29.1	29.1	29.1	29.1	29.2	29.4	29.5	29.5	29.8
1.0250	30.3	30.3	30.3	30.4	30.4	30.6	30.6	30.7	30.8	30.9
1.0260	31.6	31.6	31.6	31.6	31.7	31.7	31.9	32.0	32.1	32.2
1.0270	32.8	32.8	32.9	32.9	32.9	33.0	33.2	33.3	33.4	33.5
1.0280	34.1	34.1	34.1	34.1	34.2	34.3	34.5	34.5	34.7	34.8
1.0290	35.2	35.2	35.4	35.4	35.5	35.5	35.6	35.8	35.9	36.2
1.0300	36.5	36.5	36.5	36.7	36.7	36.8	36.9	37.1	37.2	37.3
1.0310	37.7	37.7	37.8	37.8	38.0	38.1	38.2	38.4	38.5	38.6

Table 1. Salinity in parts per thousand (ppt)

NOTE: This table is designed for use with 60°/60°F hydrometer.

Observed	Temperature of Water in Graduated Cylinder (°C)									
Reading	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0
1.0000								0.0	0.2	0.3
1.0010	0.5	0.5	0.6	0.6	0.7	0.8	1.0	1.2	1.5	1.6
1.0020	1.6	1.8	1.9	2.0	2.1	2.3	2.4	2.5	2.8	2.9
1.0030	2.9	3.1	3.2	3.3	3.4	3.6	3.7	3.8	4.1	4.2
1.0040	4.2	4.4	4.5	4.6	4.8	4.9	5.0	5.1	5.4	5.5
1.0050	5.5	5.5	5.7	5.8	5.9	6.2	6.3	6.6	6.7	7.0
1.0060	6.8	6.8	7.0	7.1	7.2	7.5	7.6	7.9	8.0	8.3
1.0070	8.1	8.1	8.3	8.4	8.5	8.8	8.9	9.2	9.3	9.6
1.0080	9.3	9.4	9.6	9.7	9.8	10.0	10.2	10.5	10.6	10.9
1.0090	10.6	10.7	10.9	11.0	11.1	11.3	11.5	11.8	11.9	12.2
1.0100	11.9	12.0	12.2	12.3	12.4	12.6	12.8	13.1	13.2	13.5
1.0110	13.2	13.4	13.5	13.6	13.7	13.9	14.1	14.4	14.5	14.8
1.0120	14.5	14.7	14.8	14.9	15.0	15.2	15.4	15.7	15.8	16.1
1.0130	15.8	15.8	16.0	16.2	16.3	16.5	16.7	17.0	17.1	17.4
1.0140	17.0	17.1	17.3	17.5	17.7	17.8	18.0	18.3	18.6	18.7
1.0150	18.3	18.4	18.6	18.8	19.0	19.1	19.3	19.6	19.9	20.0
1.0160	19.6	19.7	19.9	20.1	20.3	20.4	20.6	20.9	21.2	21.3
1.0170	20.9	21.0	21.2	21.3	21.6	21.7	22.0	22.2	22.5	22.7
1.0180	22.2	22.3	22.5	22.6	22.9	23.0	23.3	23.5	23.8	24.0
1.0190	23.5	23.6	23.8	23.9	24.2	24.3	24.6	24.8	25.1	25.3
1.0200	24.7	24.8	25.1	25.2	25.5	25.6	25.9	26.1	26.4	26.6
1.0210	26.0	26.1	26.4	26.5	26.8	26.9	27.2	27.4	27.7	27.9
1.0220	27.3	27.4	27.7	27.8	28.1	28.2	28.5	28.7	29.0	29.2
1.0230	28.6	28.7	28.9	29.1	29.4	29.5	29.8	30.0	30.3	30.6
1.0240	29.9	30.0	30.2	30.4	30.6	30.8	31.1	31.3	31.6	31.9
1.0250	31.1	31.3	31.5	31.7	31.9	32.1	32.4	32.6	32.9	33.2
1.0260	32.4	32.6	32.8	33.0	33.2	33.4	33.7	33.9	34.2	34.5
1.0270	33.7	33.9	34.1	34.3	34.5	34.7	35.0	35.2	35.5	35.8
1.0280	35.0	35.1	35.4	35.6	35.8	36.0	36.3	36.5	36.8	37.1
1.0290	36.3	36.4	36.7	36.8	37.1	37.3	37.6	37.8	38.1	38.4
1.0300	37.6	37.7	38.0	38.1	38.4	38.6	38.9	39.1	39.4	39.7
1.0310	38.9	39.0	39.3	39.4	39.7	39.9	40.2	40.5	40.7	41.0

Table 1. Salinity in parts per thousand (ppt)

NOTE: This table is designed for use with 60°/60°F hydrometer.

Observed	Temperature of Water in Graduated Cylinder (°C)									
Reading	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0
0.9990							0.0	0.1	0.2	0.3
1.0000	0.5	0.6	0.7	0.8	1.0	1.1	1.2	1.4	1.5	1.6
1.0010	1.8	1.9	2.0	2.1	2.3	2.4	2.5	2.5	2.7	2.8
1.0020	3.1	3.2	3.3	3.4	3.6	3.7	3.8	4.0	4.1	4.2
1.0030	4.4	4.5	4.6	4.8	4.9	5.0	5.1	5.3	5.4	5.5
1.0040	5.7	5.8	5.9	6.1	6.2	6.3	6.4	6.6	6.7	7.0
1.0050	7.1	7.1	7.2	7.4	7.5	7.6	7.7	7.9	8.1	8.3
1.0060	8.4	8.5	8.7	8.8	8.9	9.1	9.2	9.3	9.4	9.6
1.0070	9.7	9.8	10.0	10.1	10.2	10.4	10.5	10.6	10.7	10.9
1.0080	11.0	11.1	11.3	11.4	11.5	11.7	11.8	11.9	12.0	12.2
1.0090	12.3	12.4	12.6	12.7	12.8	13.0	13.1	13.2	13.4	13.6
1.0100	13.6	13.7	13.9	14.0	14.1	14.3	14.4	14.5	14.8	14.9
1.0110	14.9	15.0	15.2	15.3	15.4	15.6	15.7	16.0	16.1	16.2
1.0120	16.2	16.3	16.5	16.6	16.7	17.0	17.1	17.3	17.4	17.5
1.0130	17.5	17.7	17.8	17.9	18.0	18.3	18.4	18.6	18.7	18.8
1.0140	18.8	19.0	19.1	19.3	19.5	19.6	19.7	19.9	20.0	20.1
1.0150	20.1	20.4	20.5	20.6	20.8	20.9	21.0	21.2	21.3	21.6
1.0160	21.4	21.7	21.8	22.0	22.1	22.2	22.3	22.5	22.7	22.9
1.0170	22.9	23.0	23.1	23.3	23.4	23.5	23.6	23.8	24.0	24.2
1.0180	24.2	24.3	24.4	24.6	24.7	24.8	24.9	25.2	25.3	25.5
1.0190	25.5	25.6	25.7	25.9	26.0	26.1	26.4	26.5	26.6	26.8
1.0200	26.8	26.9	27.0	27.2	27.3	27.4	27.7	27.8	27.9	28.2
1.0210	28.1	28.2	28.3	28.5	28.6	28.9	29.0	29.1	29.2	29.5
1.0220	29.4	29.5	29.6	29.8	30.0	30.2	30.3	30.4	30.7	30.8
1.0230	30.7	30.8	30.9	31.2	31.3	31.5	31.6	31.7	32.0	32.1
1.0240	32.0	32.1	32.2	32.5	32.6	32.8	32.9	33.2	33.3	33.4
1.0250	33.3	33.4	33.7	33.8	33.9	34.1	34.2	34.5	34.6	34.7
1.0260	34.6	34.7	35.0	35.1	35.2	35.4	35.6	35.8	35.9	36.0
1.0270	35.9	36.2	36.3	36.4	36.5	36.7	36.9	37.1	37.2	37.5
1.0280	37.2	37.5	37.6	37.7	37.8	38.1	38.2	38.4	38.5	38.8
1.0290	38.6	38.8	38.9	39.0	39.1	39.4	39.5	39.7	39.9	40.1
1.0300	39.9	40.1	40.2	40.3	40.6	40.7	40.8	41.0	41.2	41.4
1.0310	41.2	41.4	41.5	41.8	41.9	42.0	42.1	42.3	42.5	

Table 1. Salinity in parts per thousand (ppt)

NOTE: This table is designed for use with 60°/60°F hydrometer.

Observed	Temperature of Water in Graduated Cylinder (°C)									
Reading	23.5	24.0	24.5	25.0	25.5	26.0	26.5	27.0	27.5	28.0
0.9980							0.1	0.2	0.3	0.6
0.9990	0.5	0.6	0.7	0.8	1.0	1.2	1.4	1.5	1.8	1.9
1.0000	1.8	1.9	2.0	2.1	2.4	2.5	2.7	2.9	3.1	3.2
1.0010	2.9	3.1	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.5
1.0020	4.4	4.6	4.8	4.9	5.0	5.1	5.4	5.5	5.7	5.9
1.0030	5.8	5.9	6.1	6.2	6.3	6.6	6.7	6.8	7.1	7.2
1.0040	7.1	7.2	7.4	7.5	7.7	7.9	8.0	8.3	8.4	8.5
1.0050	8.4	8.5	8.7	8.9	9.1	9.2	9.3	9.6	9.7	10.0
1.0060	9.7	9.8	10.1	10.2	10.4	10.5	10.7	10.9	11.0	11.3
1.0070	11.0	11.3	11.4	11.5	11.7	11.9	12.0	12.2	12.4	12.6
1.0080	12.4	12.6	12.7	12.8	13.0	13.2	13.4	13.6	13.7	13.9
1.0090	13.7	13.9	14.0	14.1	14.4	14.5	14.7	14.9	15.0	15.3
1.0100	15.0	15.2	15.3	15.6	15.7	15.8	16.1	16.2	16.5	16.6
1.0110	16.3	16.5	16.7	16.9	17.0	17.3	17.4	17.5	17.8	17.9
1.0120	17.7	17.9	18.0	18.2	18.3	18.6	18.7	19.0	19.1	19.3
1.0130	19.1	19.2	19.3	19.5	19.7	19.9	20.0	20.3	20.4	20.6
1.0140	20.4	20.5	20.6	20.9	21.0	21.2	21.4	21.6	21.8	22.0
1.0150	21.7	21.8	22.0	22.2	22.3	22.5	22.7	22.9	23.1	23.3
1.0160	23.0	23.3	23.4	23.5	23.6	23.9	24.0	24.3	24.4	24.7
1.0170	24.3	24.6	24.7	24.8	25.1	25.2	25.3	25.6	25.7	26.0
1.0180	25.6	25.9	26.0	26.1	26.4	26.5	26.8	26.9	27.2	27.3
1.0190	27.0	27.2	27.3	27.6	27.7	27.8	28.1	28.2	28.5	28.6
1.0200	28.3	28.5	28.6	28.9	29.0	29.2	29.4	29.6	29.8	30.0
1.0210	29.6	29.8	30.0	30.2	30.3	30.6	30.7	30.9	31.1	31.3
1.0220	30.9	31.2	31.3	31.5	31.7	31.9	32.0	32.2	32.5	32.6
1.0230	32.2	32.5	32.6	32.8	33.0	33.2	33.4	33.5	33.8	33.9
1.0240	33.7	33.8	33.9	34.2	34.3	34.5	34.7	35.0	35.1	35.4
1.0250	35.0	35.1	35.2	35.5	35.6	35.9	36.0	36.3	36.4	36.7
1.0260	36.3	36.4	36.7	36.8	36.9	37.2	37.3	37.6	37.7	38.0
1.0270	37.6	37.8	38.0	38.1	38.4	38.5	38.8	38.9	39.1	39.3
1.0280	38.9	39.1	39.3	39.4	39.7	39.8	40.1	40.2	40.5	40.7
1.0290	40.2	40.5	40.6	40.8	41.0	41.2	41.4	41.6	41.8	
1.0300	41.6	41.8	41.9							
1.0310										

Table 1. Salinity in parts per thousand (ppt)

NOTE: This table is designed for use with 60°/60°F hydrometer.

Observed	Temperature of Water in Graduated Cylinder (°C)									
Reading	28.5	29.0	29.5	30.0	30.5	31.0	31.5	32.0	32.5	33.0
0.9980	0.7	0.8	1.1	1.2	1.5	1.6	1.9	2.0	2.3	2.4
0.9990	2.0	2.3	2.4	2.5	2.8	2.9	3.2	3.4	3.6	3.8
1.0000	3.4	3.6	3.7	4.0	4.1	4.4	4.5	4.8	4.9	5.1
1.0010	4.8	4.9	5.1	5.1	5.4	5.5	5.8	5.9	6.2	6.4
1.0020	6.1	6.3	6.4	6.6	6.8	7.0	7.2	7.5	7.6	7.9
1.0030	7.4	7.6	7.7	8.0	8.1	8.4	8.5	8.8	9.1	9.2
1.0040	8.8	8.9	9.2	9.3	9.6	9.7	10.0	10.1	10.4	10.5
1.0050	10.1	10.2	10.5	10.6	10.9	11.0	11.3	11.5	11.7	11.9
1.0060	11.4	11.7	11.8	12.0	12.2	12.4	12.6	12.8	13.1	13.2
1.0070	12.8	13.0	13.1	13.4	13.6	13.7	14.0	14.1	14.4	14.7
1.0080	14.1	14.3	14.5	14.7	14.9	15.2	15.3	15.6	15.7	16.0
1.0090	15.4	15.7	15.8	16.1	16.2	16.5	16.6	16.9	17.1	17.3
1.0100	16.7	17.0	17.1	17.4	17.5	17.8	18.0	18.2	18.4	18.7
1.0110	18.2	18.3	18.6	18.7	19.0	19.1	19.3	19.6	19.7	20.0
1.0120	19.5	19.6	19.9	20.1	20.3	20.5	20.6	20.9	21.2	21.3
1.0130	20.8	21.0	21.2	21.4	21.6	21.8	22.1	22.2	22.5	22.7
1.0140	22.2	22.3	22.6	22.7	23.0	23.1	23.4	23.6	23.8	24.0
1.0150	23.5	23.6	23.9	24.0	24.3	24.6	24.7	24.9	25.2	25.3
1.0160	24.8	25.1	25.2	25.5	25.6	25.9	26.1	26.3	26.5	26.8
1.0170	26.1	26.4	26.5	26.8	27.0	27.2	27.4	27.7	27.8	28.1
1.0180	27.6	27.7	27.9	28.1	28.3	28.5	28.7	29.0	29.2	29.4
1.0190	28.9	29.0	29.2	29.5	29.6	29.9	30.0	30.3	30.6	30.8
1.0200	30.2	30.4	30.6	30.8	30.9	31.2	31.5	31.6	31.9	32.1
1.0210	31.5	31.7	32.0	32.1	32.4	32.5	32.8	33.0	33.3	33.4
1.0220	32.9	33.0	33.3	33.4	33.7	33.9	34.1	34.3	34.6	34.8
1.0230	34.2	34.5	34.6	34.8	35.0	35.2	35.5	35.6	35.9	36.2
1.0240	35.5	35.8	35.9	36.2	36.4	36.5	36.8	37.1	37.2	37.5
1.0250	36.8	37.1	37.2	37.5	37.7	37.8	38.1	38.4	38.6	38.8
1.0260	38.2	38.4	38.6	38.8	39.0	39.3	39.4	39.7	39.9	40.2
1.0270	39.5	39.8	39.9	40.2	40.3	40.6	40.8	41.0	41.2	41.5
1.0280	40.8	41.1	41.2	41.5						

DISSOLVED OXYGEN

Discussion

Dissolved oxygen (DO) is one of the most important indicators of the quality of water for aquatic life. It is essential for all plants and animals inhabiting the Bay. When oxygen levels in the water fall below about 3-5 parts per million (ppm), fish and many other aquatic organisms cannot survive. Oxygen is a particularly sensitive constituent because chemicals present in the water, biological processes, and temperature exert a major influence on its availability during the year.

A DO test (using kit or meter) tells how much oxygen is dissolved in the water. But it does not tell your how much dissolved oxygen the water is capable of holding at the temperature at which it was tested. When water holds all the DO it can hold at a given temperature, it is said to be 100 percent saturated with oxygen. The warmer the water is, the less DO it can hold, and the colder the water, the more DO it can hold. The accompanying Table 2 shows this relationship at various temperatures.

Oxygen is transferred from the atmosphere into the surface waters by the aerating action of the wind. It is also added at or near the surface as a by-product of plant photosynthesis. As a result, floating and rooted aquatic plants increase DO levels. Since the existence of plants also depends on the availability of light, the oxygen-producing processes occur only near the surface or in shallow waters. Oxygen levels may be reduced because the water is too warm (e.g., near a power plant) or because there are too many bacteria or aquatic organisms in the area. When algae growth is excessive, as in a "bloom," the upper levels of algae can shade the light to lower levels, causing fish kills, death of other organisms and bad smells. Also, at night all photosynthesis stops and the algae respire (breathe) and use up available oxygen supplies, then suffocate, die, and decay.

While the overall oxygen content (in mg/L) in the water is important in assessing the health of a water body, it is also useful to look at dissolved oxygen in terms of "percent saturation." Percent saturation is the ratio of oxygen concentration that is in the water to the oxygen concentration that could be in the water, at given temperature and salinity. One might expect that the highest obtainable percent saturation value to be 100 percent; however, "supersaturation" (values greater than 100 percent) can occur under certain conditions. Very high concentrations of oxygen are possible in areas with a great deal of aquatic vegetation (oxygen production through photosynthesis), or in areas subject to strong wind and wave action (addition of oxygen through "entrainment" of atmospheric oxygen into the water).

TABLE 2

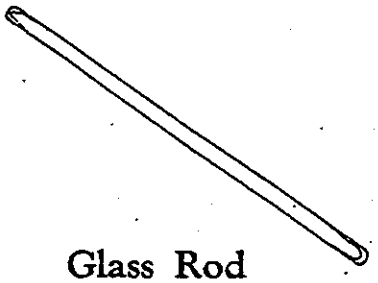
Solubility of Dissovled Oxygen in Fresh Water

Temperature (^{0}C)	Solubility Mg/L (ppm)*	Temperature (^{0}C)	Solubility Mg/L (ppm)*
0	14.6	16	10.0
1	14.2	17	9.8
2	13.8	18	9.6
3	13.5	19	9.4
4	13.1	20	9.2
5	12.8	21	9.0
6	12.5	22	8.9
7	12.2	23	8.7
8	11.9	24	8.6
9	11.6	25	8.4
10	11.3	26	8.2
11	11.1	27	8.1
12	10.9	28	7.9
13	10.6	29	7.8
14	10.4	30	7.7
15	10.2		

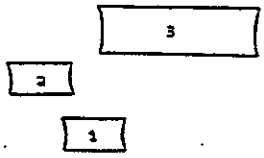
*100% saturation

As is expressed above and in Table 2, amount of dissolved oxygen in the water can vary greatly, depending upon temperature, photosynthesis, wind, light, algae blooms, etc. Very low readings (under 4 ppm) should be rechecked. Super saturated conditions of levels above the maximum listed in Table 2 for a given temperature can occur but should be rechecked. Conditions of high wind or very sunny conditions, combined with large amounts of live plant material, can create super-saturated conditions and should be looked for if this condition is confirmed by a second reading.

DISSOLVED OXYGEN EQUIPMENT

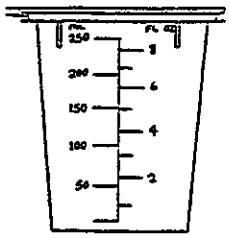


Glass Rod

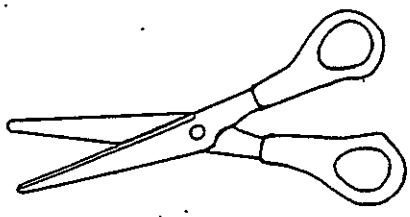


Chemical Pillows

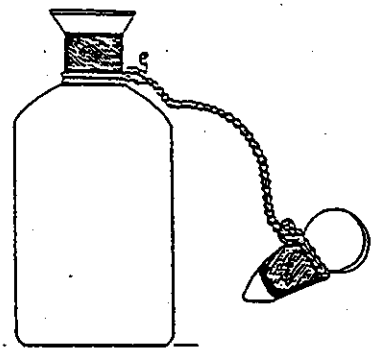
Dropper Bottle



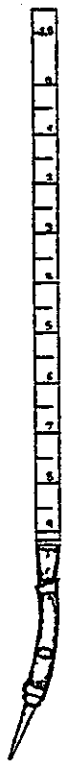
Plastic Beaker



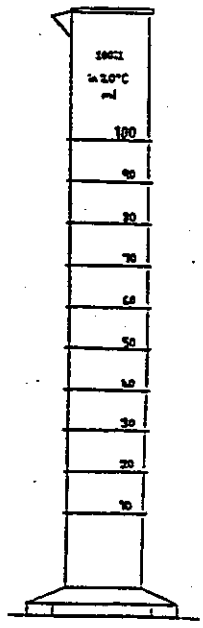
Pillow Cutter



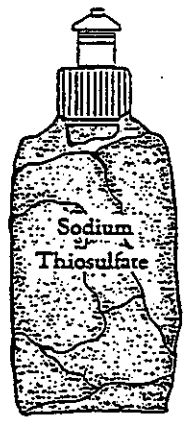
BOD Bottle



Graduated Buret



100 ml Graduated Cylinder



Equipment list:

Dissolved Oxygen Titration

2 graduated burets
2 glass rods
2 glass marbles
2 BOD bottles (glass) and stoppers
1 100 ml graduated cylinder
1 box manganese sulfate pillows
1 box iodide-azide pillows
1 pair scissors or clippers
1 bottle starch solution
1 bag of sulfamic acid pillows
1 bottle sodium thiosulfate
1 plastic beaker

Dissolved Oxygen Procedure:

STEP 1. Release clamp, empty the tubing of bubbles, and insert flow tube from sample bucket into bottle, all the way to the bottom of bottle. Keep track of the amount of time it takes to fill the bottle to the point of overflow, (counting as it fills will be fine), and allow enough time for the bottle to have filled three times. This will allow all air to escape from BOD bottle and give an accurate sample. Replace glass stopper (if carrying sample away from water's edge to do the procedure).

STEP 2. Examine sample to make sure no bubbles are trapped inside. Once a satisfactory sample has been collected, proceed to steps 3 and 4.

NOTE: Be careful not to introduce air into the sample while adding the reagents in steps 4 and 5. Simply drop the reagents into the test sample, cap carefully, and mix gently.

STEP 3. Cut open the manganese sulfate powder **(pillow # 1)** and add to sample.

STEP 4. Cut open the alkaline iodide-azide powder **(pillow # 2)** and add to sample. Add a small marble the bottle before replacing the stopper. Replace stopper, twist 1/4 turn to get a good seal, and place finger on top to hold it on bottle. Invert bottle gently several times to mix reagents with water. A precipitate will form. Place sample aside and allow precipitate to settle to bottom half of bottle. Gently invert bottle to mix and allow to settle again.

NOTE: After finishing STEP 4, go on to your other tests while the sample is settling.

Addition of the marble in STEP 4 has two benefits: first, "topping off" the level of the liquid in the bottle eliminates the air bubble that sometimes forms between the liquid and the stopper. Second, the marble helps to mix in the powered reagents when the bottle is shaken. The marble should be clean and added gently to prevent the possibility of introducing air into the bottle.

Following completion of STEP 4, contact between the water sample and the atmosphere will not affect the test result. Once the sample has been "fixed" in this manner, it is not necessary to perform the actual test procedure immediately. Thus, several samples can be collected and "fixed" in the field, and then carried back to a testing station or laboratory where the titration procedure is to be performed. (make certain samples are kept cool if titrating later)

COMPLETE STEPS 5-12 WITHIN 1 HOUR

STEP 5. Cut open the sulfamic acid **(pillow # 3)** and add to sample. Replace stopper and invert gently several times to mix until precipitate and chemical beads have dissolved. A clear-yellow to brown-orange color will develop, depending on the oxygen content of the sample.

STEP 6. Pour 100 ml of the sample carefully into a clean graduated cylinder. Tilt the cylinder and pour the sample carefully down the inside wall to avoid mixing bubbles into the sample. Then pour the sample from the cylinder into the test beaker, again, carefully pouring down the inside of the beaker.

STEP 7. Fill buret to above the zero mark with sodium thiosulfate titrant, and clear bubbles out of buret. (Make sure liquid fills buret from tip to the zero mark) Refill to zero mark.

STEP 8. Add sodium thiosulfate titrant to sample slowly, stirring as titrant is added. Stop titrating when yellow-brown solution in beaker begins to lighten to a light hay color. (White paper under beaker is used to watch color change.)

STEP 9. Add 8 drops of starch solution to beaker. Sample will turn a dark-blue color.

STEP 10. Now continue the titration process with the sodium thiosulfate remaining in the buret until sample beaker becomes clear. Do not add any more titrant than is necessary to produce the color change. Be sure to stir sample after each drop is added.

STEP 11. Using the scale on the side of the buret, count the total number of ml. used in the titration. Enter this number in the space provided on your data sheet.

STEP 12. Rinse out the beaker, refill buret to zero mark, and repeat steps 7 through 12 on a second sample.

STEP 13. Record results of the second titration in the space provided on data sheets.

STEP 14. Add the results of both titrations = mgL (ppm)

NOTE: These duplicate tests are run to guard against errors in analyses. If the DO results in the second test is 0.3 ml (0.6 mg/L) different than the first test, you should do a third test. Record all three results.

Make sure BOD bottles are rinsed out at the end of testing.

Also make sure glass marbles are cleaned and stored so they do not get lost.

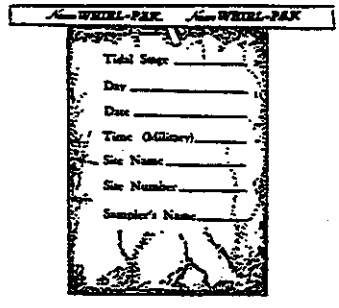
Fecal Coliform

Discussion

Fecal coliform bacteria are used as an indicator of human sewage pollution. While fecal coliforms are found in the feces of all warm-blooded animals, their presence is taken to mean that other, more dangerous bacteria are present. Their presence in high numbers can indicate pollution from improperly treated sewage effluent, waste discharges from boats, improperly functioning or failed septic systems, untreated urban storm water, runoff from agricultural operations, feces from wildlife, or other sources. New Hampshire water quality standards for tidal waters utilize another kind of bacteria (enterococci) to determine if waters are safe for swimming. State standards for tidal shellfish waters, however, do specify acceptable levels of fecal coliforms. While direct application of shellfish water standards to GBW data would not be appropriate, these standards can be used to give a general sense of contamination in the estuary. Fecal coliform tests are performed using the membrane filtration (plate count) method.

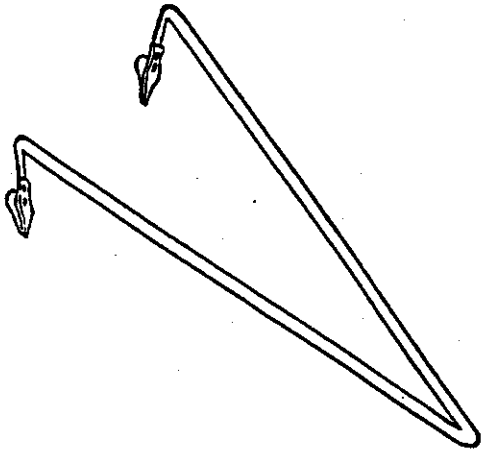
Equipment:

BLACK PERMANENT MARKER

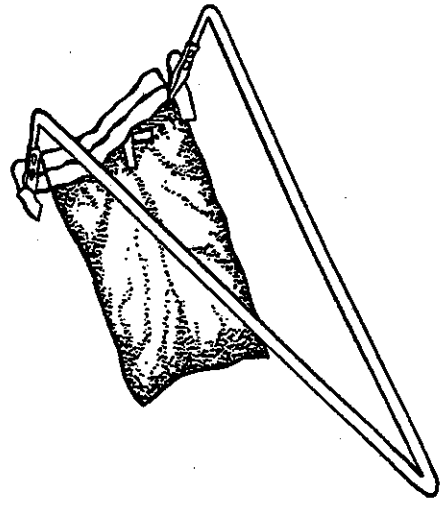


STERILE COLLECTING BAG

(Whirl-Pak)



COLLECTING TONGS



Additional equipment (not pictured) : Cooler and Cold pack

A. EQUPIMENT LIST:

Petri dishes, sterile
Sampling bags
Marking pen
Coliform record sheet
Cool packs/ cooler
Sampling tongs
Spray disinfectant
Water bath incubator
Distilled Water
Filtration flask
Base with stopper
Aluminum foil
Labeling tape
Alcohol
Phosphate buffer
Absorbant filter pads
Membrane filters
Ampules of growth medium
Sterile pipets (10 ml and 1 ml)
Automatic pipeter
Oil lamp/candle
Tissues
U.V. sterilizer
Filter funnel
Filter forceps
Autoclave tape
Vacuum pump

Fecal Coliform Processing Procedure:

B. PREPARATION: (in the lab)

1. Label sampling bags and the bottom of the Petri dishes (the smaller inner diameter plate) with a permanent marking pen. Identify the sample site, date and tide on lab tape.
2. Record the label information on the coliform record sheet.
3. Freeze two cool packs.
4. Check the incubator temperature
5. Make sure that all of filtration equipment and a sufficient supply of petri dishes are sterilized in an autoclave or other stream sterilizer device. The UV bulb should be cleaned with ethanol at least every month. First, place the support stand in the bottom of the sterilizer and make sure that there is 2 inches of water. Wrap all the items to be sterilized in aluminium foil, stick a piece of autoclave tape on it, and place into the bucket. Place the bucket in the sterilizer with the exhaust channel on the right hand side. Make sure there is a thin layer of petroleum jelly along the beveled edge of the lid. This will ensure a tight seal on the sterilizer. The petroleum jelly should be applied every 3 to 4 times the sterilizer is used. Place the lid on the sterilizer by feeding the steam exhaust tube into the exhaust channel of the bucket. Twist the lid so that the engraved marks on the lid and the

sterilizer meet. Tighten the lock nuts, two at a time (opposite from each other) to make a tight seal. Put the exhaust valve in open or verticle postion. Turn the power switch on.

Once stream begins to escape from the exhaust valve (about 20 minutes), it is necessary to wait five minutes to allow the "cold zones" to be flushed out of the sterilizer. Close the exhaust valve by putting it in the horizontal postion. When the pressure gauge reads 17 PSI, it is sterilizing. It must sterilize for at least 35 minutes at this point to completely sterilize the items. After the time is up, just turn the sterilizer off and let the pressure release by carefully lifting the exhaust valve. Use hotpad to release valve.

C. COLLECTING (GRAB) THE SAMPLE: (at the sample site)

1. Make sure the bag is labelled properly with a medium tip perment marker: sample site number, site name, date, day, time of sample taken, tidal stage and sampler's name.
2. Attach the alligator clips of the tongs to the metal tabs of the sterile sampling bag. Curl tab over and pinch clips to secure bag to the tongs. Note: The use of gloves here is optional. Finally, tug bottom of bag to make certain the bag is securely held.
3. Remove top of bag perforation strip. Be sure the bag is secure on the clips. (Do not touch the bag opening with fingers, or gloves as this will contaminate the sample.) DO NOT TOUCH THE MOUTH, OR INSIDE OF THE BAG!
4. Plunge the bag into the water to a depth of about 12 inches. You should use your other hand to support the bottom of the bag, to ease the weight off of the tabs.
5. Open the bag now by releasing the handles apart, and fill the bag. Close the bag when returning to the surface.
6. Immediately remove the filled bag from the water and pinch the bottom of the bag to ensure an air space over the surface of the water. (You want the bag to be about 2/3 the way full.)
7. Now spin the bag over itself several times, so that water won't leak out. Finally, remove the clips and twist the metal tabs together like a braclet since sharp ends could puncture other samples.

8. Refrigerate the samples in a cooler with a cold pack. Bring samples to your assigned location, Kingman Farm. If you need the sample picked up, please call Ann at Kingman Farm (749-1565), or home (749-3880).

9. Ideally, samples should be processed within one hour. If this is not possible the samples may be refrigerated below 10 degrees C and may be held up to six hours.

10. To review this procedure you may borrow the Processing Fecal Colifrom video.

D. PROCESSING THE SAMPLE: (in the lab)

1. Check the incubator temperature, it should be 44.5 (+/- 0.2) degrees C.

2. Disinfect the working surface with Lysol spray disinfectant or alcohol. **Wash your hands.**

3. UV-sterilize all filtration equipment for at least 10 minutes. The filtration apparatus should be placed in the UV-sterilizer with the inside of the funnel facing towards the bulb. Place the filter funnel base into the flask.

4. To begin processing the sample, remove the cover of the petri dish and pack up side down on the lab surface. **It is important to make sure that you do not touch the inside of the petri dish at any time.** Place a sterile absorbent pad aseptically into the bottom of the petri dish, by using the sterile pad dispenser. Twist the cap off of the plastic ampule. Then squeeze the nutrient medium onto the absorbent pad. Note: It is not necessary to get every drop of the medium.

5. Sterilize a pair of forceps by dipping them open into a container of alcohol and then flaming them. Using a pair of sterile forceps, place a membrane filter on the steel support of the filtration assembly. Keep the filter flat, grid side up, and discard the blue protective paper. Place the funnel over the filter. Rinse a little buffer solution into the funnel and allow it to drip into the glass base. Check for leaks. If there is a leak, remove the funnel and reattach. For the first run (as a blank), simply filter a bottle of buffer solution to test the setup for possible contamination.

6. Shake the bag containing the sample 20-30 times to thoroughly mix. Open the sample bag and pipet the desired dilution amount into a fresh bottle of buffer solution. Slowly pour the diluted sample into the filter funnel.

7. Filter the sample using a vacuum pump or hand pump. When the water is completely filtered, rinse the inside of the funnel with a new bottle of phosphate buffer solution. This is to ensure that all of the coliform is washed onto the filter.

8. Use alcohol to sterilize forceps before lifting membrane from filter. After lifting the funnel, remove the membrane filter from the support with sterile forceps. Place the filter to the absorbent pad in the Petri dish grid side up. NOTE: The filter should be placed on the pad using a "rolling action"; touching one end first and proceding to the other side. Be careful to avoid trapping air bubbles under the membrane. Remember to replace the Petri dish cover. After replacing the cover to the petri dish, tap the bottom of the dish to get the nutrient medium to go into the membrane.

9. Between site samples, UV-sterilize the funnel, filter, and forceps for three minutes.

10. To process the next sample, rinse the bottom of the funnel with sterile phosphate buffer. Clean the steel support and funnel with alcohol. Wipe excess water from the steel support with a tissue. Wash your hands between each sample.

11. Filter a sample of buffer at the end of a series of samples as a negative control. Other controls might be duplicating a sample or performing split samples with another filtering location. Run blacks filtration of buffer in the middle of the testing, after every 10 filtrations. This will allow for the data before the middle test to be valid in case the end control came up postive.

12. Enclose the Petri dishes in a tightly closed and labelled Whirlpack bag. You may place up to four dishes in a bag (stacked two on top of each other, two deep).

13. Once a series of samples has been filtered and the Petri dishes bagged, slide the bags into the Petri dish rack. Make sure that the petri dishes are placed upside down. This is so that the condensation that forms does not ruin the sample. Submerse the rack in a water incubator set exactly at 44.5 C for 24 hours.

14. After 24 hours (+/- two hours), remove the dishes and count the number of blue colonies with a metallic sheen which have grown on the filter paper. Use the 10x power on a dissecting microscope if available. This gives an approximation of the number of fecal coliform bacteria in 100 mL of water.

15. Record the number of colonies per 100 mL sample on the data sheet for each sample. To do this use this formula:

    # of colonies X 100mL
    ---------- = colonies/100mL
    # of mL used in sample

16. When you are done counting the colonies, sterilize the plates for 35 minutes to kill the bacteria. Dispose of filters or refrigerate for later viewing.

17. After sterilizing the plates, simply dispose of the pad and filter properly and wash in plain hot water. Note: You will have to resterilize the dishes before using them again.

E. TROUBLESHOOTING: (some helpful hints)

1. If there's a ring around the filter, you probably did not have the filtration assembly closed properly.
2. If colonies do not look rounded, the water was not completely filtered.
3. There might be some other colonies present on the filter besides the blue colonies with the metallic sheen (most likely to be yellow). That's OK - they are bacteria other than fecal coliforms. However, do not include them in your count on the data sheet.
4. The accepted range for colonies to be counted on a membrane filter is 20-80 colonies. If you have more than 200 colonies, use a smaller dilution or write TNTC (Too Numerous To Count).

Table 3: Suggested Sample Volumes for Membrane Filter Fecal Colifrom Test (Taken from Standard Methods)

	Volume (X) To Be Filtered (ml)						
Water Source	**100**	**50**	**10**	**1**	**0.1**	**0.01**	**0.001**
Lakes, reservoirs	X	X					
Wells, spring	X	X					
Water supply intake		X	X	X			
Natural bathing waters		X	X	X			
Sewage Treatment Plant			X	X	X		
Farm Ponds, rivers				X	X	X	
Stormwater runoff				X	X	X	
Raw municipal sewage					X	X	X
Feedlot runoff					X	X	X

Sample processed by: _____ Date: _____ ← Incubator Temperature: _____
Examined by: _____ Date: _____ ← Incubator Temperature: _____

Site #	Site Name:	Sampler Name:	Time of Sample:	Tidal Stage:	Dilution:	Fecal Coli. Count:	/100ml Count:	Other Colonies:	Incubate Times: IN:	OUT:	Comments:

5/24/93

GREAT BAY WATCH TIP SHEET

WATER TEMP:

- Make sure thermometer is in the water for 3 minutes and read while still in the water.
- Read the thermometer while it is straight up and down (option: flat)

STARTED THE D.O. TEST?

- is the tube touching the bottom of the BOD bottle when decanting water from the bucket?
- did you count the seconds it takes to fill the bottle and then let it overflow twice more?
- did you remove the tube slowly?
- Is the bottle full after removing the tube?
- add pillow #1, followed by #2. THEN, stopper the bottle. was the bottle agitated properly?
- are there air bubbles trapped inside? (start over if there are).

pH

- is calibration correct?
- are the bottles in order?
- have you remembered to bring a container of fresh water?
- are the buffer bottles filled?
- did you remove black cap from the meter to measure the pH?
- did you throw out the rinse AFTER A DAY'S SAMPLING and clean and dry bottles?
- did you follow directions for new "test "buffer pH 7?

SALINITY:

- did you fill below the lip on the cylinder?
- did you put thermometer and hydrometer into the cylinder at the same time?
- did you wait three minutes to read the thermometer?
- did you remove the thermometer before trying to read the hydrometer?
- did you read from the bottom of the meniscus in reading the hydrometer?
- did you use chart on record sheet and mark the water line?
- did you use the temp chart and salinity conversion charts correctly?

BACK TO D.O. TEST

- did you add the third pillow -- make sure grains are dissolved?
- did you pour down the side of the cylinder rather than dumping water?
- did you fill burette to zero?
- did you clear the bubbles?
- did you add titrant carefully and stir?
- did you add 8 drops of starch?
- is the color completely clear?
- did you do the test twice?

Clean equipment and dry.

Put equipment away properly.

References

1. New Hampshire Office of State Planning, Linda Maxson, Jackson Estuarine Laboratory. 1989. ***Great Bay National Estuarine Research Reserve Management Plan***. p.7.

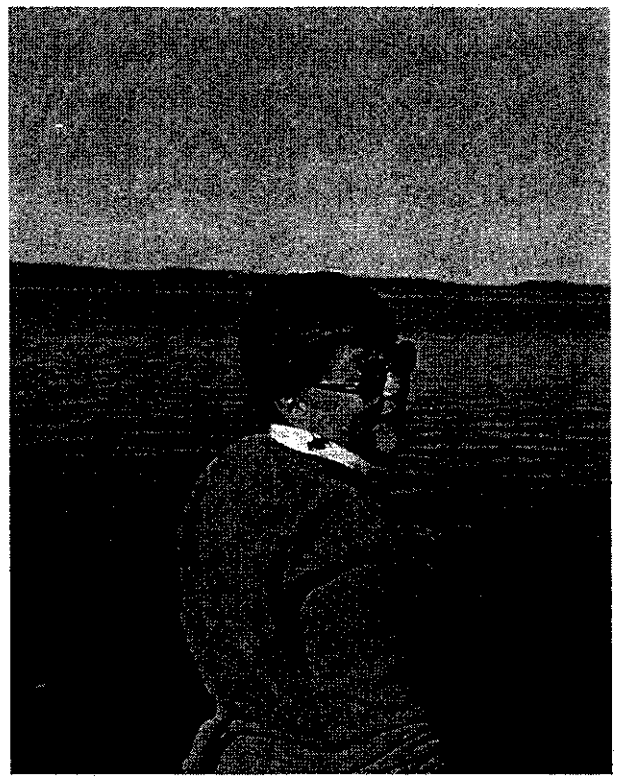
2. Ibid.

3. Anne Arundel County, Office of State Planning and Zoning, Annapolis, Maryland. ***1986 Citizen Monitoring Water Quality Monitoring Manual***. p.3,4, intro.

4. Ibid. NHOSP.

5. Maine/New Hampshire Sea Grant Marine Advisory Program and University of Maine; Orono, Maine. Nov. 1992. ***Clean Water: A Guide to Water Quality Monitoring***. p. 47,48,49.

APPENDICES



To mail: Great Bay Watch, Sea Grant Extension
Kingman Farm
Durham, NH 03824-3512
To call: (603) 749-1565
Sharon's Home Phone (603) 659-5441
Ann's Home Phone (603) 749-3880

TENTATIVE DRAFT

Dates to Remember for the 9th Season
Great Bay Watch

Feb	20	Fri	Annual Report to Printers	
Mar	4	Wed	Annual Meeting at NH Fish and Game, Durham	7:00pm-9:00pm
	11	Wed	Training New Watchers, Students and Adults	2:45pm-5:15pm
		or		
	12	Th	Data Sheets, Salinity, pH, Secchi	6:00pm-8:30pm
		and		
	18	Wed	Training New Watchers, Students and Adults	2:45pm-5:15pm
		or		
	19	Th	D.O., Fecal, Temperature, etc.	6:00pm-8:30pm
	25	Wed	Combination Meeting/Retraining, Phytoplankton Lecture	6pm-8:00pm
	26	Th	Phytoplankton Workshop	9:00am-1:00pm
Apr	8	Wed	Technical Advisory Meeting	3:00pm-5:00pm
	15	Wed	QAQC	12:30pm-6:30pm
		or		
	16	Th	1 Hour Sign-ups	12:30pm-6:30pm
	22	Wed	Field training	10am-1:30pm
May		6 Wed	Monthly Meeting	7:00pm-8:30pm
	12	Tue	**Sampling**	6:29am-5:43pm
	19, 20, 21		Possible Shoreline Surveys	noonish, TBA
June	3	Wed	Monthly Meeting	7:00pm-8:30pm
	10	Wed	**Sampling**	6:03am-3:00pm
	16, 17, 18		Possible Shoreline Survey	noonish, TBA
July	1	Wed	Monthly Meeting	7:00pm-8:30pm
	9	Th	**Sampling**	5:30am-4:00pm
	14, 15, 16		Possible Shoreline Survey	midmorning,TBA
	28, 29, 30		Possible Shoreline Survey	midmorning,TBA
Aug	2-9	Sun-Sat	NMEA Conference	Puerto Rico
	10	Mon	**Sampling**	
	19/20	Wed/Th	QAQC	12:30pm-6:30pm
Sept	2	Wed	Monthly Meeting	7:00pm-8:30pm
	9	Wed	**Sampling**	7:30am-5:00pm
	16	Wed	Technical Advisory Meeting	3:00pm-5:00pm
	19	Sat	International Coast Clean-up	
Oct	7	Wed	**Sampling**	6:23am-3:30pm
	14	Wed	Monthly Meeting	7:00pm8:30pm
Nov	5	Th	**Sampling**	6:00am-4:00pm
	18	Wed	Chili and Chowda Festival	6:00pm-8:30pm
Dec			Report Writing	
			QAQC Data Entry	
			Grant Writing	
			Holidays	

March

1998

Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	2	3	4 Annual Meeting	5	6	7
8	9	10	11 Training new watchers 2:45 - 5:15 pm	12 Training new watchers 6:00 - 8:30 pm	13	14
15	16	17	18 Training new watchers 2:45 - 5:15 pm	19 Training new watchers 6:00 - 8:30 pm	20	21
22	23	24	25 Meeting, and Phytoplankton lecture 6 -8 pm	26	27	28
29	30	31				

April

1998

Sun	Mon	Tue	Wed	Thu	Fri	Sat
			1	2	3	4
5	6	7	8 Technical Advisory Meeting 3 - 5 pm	9	10	11
12	13	14	15 QA Sign up for 12:30-	QC one hour 6:30 pm	17	18
19	20	21	22 Field Training 10 am - 1:30 pm	23	24	25
26	27	28	29	30		

Lh

May

1998

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					1	2
3	4	5	6 Monthly Meeting 7 - 8:30 pm	7	8	9
10	11	12 SAMPLING !	13	14	15	16
17	18	19 Possible	20 Shoreline noonish, TBA	21 Survey	22	23
24	25	26	27	28	29	30
31						

June

1998

Sun	Mon	Tue	Wed	Thu	Fri	Sat
	1	2	3 Monthly Meeting 7 - 8:30 pm	4	5	6
7	8	9	10 SAMPLING !	11	12	13
14	15	16 Possible	17 Shoreline noonish, TBA	18 Survey	19	20
21	22	23	24	25	26	27
28	29	30				

July

1998

Sun	Mon	Tue	Wed	Thu	Fri	Sat
			1 Monthly Meeting 7 - 8:30 pm	2	3	4
5	6	7	8	9 SAMPLING !	10	11
12	13	14 Possible	15 Shoreline midmorning, TBA	16 Survey	17	18
19	20	21	22	23	24	25
26	27	28 Possible	29 Shoreline midmorning, TBA	30 Survey	31	

August

1998

Sun	Mon	Tue	Wed	Thu	Fri	Sat
						1
2 NME	3 A	4 CO	5 NFER	6 ENCE:	7 PUER	8 TO RI CO
9	10 SAMPLING !	11	12	13	14	15
16	17	18	19 QA Sign up for 12:30-	QC one hour 6:30 pm	21	22
23	24	25	26	27	28	29
30	31					

September

1998

Sun	*Mon*	*Tue*	*Wed*	*Thu*	*Fri*	*Sat*
		1	2 **Monthly Meeting** **7 - 8:30 pm**	3	4	5
6	7	8	9 **SAMPLING !**	10	11	12
13	14	15	16 **Technical Advisory Meeting** **3 - 5 pm**	17	18	19 **International Coast Cleanup**
20	21	22	23	24	25	26
27	28	29	30			

October

1998

Sun	Mon	Tue	Wed	Thu	Fri	Sat
				1	2	3
4	5	6	7 SAMPLING !	8	9	10
11	12	13	14 Monthly Meeting 7 - 8:30 pm	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

November

1998

Sun	*Mon*	*Tue*	*Wed*	*Thu*	*Fri*	*Sat*
1	2	3	4	5 SAMPLING !	6	7
8	9	10	11	12	13	14
15	16	17	18 Chili & Chowda Festival	19	20	21
22	23	24	25	26	27	28
29	30					

December

1998

Sun	Mon	Tue	Wed	Thu	Fri	Sat
REPORT WRITING	QAQC Data Entry	1	2	3	4	5
6	7 H	8 A	9 P	10 P	11 Y	12
13 H	14 O	15 L	16 I	17 D	18 A	19 Y
20	21	22	23	24	25	26
27	28	29	30	31	GRA NT WRIT ING	

Great Bay Watch 1997 Sampling Season

idal and Sampling Times for 1998 Season

		adjustment	12-May	10-Jun	9-Jul	10-Aug	9-Sep	7-Oct	5-Nov
ow			6:29 AM	6:03 AM	5:34 AM	7:13 AM	7:37 AM	6:23 AM	5:01 AM
gh			12:43 AM	12:16 PM	11:47 PM	12:55 PM	1:52 PM	12:37 PM	11:58 PM
ite 1 - Peninsula - Oyster River	LOW	1:50	8:19	7:53	7:24	9:03	9:27	8:13	6:51
	HIGH	1:45	2:28	14:01	1:32	14:40	15:37	14:22	1:43
ite 2 - Jackson Laboratory	LOW	2:00	8:29	8:03	7:34	9:13	9:37	8:23	7:01
	HIGH	2:00	2:43	14:16	1:47	14:55	15:52	14:37	1:58
ite 3 - Lamprey River	LOW	3:00	9:29	9:03	8:34	10:13	10:37	9:23	8:01
	HIGH	2:40	3:23	14:56	2:27	15:35	16:32	15:17	2:38
ite 4 - Depot Road (Sandy Pt) *	LOW	2:45	9:14	8:48	8:19	9:58	10:22	9:08	7:46
	HIGH	2:45	3:28	15:01	2:32	15:40	16:37	15:22	2:43
ite 5 - Portsmouth Country Club	LOW	2:40	9:09	8:43	8:14	9:53	10:17	9:03	7:41
	HIGH	2:20	3:03	14:36	2:07	15:15	16:12	14:57	2:18
ite 6 - Fox Point	LOW	2:00	8:29	8:03	7:34	9:13	9:37	8:23	7:01
	HIGH	2:00	2:43	14:16	1:47	14:55	15:52	14:37	1:58
ite 7 - Cedar Point	LOW	1:50	8:19	7:53	7:24	9:03	9:27	8:13	6:51
	HIGH	1:55	2:38	14:11	1:42	14:50	15:47	14:32	1:53
ite 9 - Cocheco River	LOW	1:20	7:49	7:23	6:54	8:33	8:57	7:43	6:21
	HIGH	1:20	2:03	13:36	1:07	14:15	15:12	13:57	1:18
ite 10 - Piscataqua River	LOW	1:20	7:49	7:23	6:54	8:33	8:57	7:43	6:21
	HIGH	1:20	2:03	13:36	1:07	14:15	15:12	13:57	1:18
ite 11 - Coastal Marine Lab	LOW	0:16	6:45	6:19	5:50	7:29	7:53	6:39	5:17
	HIGH	0:16	13:59	12:32	1:03	13:11	14:08	12:53	1:14

Revised 3/9/98

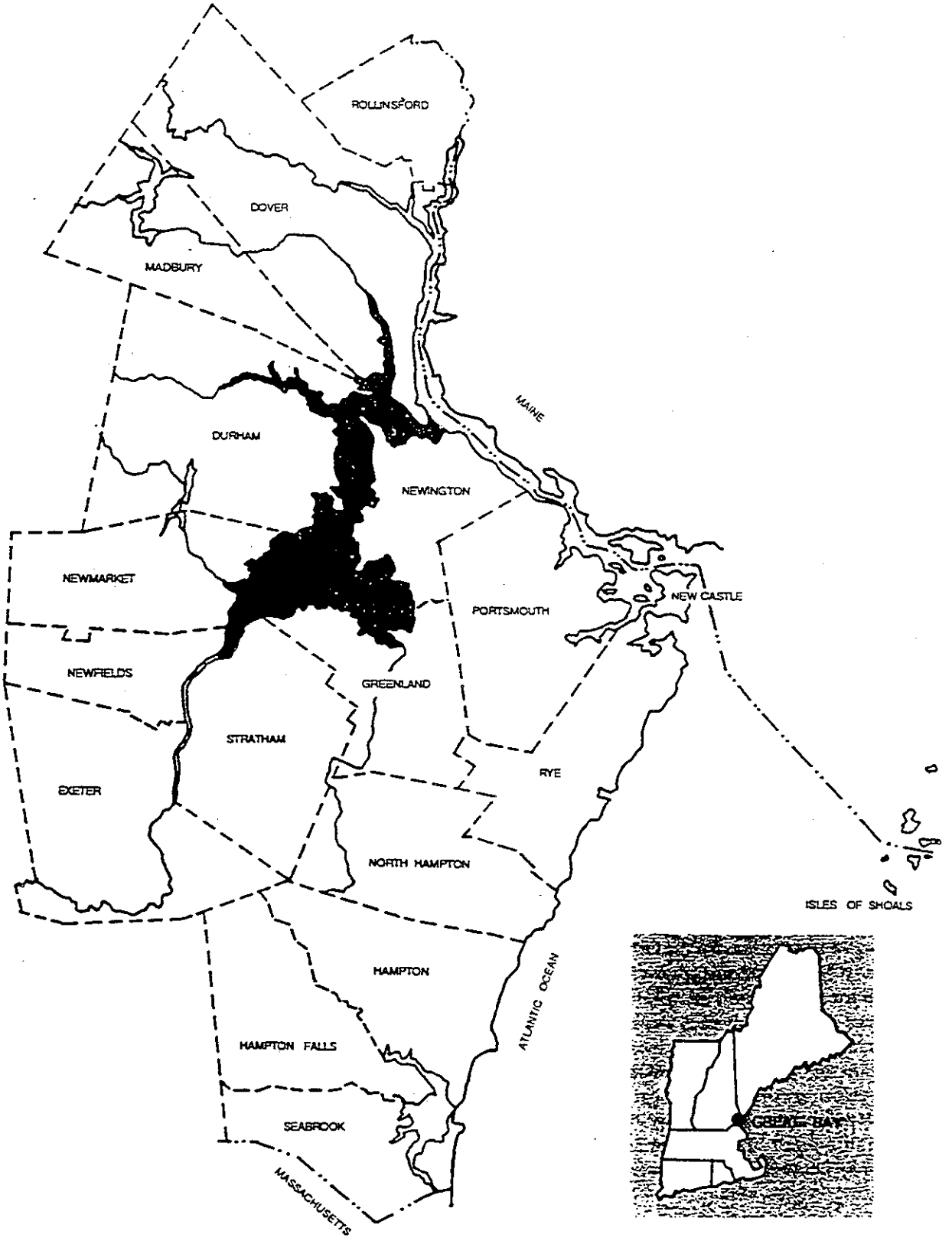
Great Bay Watch 1997 Sampling Season

		adjustm	12-May	10-Jun	9-Jul	10-Aug	9-Sep	7-Oct	5-N
Site 12 - Newmarket STP	LOW	3:00	9:29	9:03	8:34	10:13	10:37	9:23	8
	HIGH	3:00	3:43	15:16	2:47	15:55	16:52	15:37	2
Site 13 - Marina Falls Landing	LOW	3:00	9:29	9:03	8:34	10:13	10:37	9:23	8
	HIGH	3:00	3:43	15:16	2:47	15:55	16:52	15:37	2
Site 14 - Fowler's Dock	LOW	3:00	9:29	9:03	8:34	10:13	10:37	9:23	8
	HIGH	3:00	3:43	15:16	2:47	15:55	16:52	15:37	2
Site 15 - Patten Yacht Yard, Inc.	LOW	1:00	7:29	7:03	6:34	8:13	8:37	7:23	6
	HIGH	1:00	1:43	13:16	1:47	13:55	14:52	13:37	1
Site 16 - Exeter Docks	LOW	2:50	9:19	8:53	8:24	10:03	10:27	9:13	7
	HIGH	3:10	3:53	15:26	2:57	16:05	17:02	15:47	3
Site 17 - Dover Foot Bridge	LOW	2:50	9:19	8:53	8:24	10:03	10:27	9:13	7
	HIGH	3:10	3:53	15:26	2:57	16:05	17:02	15:47	3
Site 18 - Maplewood Ave	LOW	1:16	7:45	7:19	6:50	8:29	8:53	7:39	6
(NMPA)	HIGH	1:16	1:59	13:32	1:03	14:11	15:08	13:53	1
Site 19 - Bartlett St.	LOW	1:16	7:45	7:19	6:50	8:29	8:53	7:39	6
(NMPA)	HIGH	1:16	1:59	13:32	1:03	14:11	15:08	13:53	1
Site 20 - Junkins Ave.	LOW	1:16	7:45	7:19	6:50	8:29	8:53	7:39	6
(FOSE)	HIGH	1:16	1:59	13:32	1:03	14:11	15:08	13:53	1
Site 21 - Pleasant St.	LOW	1:16	7:45	7:19	6:50	8:29	8:53	7:39	6
(FOSE)	HIGH	1:16	1:59	13:32	1:03	14:11	15:08	13:53	1

Revised 3/9/98

ENDIX IV GREAT BAY MAP

Figure 1. LOCATION OF GREAT BAY IN NEW ENGLAND



New Hampshire Office of State Planning

APPENDIX V
Environment of the Great Bay Estuary

1. GENERAL DESCRIPTION

An estuary is defined as a coastal area where freshwater inflow mixes with seawater (Ketchum 1951)*. As a result, the primary parameter structuring the estuarine environment is salinity variation. Within northern temperate estuaries (e.g. the Great Bay estuary) substantial salinity variations occur on diurnal (tidal), monthly (lunar) and annual (seasonal) scales. Additionally, there may be episodic low salinity extremes produced by rainfall or spring snow/ice melt. The characteristics of the drainage basin surrounding an estuary further distinguish the variability of salinity regimes by affecting runoff amounts and patterns. Organisms that occur within estuaries must be able to tolerate or avoid salinity extremes.

Estuaries may be formed as a result of several geological processes. The most common estuarine type is the drowned river valley formed by rising sea level inundating an existing river drainage. Locally, sea level has been rising since the end of the last glaciation resulting in the formation of numerous Gulf of Maine estuaries, including Great Bay (Texas Instruments, Inc. 1974). The Great Bay estuary, extending 25 km (15 mi) (Brown and Arellano 1979) from the coast at New Castle, NH, to the upper Great Bay, represents a major geographic feature of the southeastern New Hampshire coastal zone (Figure 1). Historically, the economic development of many parts of coastal New Hampshire have been intimately tied to the ability of commerce to utilize Great Bay as an inexpensive route to the ocean. Additionally, substantial harvests of finfish and shellfish have come directly from the Bay. In spite of the major historical economic uses of Great Bay itself and the surrounding drainage basins, the estuary remains a relatively pristine and healthy environment. In view of the substantial human impact (e.g. pollution and wetland loss) on many estuaries in the middle Atlantic region of the coastal US, Great Bay offers an important example of an essentially unperturbed, natural estuarine ecosystem. Relatively little salt marsh surrounding Great Bay has been lost to development. Although there are historic references to the impact of water-born particulate pollutants (e.g. sawdust) negatively impacting Great Bay mudflat communities (Jackson 1944), these practices have long since ended.

The Great Bay estuary derives its freshwater inflow from seven major rivers (Table 2). Three of these flow directly into Great Bay, i.e. the Lamprey, Squamscott and Winnicut Rivers. The remainder flow into the estuary between Furber Strait and the open coast, i.e. the Salmon Falls, Cocheco, Bellamy, and Oyster Rivers. Even so, the flows from the latter four rivers directly affects Great Bay through tidal flushing. Overall, the seven rivers drain an area of 2410 km^2 (930 mi^2), two-thirds of which is located within New Hampshire, the remainder being in southern Maine (Reichard and Celikkol 1978). Estuarine tidal waters cover approximately 45 km^2 (17 mi^2) with a 161 km (100 mi) shoreline. Because of the dynamic nature of an estuary, pollution at any point within the drainage basin or throughout the estuary itself will ultimately impact the entire system. Thus, it is important to acknowledge the need to manage an estuary as a total system rather than an individual embayment.

Table 2 Drainage Areas of Rivers Entering the Great Bay Estuary
(Modified from Brown and Arellano 1979)

River Basin	Km^2	Mi^2
Lamprey	542.6	209.5
Squamscott	331.0	127.8
Oyster	78.0	30.1
Bellemy	85.0	32.8
Cocheco	471.6	182.1
Salmon Falls	392.4	151.5
Piscataqua	414.4	160.0

The Great Bay estuary (Figure 2) extends from the mouth of the Piscataqua River between Kittery, Maine, and New Castle, New Hampshire, inland to the junction of Little Bay and the Piscataqua. Little Bay extends from Dover Point turning sharply at Cedar and Fox Points near the mouth of the Oyster River. Little Bay ends at Furber Strait near Adams Point. Great Bay begins immediately inland or "upstream" of Furber Strait. Thus, while the GBNERR only includes Great Bay proper, an increased understanding of the interconnection and dependency of Great Bay to the other segments of the estuarine system is crucial to management of the Reserve.

Great Bay (Figure 2), starting at Furber Strait, is a large, shallow, estuarine embayment having a tidal volume of 393 x 106 m^3 (EBASCO Services, Inc. 1968). The Bay has an average depth of 2.7 m (8.85 ft), however, deeper channels extend to 17.7 m (58 ft). Channels from the Lamprey, Squamscott and Winnicut Rivers intersect near the center of the Bay to form the main channel which connects to

Little Bay at Furber Strait. Strong tidal currents occur at Furber Strait since the tidally flushed water from Great Bay must pass through a restricted outlet. A similar tidal flow restriction occurs at Dover Point where Little Bay meets the Piscataqua River. At this site the channel is 430 m (0.27 mi) wide with a maximum depth of 10.5 m (34 ft). The Great Bay estuary has a low tide volume of 166 x 106 m^3 and a high tide volume of 230 x 106 m^3 (Brown and Arellano 1979).

The water surface of Great Bay covers 2307 x 104 m2 (8.9 mi^2) at mean high water and 1093 x 104 m^2 (4.2 mi^2) at mean low water (Turgeon 1976). Approximately 50% of the aerlal surface of Great Bay is exposed as mudfiat at low tide. Additionally, extensive intertidal salt marsh borders much of the mouth of the Squamscott River, Crommett and Lubberland Creeks. Several small islands (i.e. Nannie, Swan, Vols, and the Footman Islands) occur within the Bay.

2. METEOROLOGY

The average annual air temperature in the Great Bay area is 7.8° C (46° F). Monthly average air temperatures vary from 20° to 22.8° C (68° to 73° F) in July and August to -7.8° to -2.8° C (18° to 27° F) in January and February (NH Water Supply and Pollution Control Commission 1975).

Average annual precipitation in the Durham area during 1941 to 1970 was 41.55 in. (1.06 m) (Normandeau Assoc., Inc. 1975). Only minor differences in precipitation (i.e. approximately 1 in., 0.025 m) occur between months. February is the driest and November the wettest month (Texas Instruments, Inc. 1974). The driest year on record was 1941 with 23.95 in (0.61 m) precipitation and the wettest year was 1954, 60.18 in. (1.53 m) (Texas Instruments, Inc. 1974). Snowfall in Durham averages 56 in (1.42 m) (NH Water Supply and Pollution Control Commission 1975).

Winds are predominantly from the west and northwest. However, in July southeasterly winds prevail (Texas Instruments, Inc. 1974).

3. GEOLOGY

The region surrounding the Great Bay is included in the Seaboard Lowland section of the New England Province (Fenneman 1938, Novotny 1969). Elevations in the area are generally under 200 ft. Most hills are either bedrock covered with glacial till or drumlins.

The most recent glaciation of the area ended during the Wisconsin stage of the Pleistocene epoch (10,000 to 20,000 yr B.P.) (Texas Instrument, Inc. 1974). The glaciation proceeded through the area in a southeasterly direction, resulting in the orientation of the many drumlins in the area. Substantial amounts of glacial till were deposited as the glacier receded.

Bedrock surrounding Great and Little Bays is primarily metamorphic, consisting of dark-gray slate of the Kittery formation visible as outcrops along the northern and western shores and in the Pierce Point area of Greenland. The Eliot formation, also dark-gray slate, can be seen along the shores of Stratham and Newington. A fold in the Eliot formation, the Great Bay syncline, passes through Newington to Thomas Point, under Great Bay, then into Stratham near Bracketts Point. Immediately to the north and west of Great and Little Bays, a granitic intrusion of Exeter diorite comprising the Exeter plutonic (i.e. part of the Hillsboro plutonic series) is present (Novotny 1969). Large outcrops of the slate described above serve as an important source of stable substratum for macroalgal attachment and contribute to the shingle beach common around Great Bay.

Crustal depression in New Hampshire from glacial weight was on the order of 12.2 m (40 ft). After glacial melt, crustal rebound occurred and is complete today. The Seacoast Region of New Hampshire rebounded approximately 61 m (200 ft) after the loss of the glacial overcover. However, the uplift was not uniform throughout the region and Great and Little Bays represent a sag in the surface (Novotny 1969). The low-lying area was filled by rising sea level from glacial melting. Thus, the Great Bay estuary is representative of a drowned river valley.

Present sea level was reached approximately 3,000 to 5,000 years B.P. During the period 6,300 to 3,400 yr B.P. sea level rise in the Northeast was on the order of 0.80 m (31.5 in) per 100 yr. For the past 3,000 years this rate has slowed to 0.035 m (1.4 in.) per 100 yr. Projections of further sea level rise by the year 2100 range from 0.55 to 3.44 m (1.8 to 11.3 ft) (NH Office of State Planning 1987).

A major feature of North temperate estuaries is the presence of extensive intertidal mudflats. Approximately one-half of Great Bay is exposed at low tide; most of the intertidal area is mudflat. The fine sediment brought into the estuary primarily by river runoff and shore erosion is deposited in the relatively calm estuarine environment resulting in extensive intertidal flats. Tidal currents are of greatest influence within the channels and minimize subtidal sediment deposition. A marked seasonal variation of sediment deposition resuspension occurs throughout the Great

Bay (Anderson 1983). During winter, ice cover of the intertidal zone minimizes sediment resuspension. However, spring ice out and subsequent wind mediated erosion result in substantial movements of resuspended sediment (Anderson 1983). Bioturbation and sediment-binding by algal mats rather than physical processes predominate during summer months. As temperatures decrease during the fall biological processes become less important and storm mediated resuspension again causes intertidal flat erosion (Anderson 1983).

Soil associations surrounding Great Bay include Merrimac-Buxton along the south and east shores of Newington and Greenland, Hollis-Warwick-Buxton in Greenland and Stratham, and Hollis-Charlton-Buxton-Merrimac-Scantic from Stratham through Newfields and Newington to Durham (Texas Instruments, Inc. 1974). The Merrimac-Buxton association consists of soils that are nearly level or gently sloping and are well-drained on glacial till or moderately well-drained on silts and clays. The Hollis-Warwick-Buxton soil association consist of well-drained soils on shallow glacial till or silts and clays. Hollis-Charlton-Buxton-Merrimac-Scantic soils are shallow to deep, excessively drained to well-drained soils in upland areas as well as moderately well-drained to poorly drained soils of marine silt and clay deposits (Texas Instruments, Inc. 1974) .

4. HYDROLOGY

The major sources of freshwater inflow are the seven rivers entering the Great Bay estuary (described above). River flow varies seasonally with the greatest volumes occurring as a result of spring runoff. However, throughout most of the year, the tidal component in the estuary dominates over freshwater influence. Thus, freshwater input represents only 2% or less of tidal prism volume (Reichard and Celikkol 1978, Brown and Arellano 1979) although the percentage varies seasonally.

Stream flow entering the Great Bay estuary is gauged at the Oyster, Lamprey, and Salmon Falls Rivers (Normandeau Assoc., Inc. 1975). Historical river flow data are presented in Table 3. Approximately 50% (i.e. 0.508 m, 20 in) of the average annual precipitation in the Great Bay estuary drainage basin enters the estuary as stream flow (NH Water Supply and Pollution Control Commission 1975).

Great Bay is a mesotidal estuary with the average tidal range varying from 2.5 m (8.2 ft) at the mouth of the estuary to 2.0 m (6.6 ft) at Dover Point, increasing slightly to 2.1 m (6.9 ft) at the mouth of the Squamscott River (Reichard and Celikkol 1978). Differences in tidal phase and amplitude are minor between Dover Point and the Squamscott River (Reichard and Celikkol 1978). Tidal currents are greatest at Dover Point and in the Piscataqua River (1.5 to 2.0 m/s) and decrease in Little Bay (0.75 m/s). Because of the channel restriction at Furber Strait, the currents here are greater than in Little and Great Bays. Thus, speeds of 1.0 m/s or greater occur at Adams Point but decrease to 0.5 m/s in Great Bay (Reichard and Celikkol 1978). Due to the Coriolis effect on water movement, flood tide currents are concentrated on the north and west shores of Great and Little Bays while ebb tide currents are on the eastern shore. Strong tidal currents act to limit vertical stratification throughout the estuary during most of the year. Partial stratification may occur during periods of intense freshwater runoff, particularly at the upper tidal reaches of rivers entering the Bay.

The flushing time for water entering the head of the estuary is 58 tidal cycles (26.0 days) during low river flow and 48.5 (25.1 days) during high river flow (Brown and Arellano 1979). Turgeon (1976) estimated a flow time of four days for a particle to traverse 4 km (2.5 mi) in the mid-estuary.

Water temperature and salinity vary seasonally and diurnally (with the tidal cycle). Within Great Bay salinity may vary from essentially 0 °/°° during extreme spring runoff to 30 °/°°. Similarly, temperature has a marked pattern of seasonal variation from a winter low of -1.9° C (freezing point of salt water) to 28°-30° C in the summer. The relative shallowness of Great Bay allows for rapid warming in the spring-summer and cooling in the autumn-winter. Time series analyses of hydrographic trends in the Great Bay estuary during 1973 to 1982 showed significant changes in water temperature and salinity (Loder et al. 1983a). Over the period studied, water temperature in Great Bay decreased 0.17° C per year while salinity rose (at Dover Point) 0.34 °/°° per year (Loder et al. 1983a). Both trends, i.e. to colder more saline water, may be indicative of either local river-flow changes or regional trends affecting the Gulf of Maine (Loder et al. 1983a).

A long-term database of dissolved nutrient concentrations throughout the Great Bay estuary has been collected by the Jackson Estuarine Laboratory and the University of New Hampshire (Norall and Mathieson 1976, Loder and Glibert 1977, Daly et al. 1979, Daly and Mathieson 1979, Loder et al. 1979, 1983a, 1983b, Norall et al. 1982). Dissolved nitrate, nitrite, ammonia, phosphate (total and reactive), oxygen and silicate show substantial seasonal variation within Great Bay. No significant long-term trends were apparent from time series analyses of dissolved oxygen, ammonia, phosphate, nitrate, nitrite, or silicate (Loder et al. 1983a). Thus, while sewage inflow to the Great Bay estuary increased during 1973 to 1982 (Table 4), no increased nutrient loading was apparent (Loder et al. 1983a) which was attributed to the flushing potential of the estuary.

Table 3. GAUGED STREAM FLOW DATA
(Modified from Normandeau Associates, Inc. 1979)

Drainage	Period of Record		Discharge(cfs)	
		mean	max	min
Salmon	1968-1978	204.0	3500	19.00
Oyster	1934-1977	19.2	862	.23
Lamprey	1934-1977	278.0	5490	1.00

Table 4. WASTEWATER VOLUMES ENTERING THE GREAT BAY ESTUARY
(Modified from Lodger et al. 1983a)

Community Served[a]	Treatment Level	Design	1973	1982	Recieving Water	Start-Up Year
New Hampshire						
Dover	Primary	3.92	1.62	1.93	Cocheco River	1955
Durham	Primary	1.35	1.16	-	Oyster River	1965-1980
Durham	Secondary	2.50	-	0.83	Oyster River	1981
Epping#	Secondary	0.15	0.10	0.11	Lamprey River	1971
Exeter	Secondary	2.50	1.36	1.12	Squamscott River	1965
Farmington	Secondary	0.35	-	0.32	Cocheco River	1978
Newmarket	Primary	0.85	0.31	0.30	Lamprey River	1971
Newington	Secondary	0.30	-	0.08	Piscataqua River	1980
Pease AFB	Secondary	1.20	0.077	0.72	Piscataqua River	1953
Portmouth (Pierce Is.)	Primary	1.50	2.09	5.6	Portsmount Harbor	1964
Portsmouth (Seacrest)	Primary	0.45	0.21	0.30	Piscataqua River	1964
Rollinsford#	Secondary	0.15	0.08	0.04	Salmon Falls River	1967
Somersworth#	Secondary	2.40	1.02	1.47	Salmon Falls River	1967
SmallVolume others#	Primary	0.20	-	0.06		
Maine						
Berwick#	Secondary	0.60	0.48	0.80	Salmon Falls River	1975
South Berwick	Primary	0.45	-	0.19	Salmon Falls River	1965
Kittery	Secondary	1.22	0.61	0.65	Portsmouth Harbor	1970
Total		**17.6**	**10.0**	**16.8**	**Cumulative Great Bay**	

[a]Communities labeled with # indicate that effluent is discarged upstream of the dam defining head-of-tide.

5. VEGETATION

Macroalgae

Great Bay is typical of northern New England estuaries in having a variety of marine plant communities. More southern estuaries (i.e. south of Cape Cod) are dominated by salt marsh and have limited areas of stable substratum for macroalgal attachment. Within Great Bay, substantial intertidal populations of the fucoid macroalgae, *Ascophyllum nodosum* and *Fucus vesiculosus,* occur along the shingle and rocky intertidal. An extensive record of seaweed species occurring within the Great Bay estuary has been compiled (Appendix A, Table 1) (Mathieson and Hehre 1986, Mathieson and Penniman 1986).

Ascophyllum nodosum is intolerant of extreme wave exposure and generally requires sheltered to semi-exposed shorelines to reach its maximum development. Thus, the sheltered habitat of Great Bay allows extensive growth of *A. nodosum.* Throughout the estuary, the percent cover of *Ascophyllum* varies from 2.5 to 97.8% within the mid-intertidal zone (NH Fish and Game Department 1981). The standing crop of fucoids throughout the Bay has a range of 0-5, 474 g dry wt/m^2 (average 2,073 g dry wt/m^2) (NH Fish and Game Department 1982). Maximum seasonal growth of *Ascophyllum* occurs during spring and fall in Great Bay (Mathieson *et al.* 1976). *Ascophyllum* plants may be quite long-lived in some areas persisting for 15 years (Baardseth 1970). Within Great Bay *Ascophyllum is* heavily pruned annually by ice. The distal tips of fronds freeze into ice cover and are then torn free when iceout occurs (Mathieson *et al.* 1982). During extreme winters, the annual loss of biomass by ice-rafting may represent one-half the winter *Ascophyllum* standing crop (Mathieson et *al.* 1982). The ice-mediated pruning of *Ascophyllum* results in estuarine plants being shorter and bushier than their coastal counterparts (Mathieson et *al.* 1982). Fragments of *Ascophyllum* torn loose by ice-pruning may enter the detrital cycle as described above, or they may lodge among *Spartina alterniflora* culms and grow, forming the unattached form *Ascophyllum nodosum* ecad *scorploides* (Chock and Mathieson 1983). In certain areas of the Bay the biomass of ecad *scorpioides* in the upper intertidal can reach 89.6 g dry wt/0.1 m^2 (Chock and Mathieson 1983).

Ascophyllum produces an abundance of reproductive cells over an annual cycle (Baardseth 1970). Lateral shoots termed receptacles bear the gametes which are released during March-May within Great Bay (Mathieson *et al.* 1976). During the episodic loss of reproductive structures an amount of plant material detaches that may equal the standing biomass of vegetative plant material (Josselyn and Mathieson 1978). Thus, *Ascophyllum nodosum,* as well as other fucoids in Great Bay, is extremely important to the estuarine detrital food web by producing substantial quantities of organic material (Josselyn 1978, Josselyn and Mathieson 1978, 1980) with a relatively high nitrogen content (i.e. up to 4% of ash-free dry weight) (Hardwick-Wirman and Mathieson 1986). Furthermore, intertidal seaweeds such *asAscophyllum* and Fucus, release large quantities of dissolved organic matter, that may be utilized by heterotrophic microorganisms. The dissolved organic matter from intertidal seaweeds is a major component of surface "slicks" frequently observed in estuaries and nearshore waters.

In addition to being important to the primary productivity of northern estuaries, *Ascophyllum* provides structural complexity to intertidal habitats (Baardseth 1970). In muddy intertidal zones of northeastern estuaries, the limited stable substratum available for algal or invertebrate attachment, makes valuable any surfaces that will support colonization. A variety of smaller seaweeds (e.g. *Pilayella littoralis* and *Ectocarpus siliculosus)* are epiphytic upon *Ascophyllum* (Mathieson and Hehre 1986). The small, filamentous seaweeds potentially contribute a substantial proportion of total annual intertidal primary production (Chock and Mathieson 1983). A variety of invertebrates also colonize intertidal fucoids. The shade and cover provided by *Ascophyllum* fronds at low tide acts to protect smaller species from drying out rapidly during low tide. This amelioration of desiccation allows some species (e.g. *Chondrus crispus)* to extend higher into the intertidal zone than in open, unvegetated areas.

Within the low intertidal to upper subtidal zone on stable rocky substrata, Irish moss, *Chondrus crispus,* is an important algal colonizer. Although *Chondrus* extends subtidally, the most abundant subtidal macroalga within Great Bay is *Gracilaria tikvahiae* (Penniman *et al.* 1986). *Gracilaria* occurs abundantly in the subtidal at several sites throughout Great Bay (e.g. Adams Point-Footman Islands, Thomas Point, and Nannie Island). The occurrence of subtidal seaweeds in Great Bay is limited by the lack of stable substrata the subtidal being predominantly fine sediment. *Gracilaria,* as well as a variety of other subtidal seaweeds, grows attached to oyster shells, small rocks, discarded bottles and sunken logs. Because of

extreme turbidity, the lower distribution of seaweeds is quite limited in Great Bay versus the open coast (Mathieson and Penniman 1986).

As water temperatures warm during the summer, growth of *Gracilaria* may reach 10% per day in Great Bay (Penniman et al. 1986). Growth of *Gracilaria* is primarily limited by water temperature and irradiance, while dissolved nutrients (i.e. nitrogen and phosphorus) do not appear to limit production (Penniman 1983, Penniman and Mathieson 1987). No quantitative studies have been conducted to determine standing crops of subtidal seaweeds throughout Great Bay.

A variety of seaweed species occur within Great Bay that are absent on the open Atlantic coast north of Cape Cod (Penniman et al. 1985). These species, which have a disjunct distributional pattern, may represent relict populations that were more widely distributed during a previous time when coastal water temperatures were warmer (i.e. during a "hypsithermal period" 5000 yr B.P.) (Bousfield and Thomas 1975). These seaweeds grow and reproduce during the warm summer and are able to tolerate colder winter temperatures. Examples of species that exhibit such disjunct distributional patterns include *Gracilaria tikvahiae, Bryopsis plumosa, Daya baillouviana, Chondria tenuissima, Lomentaria clavellosa, Lomentaria orcadensis* and *Polysiphonia subtilissima* (Penniman et al. 1985, Mathieson and Hehre 1986). Several of these taxa also occur in the Great Salt Bay at the head of the Damariscotta River in Maine, an area somewhat similar to Great Bay. The disjunct distributional pattern described for the seaweeds is also found for several marine-estuarine invertebrates (Bousfield and Thomas 1975, Turgeon 1976). Specifically, the American oyster, *Crassostrea virginica,* only occurs naturally along the U.S. coast north of Cape Cod in Great Bay and the Damariscotta River. It should be noted that these disjunct plant and animal populations have probably been reproductively isolated from the widespread southern populations since the period of warmer coastal water temperatures. A second explanation for these distributions is that some of the disjunct populations may be organisms carried with American oysters possibly introduced into Great Bay during the early 1900's (Turgeon 1976).

Microalgae

Phytoplankton are a major component of primary production within estuaries. Little data are available concerning phytoplankton species composition, abundances, or production within Great Bay. During 1970 to 1978 as part of a baseline study to determine the potential environmental impact of an electric power generating station located on the Piscataqua River in Newington, several measurements of phytoplankton populations were taken (Normandeau Assoc., Inc. 1971-1980). As part of this study, phytoplankton species composition (retained on 0.076 mm net or as whole water samples), chlorophyll a concentrations and primary production as 14C uptake were measured at five stations throughout the Great Bay estuary (reduced to one in 1978).

Phytoplankton species composition within the estuary (Appendix A, Table 2) is dominated by diatoms (e.g. 96% of total abundance during 1978, Normandeau Assoc., Inc. 1979a, 1979b). Specific dominant net phytoplankton taxa are *Chaetoceros* species, *Skeletonema costatum* and *Ceratium* species, the former two groups are diatoms, while the latter is a dinoflagellate. Whole water phytoplankton samples were dominated by *Skeletonema costatum.* High numbers of pennate diatoms also occurred in the water column (e.g. *Navicula-* spp. and Fragilaria spp.) an indication of resuspension of benthic forms. The diatom, *Detonula confervacea,* was a major component of the winterspring inner estuarine phytoplankton community during 1971 to 1973 (Donovan 1974). *D. confervacea* dominated over Thalassiosira spp. in areas of lower salinity. Detonula was infrequent during 1971 to 1973 at more coastal stations in the estuary (Donovan 1974).

In the Piscataqua River shifts in species composition occurred with tidal phase. Blooms of estuarine taxa dominated during ebb tide stages, conversely neritic species were predominant during flood tides (Normandeau Assoc., Inc. 1980). Cell numbers during blooms were generally 104 to 106 cells/liter. During 1976 to 1978, two periods of phytoplankton blooms were evident during later spring and late summer/fall (Normandeau Associates, Inc. 1979a, 1979b). Late spring and autumn blooms were dominated by Chaetoceros spp. while Skeletonema costatum peaked in late summer (Normandeau Assoc., Inc. 1976).

Throughout the estuary phytoplankton primary production was greatest during April to July, declining through the August and September with a slight increase in October (Normandeau Associates, Inc. 1978a, 1978b). Average annual phytoplankton production was greatest in Great Bay (14 mg $C/m^3/h$ on ebb tide) versus more coastal stations (Normandeau Assoc., Inc. 1978a, 1978b). Chlorophyll a values were similarly distributed (6 mg/m^3 surface ebb tide sample in Great Bay) (Normandeau Assoc., Inc. 1978a, 1978b). Within the mid/upper estuary chlorophyll a concentrations varied during 1973 to 1981 from 1 to 14 $mg/m^3$with an average of 5 mg/m^3 (Loder et al.1983a). These values are comparable to two other Gulf of Maine estuaries (i.e. Sheepscot and Damariscotta River Estuaries, Maine, Loder et al. 1983a).

Another important microalgal component of the estuarine flora are diatoms and other microscopic algae occurring on mudflats. These microalgae may contribute a substantial portion of total estuarine primary production. However, within north temperate Atlantic estuaries very little quantitative information is available on the magnitude of epibenthic microalgal production.

Salt Marsh

North of Cape Cod, Massachusetts, salt marshes are progressively less important to total estuarine primary production than further south on the Atlantic Coast and in Gulf coast estuaries. However, the Wells National Estuarine Sanctuary, Maine, is somewhat atypical of Gulf of Maine estuaries in having a relatively high proportion of salt marsh habitat. In contrast, as described above, Great Bay is dominated by intertidal mudflats with substantial areas of intertidal macroalgae. Nonetheless, 3.39 km^2 (837.5 acres) of salt marsh surround Great and Little Bays and the Squamscott River (NH Fish and Game Department 1982). Within the boundaries of the GBNERR extensive salt marshes are present along the Squamscott River, 1.62 km2 (400.8 acres), and Lubberland and Crommett Creeks. In Great Bay, salt marsh occurs more commonly as a thin fringe along the uppermost intertidal (Chock and Mathieson 1983).

Salt marshes in Great Bay are dominated by the *Spartina species, S. alterniflora* (smooth cord grass) and *S. patens* (salt meadow hay). Both species are perennial grasses, annually producing large amounts of organic matter that may be exported from the marshes into the detrital food web or that is deposited within the marshes and contributes to the underlying marsh peat (Nixon 1982, Teal 1986).

Maximum standing biomass of *Spartina alterniflora* occurs during July to August in Great Bay. Maximum mean above-ground S. alterniflora biomass within Great and Little Bays was approximately 400 g dry wt/m^2 during 1980 to 1982 (NH Fish and Game Department 1981, 1982). These data are equivalent to measurements of production in other New England salt marshes (i.e. Maine, McGovern 1978; Rhode Island, Oviatt et al. 1977). Below ground standing crop (i.e. roots and rhizomes), which is quite variable geographically (Nixon 1982), has not been assessed. *S. alterniflora* flowers during July to September (Chock 1975, NH Fish and Game Department 1981, 1982).

Since most marshes surrounding Great Bay are relatively narrow in aerial width and because of the large tidal amplitude in the region, most of the marsh grass standing crop is probably exported from the marshes to the estuary (Nixon 1982). Furthermore, annual ice scouring of the intertidal marsh surface removes most remaining *Spartina* culms which are then exported during spring tidal cycles associated with ice melt. Ice cover and scour of the intertidal salt marsh also removes portions of the surface peat, which may be rafted into the lower intertidal or subtidal areas that are too deep for survival of *Spartina* (Hardwick Witman 1985). Hardwick-Witman (1986) determined that 11% of the surface area of an intertidal mudflat bordering Crommett Creek (Adams Point) was pieces of ice-rafted salt marsh peat. During spring ice-out overall movement of the peat islands was from the high to low intertidal (Hardwick-Witman 1986). Therefore, ice-rafted marsh segments may be deposited within the intertidal zone and are potentially a major means of propagation of salt marsh within the Great Bay (HardwickWitman 1985, 1986). Furthermore, several dominant intertidal species (e.g. *Fucus vesiculosus* and *Geukensia demissa)* are carried within ice-rafted marsh peat (Hardwick-Witman 1985).

A variety of other plant species are found in Great Bay salt marshes (Appendix A, Table 3). Unlike the extensive *Spartina* grass monocultures typical of more southern salt marshes, Great Bay marshes have a greater diversity of species and thus appear more as a mosaic of plant distributions. Furthermore, several species found within Great Bay salt marshes are classified as rare or endangered species (Appendix A, Table 4).

Soil types of coastal New Hampshire salt marshes were described by Breeding *et al.* (1974). Marshes bordering streams such as the Squamscott River and Crommett and Lubberland Creeks are generally sulfihemists. The fringing marshes, common around the Bay, also have sulfihemist soils of varying thicknesses and overlaying a variety of substrata (i.e. mud, sand, bedrock). The sulfihemist soil type has slow internal drainage, a very high water table and contains high amounts of organic matter and sulfidic minerals.

Eelgrass

Eelgrass, *Zostera marina,* is an important component of the estuarine environment. Production from eelgrass enters the estuarine nearshore detrital food web, eelgrass leaves serve to slow water flow and enhance sediment deposition, and root systems further stabilize sediments. Eelgrass beds provide structural diversity within the estuary as substrata for algal and invertebrate attachment, as well as protection for larval fish and invertebrates from predators. Eelgrass is distributed throughout the Great Bay estuary (NH Fish and Game 1981, 1982).

Several extensive *Zostera* beds occur within Great Bay (NH Fish and Game Department 1981, 1982, Short et al. 1986). However, unit aerial biomass is greater at more coastal sites (NH Fish and Game Department 1981, 1982). Additionally, during 1980 to 1982 and continuing to the present, a decrease in the abundance of eelgrass within Great Bay has been noted (NH Fish and Game Department 1981, 1982, Short et al. 1986). Maximum biomass occurs during July and a minimum in March (e.g. 30 g dry wt/m^2 in March versus 100 g dry wet/m^2 in July at Weeks Point in Great Bay, NH Fish and Game Depart nent 1982). Lengths of individual plants of *Zostera marina* are shorter within Great Bay versus stations on Little Bay and the Piscataqua River (NH Fish and Game Department 1982). Riggs and Fralick (1975) observed a temporal progression of flowering in *Zostera* populations with populations nearest the coast flowering three months earlier than those farthest into Great Bay.

Surveys by the New Hampshire Fish and Game Department noted a decline of 4406 in maximum (July) standing crop of *Zostera* from 1981 to 1982 (NH Fish and Game Department 1982). A "wasting disease" in eelgrass populations throughout the Great Bay estuary has been reported (Short et al. 1986, 1987). A more widespread loss of eelgrass occurred during the 1920-1930's along both shores of the north Atlantic (Milne and Milne 1951).

Upland

The boundaries of the GBNERR include several upland areas (e.g. Adams Point, areas bordering Crommett Creek and the Pease Air Force Base shoreline). No specific studies have documented the upland vegetation within the Reserve boundaries. However, a flora of Strafford County, NH, was compiled by Hodgdon (1932).

The region is characterized as a transition zone between the deciduous forest to the south and the coniferous forest to the north (Texas Instruments, Inc. 1974). Common tree species within the area include white pine (*Pinus strobus*), red oak *(Quercus rubra),* red pine *(Sinus restnosa),* hemlock *(Tsuga canadensis),* red maple *(Acer rubrum),* gray birch *(Betula populifolia)* and quaking aspen (*Populus tremuloides*) (Texas Instruments, Inc. 1974). A more complete listing of the common upland vascular plants found within Strafford County, NH, is presented in Appendix A, Table 5. Furthermore, several threatened or endangered plant species occur within the boundaries of the Reserve (Appendix A, Table 4).

6. FAUNA

Intertidal and Subtidal Invertebrate Fauna :

Substratum type (i.e. mud/sand versus rock) is an important determinant of species composition within Great Bay. Rock and shingle substrata are populated by epibenthic organisms, while mud and sand have both epibenthic and infaunal components.

Typical muddy intertidal dominants throughout most of the Great Bay estuary (based on retention by a 1 mm screen) are *Macoma balthica, Mya arenaria, Nephtys caeca* and *Nereis virens,* with *Clymenella torquata, Gemma gemrna* and *Scoloplos* spp. being occasionally abundant (Normandeau Assoc., Inc. 1973). Typical rocky shore dominants are *Littorina littorea, Mytilus educes* and *Semibalanus balanoides.* Within Great Bay, however, *Semibalanus, Macoma, Mytilus,* and *Littorina littorea* occur in low numbers and *Crassostrea virginica, Geukensia demissa* and *Mulinia lateralis* replace the more coastal species.

Population structure of the intertidal fauna within Great Bay is distinct from more coastal sites (Normandeau Assoc., Inc. 1976). The small bivalve, *Gemma gemma,* is the most abundant intertidal infaunal organism in Great Bay (e.g. 800/0.0078 m^2) and *Hydrobia minuta* is the most abundant gastropod.

Recent studies (1980-1982) by the NH Fish and Game Department found that subtidal soft sediment communities in Great Bay contained (based on retention by a 0.5 mm screen) primarily the polychaetes *Streblospio benedicti* and *Heteromastus filiformis* and the amphipods *Ampelisca abdita/vadorum* (NH Fish and Game Department 1982). *Streblo spio* and *Heteromastus* densities were greatest during the summer, *Ampelisca* is at a minimum at that time. Maximum abundance of *Hereromastus* within Great Bay was 23.2/0.0078 m^2 (NH Fish and Game Department 1982). Soft-shell clams, *Mya arenaria,* are found throughout Great Bay, with maximum densities of 6.4/0.0078 m^2 (NH Fish and Game Department 1981).

Large oyster beds *(Crassostrea virginica)* occur within the Great Bay estuary. The highest densities of oysters (i.e. 203/m^2) are in the southwest part of Great Bay where sizes ranged from 80.0 to 99.9 mm (NH Fish and Game Department 1982). Oyster abundances in Great Bay decreased from 1980-1981 to 1981-1982 (NH Fish and Game Department 1982).

During 1980-1981, ninety-one species of intertidal and one hundred fourteen subtidal infauna were collected throughout the Great Bay estuary by the NH Fish and Game Department (1981). In a subsequent investigation, a total of only sixty-seven intertidal and eighty-two subtidal species were found (NH Fish and Game Department 1982) (Appendix A, Tables 6 and 7). Both studies were based upon organisms retained by a 0.5 mm screen. During 1980-1981 samples were collected monthly, while during 1981-1982 only bimonthly sampling was conducted. The decreased frequency of sampling may explain the lower species numbers observed in the 1981-1982 investigation. The 1981-1982 collections contained polychaetes (45%), crustacea (26%), bivalves (15%), and gastropods (11%).

Hardwick-Witman and Mathieson (1983) compared the epibenthic species composition of the intertidal zone over a gradient extending from the mouth of the Piscataqua River into Great Bay. Within Great Bay the dominant epibenthic intertidal invertebrates were *Lanassa obsoleta, Geukensia demissa, Crassostrea virginica, Balanus eberneus, Littorina littorea, L. saxatilis* and *L. obtusata.* Dominant macroalgal species included *Ascophyllum nodosum, Fucus vesiculosus, Hildenbrandia rubra* and a filamentous algal mat. *Spartina alternifloria*

predominated in the high intertidal. The species were divided into three distinct elevational zones: an upper *Spartina-Fucus-L. soxatilis* zone, a *mid Ascophyllum-Geukensia-L. Iittorea* zone and a lower *llyanassa-Crassostrea* zone (Hardwick-Witman and Mathieson 1983).

As described above for several seaweed species, the warm summer waters within Great Bay allow the persistence of several invertebrate species more common further south along the open Atlantic coast (Bousfield and Thomas 1975). Gable and Croker (1977, 1978) described the ecology of the salt marsh amphipod *Gammarus palustris.* Great Bay is the northern limit of the species' distribution (Gable and Croker 1977). Turgeon (1976) commented on the occurrence of disjunct populations of several primarily warm-water invertebrate species within the Great Bay, e.g. *Balanus improvisus, Crassostrea virginica, Urosalpinx cinerea, Tellina agilis, Molgula manhattensis, Cliona sp.* and *Polydora sp.* These disjunct taxa may represent relict populations from a period 10,000 to 6,000 yr B.P. when coastal water temperatures were warmer (sensu Bousfield and Thomas 1975) or they may only be present due to human introduction of oysters and associated fauna and flora (Jackson 1944).

Within the estuary there is commercial fishing for lobsters *(Homarus americanus)* and rock crabs *(cancer irroratus),* as well as recreational fishing for oysters *(Crassostrea virginica).* Historically there was a fishery for soft-shell and razor clams (Jackson 1944) but harvesting is now limited by reduced clam densities and closures of beds due to bacterial pollution.

A study on the colonization of artificial substrata placed in the Great Bay estuary was conducted by Normandeau Assoc., Inc. (1972-1978). During 1972, fouling panels at Adams Point were colonized by colonial diatoms, especially *Melosira* moniliformis, a spionid polychaete, Polydora ligni, amphipods, especially, *Corophium sp., Amphithoe sp., Jassa falcata, Coremapus versiculatus* and *Hemiaegina minuta,* as well as the coelenterate *Tubularia crocea* (Appendix A, Table 8). Marked seasonal succession was observed (Normandeau Assoc., Inc. 1978a. 197b). *Balanus* sp. and *Mytilus edulis* were rare at Adams Point but abundant on fouling panels in the outer estuary (Normandeau Assoc., Inc. 1973).

Zooplankton

Zooplankton numbers varied from 1000 to 10,000/m^3 during 1975 in Great Bay (Normandeau Assoc., Inc. 1976). Abundance increased throughout the spring, peaking in early summer and declining sharply in later summer. A total of 32 zooplankton taxa were detected within Great Bay (Appendix A, Table 9) - fewer than at more outer estuarine sites (Normandeau Assoc., Inc. 1976). Throughout the estuary, holoplankton (those forms which spend their entire lives in the zooplankton community) accounted for 73% of the zooplankton. Dominants were copepod nauplii (29%), *Pseudocalanus minutus* (14%), *Oithona similis* (8%), *tintinnid protozoans* (7%) and *Temora longicornis* (2%). Meroplankton (forms which enter the zooplankton for only a portion of their life histories, e.g. to reproduce) comprised 22% of the zooplankton, including polychaete larvae (11%), gastropod larvae (5%), cirriped larvae (2%) and bivalve larvae (5%). Tychoplankton (organisms which are only temporarily suspended into the zooplanktonic community), primarily harpacticoid copepods, represented 5% of zooplankton (Normandeau Assoc., Inc. 1976).

Turgeon (1976) monitored meroplanktonic abundances in the Great Bay estuary during 1970 through 1973. The numbers of bivalve larvae generally decreased from the mouth of the estuary into Great Bay (Turgeon 1976). Bivalve larval numbers were greatest in July and September. Early stage bivalve larvae occurred in the near-surface, while later stages were in deeper waters.

Barnacle nauplii *(Semibalanus belanoides)* are one of the first meroplankton forms to appear seasonally, during February (Turgeon 1976), coinciding with the spring phytoplankton bloom. Trocophores and early stage spionid polychaete larvae appear in April through May having highest densities within the inner estuary (Turgeon 1976). Mollusk larvae are most abundant during June through July with a second peak abundance in September. Prosobranch veliger numbers peak during June and July and are most abundant within the inner estuary. Concentrations of 2500 veligers/100 liters are reached in Great Bay waters, probably primarily *Ilyanassa obsoleta* (Turgeon 1976). These patterns were consistent during 1970-1973 (Turgeon 1976) although absolute numbers varied year-to-year.

Turgeon (1976) identified two distinct meroplanktonic communities. One predominated in the outer estuary and a second in Great Bay although there was overlap in the middle estuary. Larval populations were most dense and species composition most varied during February to July and again during September through November.

Larval abundances of soft-shell clam, *Mya arenaria,* were seasonally bimodal (Turgeon 1976). Oyster larvae, as well as larvae of several other bivalves, migrate vertically depending upon the tidal stage. Movement up in the water column at flood tide and downward with ebbing tide allows retention within the inner estuary (Turgeon 1976). Larvae of warm water species, such as *Crassostrea virginica, Geukensia demissa, Molgula manhattensis* and *Balanus improvisus,* were detected infrequently by Turgeon during 1970 to 1973 (Turgeon 1976).

Ichthyofauna

The NH Fish and Game Department (1981), using a variety of sampling techniques to collect finfish throughout the Great Bay estuary during 1980-1981, identified a total of fifty-two species (Appendix A, Table 10). During 1981-1982 using only beach seines and otter trawls, the NH Fish and Game Department (1982) collected thirty-two finfish species. Atlantic silverside *(Menidia menidia)* was the most abundant species, particularly during autumn. Other abundant finfish in the Great Bay estuary included (in order of abundance):

Fundulus heteroclitus	Common Killfish, mummichog
Apeltes quadracus	Four-spined stickleback
Gasterosteus aceleatus	Three-spined stickleback
Pungitius pungitius	Nine-spined stickleback
Osmerus mordax	Smelt
Pseudopleuronectes americanus	Winter flounder
Microgadus tomcod	Atlantic Tomcod
Liopsetta putnami	Smooth Flounder
Alosa pseudoharengus	Alewife
Myoxocephalus aenaeus	Grubby

A similar overall list of finfish species for the Great Bay estuary was tabulated during 1970-1978 by Normandeau Associates, Inc. (1971-1979)

Resident finfish species occurring throughout the estuary include silversides, sticklebacks, common killifish, winter flounder and grubby. Anadromous species include smelt and alewife. Adult and juvenile smelt occur year-round throughout the estuary, while adult alewife occur in May to June and juveniles from May through November (NH Fish and Game Department 1981, 1982).

Commercial fisheries in the Great Bay estuary include herring, American eel and smelt. Striped bass, smelt, Coho salmon, and winter flounder are the most important recreational fisheries. Coho salmon were first stocked in the Great Bay estuary during 1969 by the NH Fish and Game Department (NH Fish and Game Department 1981).

During 1973-1979 a variety of fish larvae (Appendix A, Table 11) were collected throughout the Great Bay estuary in conjunction with the environmental impact assessment of the Newington Generating Station (Normandeau Assoc., Inc. 1980). Larvae of American sand lance *(Ammodytes americanus)* were the most common during 1975-1979, followed by radiated shanny *(Ulvaria subbifurcata)*, smooth flounder *(Liopsetta putnam)* and smelt *(Osmerus mordax)* (Normandeau Assoc., Inc. 1980).

Avifauna

A diverse avifauna occurs throughout southeastern New Hampshire (Appendix A, Table 12). Surveys by the NH Fish and Game Department recorded forty-three species using the estuary's waters and intertidal areas during 1982 (Appendix A, Table 13). Mean monthly abundances varied from 322 in June to 3,319 during March (NH Fish and Game Department 1982). The highest numbers of species occurred during April and September coincident with spring and fall migrations, respectively. (Ice cover during the winter severely restricts the areas in Great Bay utilized by birds.) Common species include:

Larus argentatus	Herring gull
Anas rubripes	American Black duck
Phalacrocorax auritus	Double-crested cormorant
Ardea herodias	Great blue heron
Corvus brachyrhynchos	American crow

Abundant overwintering migrants include:

Branta canadensis	Canada goose
Aythya marila	Greater scaup
Bucephala albeola	Bufflehead
Bucephala clangula	Common goldeneye
Anas rubripes	American black duck
Anas platyrhynchos	Mallard
Mergus serrator	Red-breasted merganser

Functionally, the avian groups observed within Great Bay may be divided into five categories: seabirds, waterfowl, wading birds, terrestrial and shore birds. (Appendix A, Table 13) (NH Fish and Game Department 1981, 1982).

Seabirds (i.e. cormorants and gulls) are common year-round within Great Bay. Herring gulls *(Larus argentatus)* had a maximum mean monthly abundance of 432 during September (NH Fish and Game Department 1982). Great black-backed gulls *(Larus marinus)* are also common within the estuary. The common tern *(Sterna hirundo)* occurs in Great Bay during later spring and summer. Terns have nested in the past on Nannie Island in Great Bay (NH Fish and Game Department 1981). Double-crested cormorants *(Phalacrocorax auritus)* are common in Great Bay during April to November.

Waterfowl are most abundant in the estuary during the fall and winter months. Black ducks *(Anas rubripes)* are in high abundance from August (maximum abundance 895) through March. During winter large numbers (900) of Canada geese *(Branta canadensis)* occur in Great Bay. A major source of food for overwintering geese may be the abundant intertidal green seaweeds, e.g. *Ulva lactuca* and *Enteromorpha* spp. (Penniman, personal observation).

Greater scaup *(Aythya marila)* are present during late summer to spring. Other relatively common waterfowl include bufflehead *(Bucephala albeola)*, common goldeneye *(Bucephala clangula)*, mallard *(Anas platyrhynchos)* and red-breasted merganser *(Mergus serrator)*.

The great blue heron *(Ardea herodias)* is the most prominent wading bird, occurring primarily from April to October. Other wading species include snowy egrets *(Egretta thula)*, green-backed heron *(Butorides striatus)*, black crowned night heron *(Nycticoraxnycticorax)*, glossy ibis *(Plegadis falcinellus)*, greater and lesser yellowlegs *(Tringa rnelanoleuca* and *T. flavips)* and least sandpiper *(Calidris minutilla)*.

Common terrestrial species utilizing these estuary are the American crow *(Corvus brachyrhynchos)* and the belted kingfisher *(Megaceryle alcyon)*. Adams Point also has a large population of ruffed grouse *(Bonasa umbellus)* (Texas Instruments, Inc. 1974).

Endangered and Threatened Bird Species

Several endangered and threatened bird species utilize Great Bay as habitat at various times of the year. The estuary supports the largest winter population of bald eagles and is one of the best documented wintering sites for bald eagles in New England. Regularly used areas within the GBNERR boundary include the entire shore of Pease Air Force Base, a section of shore in Durham, the Squamscott River, and several islands within the estuary. Ospreys, common loons and pied-billed grebes forage in the Bay during migration. Common terns have nested on Nannie Island and the Footman Islands as well as on several islands in Little Bay in the recent past, although none are nesting there at present. Migrating Northern Harriers use the saltmarshes and agricultural land for foraging. Sedge Wrens and Henslow's Sparrows ocasionally occur in short grass habitats around the Bay.

Mammals and Other Terrestrial Vertebrates

Harbor seals *(Phoca vitulina)* are observed frequently throughout the Great Bay estuary particularly at a rock ledge near the mouth of the Oyster River (Normandeau Assoc., Inc. 1974b, Texas Instruments, Inc. 1974, NH Fish and Game Department 1982).

Terrestrial mammals which utilize Great Bay include raccoons, whitetail deer, red fox, woodchuck, muskrats, chipmunks, grey squirrels, cottontail rabbits, mink, otter and beaver. Whitetail deer are very common in Durham and Adams Point with several overwintering yards present in the area (Texas Instruments, Inc. 1974). In Appendix A, Table 14 enumerates the common terrestrial mammals in the seacoast region of New Hampshire. A checklist of New Hampshire amphibians and reptiles is included in Appendix A, Table 15.

7. THREATENED/ENDANGERED SPECIES

Plant and animal species listed as threatened or endangered have been discussed in previous sections. A complete listing of these species is included as Appendix A, Table 4.

It should be mentioned that the disjunct estuarine invertebrate and seaweed species discussed in previous sections are limited to only several locations north of Cape Cod, Massachusetts. In fact, *Crassostrea virgintca* (American oyster) and *Dasya baillouviana* (a red seaweed) are species listed as part of the Maine Critical Areas Program (Cowger 1975, Yadas 1977).

D. Reserve Uses

The Great Bay National Estuarine Research Reserve has a rich New England tradition and presently supports many scientific, recreational, and educational uses, all dependent on the estuarine environment and its resources. The diversity of its present and past uses contributes greatly to the uniqueness of the estuary and is an important factor in the development of this management plan.

1. TRADITIONAL

In order to appreciate the impact of the strong cultural tradition on the Resene, it is important to look back at the entire region's history. Observing the arbitrary boundaries of the Reserve does not serve to convey the wealth of both the history and lore of the area.

A descriptive picture of the Reserve can best be painted using some of the words set down over a hundred years ago, by the earliest inhabitants of the region. The Atlantic coastline of New Hampshire is only "eighteen miles long as a seagull might fly item but the bays and inlets extending far inland add another eighty miles of saltwater shore. This inland system is arranged like 5 spindling fingers;" the 5 rovers mix fresh water from interior New Hampshire with sea water forced up the Piscataqua on a seven-foot tide to form "that remarkably salty lake composed of Broad Cove, Little Bay, and Great Bay."2 The system may be "rudely represented as a man's left hand and wrist laid upon the table, back upwards and fingers wide apart. The thumb would stand for the Salmon Falls River, the forefinger for Bellamy River, the second finger for Oyster River, the third for Lamprey River and the fourth for Exeter or Squamscot River; while the palm of the hand would represent Great Bay, into which most of the streams pour their Waters, and the wrist of the Piscataqua proper."[3]

The name of the Piscataqua River "is from the Indians. It is not a river because the tides flow in and out to Great Bay . . the correct name is a drowned valley."[4]

The Piscataqua region that 17th century explorers and settlers found was incredibly rich in resources. Not only did the coastal waters and waters of Great Bay yield great quantities of fin and shellfish, the shores were covered by pine forests, with white pine far more awesome than the scrubby second growth found today. These white pine were invaluable as masts and spars for building the British Royal Navy's ships. Consequently, the commercial value of the region led to a merchant-dominated society in contrast to the Puritan communities to the south in Massachusetts.

The abundant resources of the region were utilized in a number of ways. Most of the rivers had at least one ship building concern located along their banks. The Towns of Exeter and Durham sent many fine ships down their rivers to the Piscataqua, and out to sea, never to return to the towns as the rivers were too shallow and narrow to permit the passage of heavily-laden ships.

Salt marsh farming utilized the nutritious marsh hay found along the banks of Great Bay and its rivers for livestock, the rich river soil for crops and the proximity to the water for transporting produce. Two of the Reserve's key land and water areas (Squamscott River and Crommet Creek) were important salt marsh farming sites. Additionally, Crommet Creek was once known as Mill Creek, an indication of the lumbering and timber milling that went on in the area. The importance of these early commercial ventures is reflected in the name of a residence near Crommet Creek built on an old (approximately 1690) house site. "Salty" refers to the salterns, or salt licks, which were a valuable commodity in the colonial farm and barter economy. As settlers moved inland up the tidal rivers, more milling concerns developed. By the early 1800's Salem, Massachusetts merchants had founded textile companies along the Lamprey River in Newmarket.

The vessel used for transportation of hay, timber, people, etc. was the gundalow. Heavy and broad-bottomed, this local craft was ideally suited to the shoaly conditions of the rivers and Great Bay. Plying the river systems that served as natural roadways for commerce and communication, the gundalow was an integral part of the river and coastal traffic which tied the regions together for almost three hundred years. One of the last gundalow captains was Edward H. Adams. His family resided for 120 years at Adam's Point, and in this century ran a guest house for summer visitors. From this early beginning, tourism became an important

economic factor in the region in the mid 1800's, and the natural resources that had originally brought people to the area continue to attract visitors today.

2. EXISTING

As mentioned in previous sections, the water-dependent uses of the estuary (including Little Bay) consist of limited commercial and recreational fishing, clamming/oystering, bird hunting and watching, and boating. Transportation and storage of petroleum products is confined to the Piscataqua River, which is outside of the GBNERR's boundary. Commercial fishing in the estuary is limited. There is some lobstering at Little Bay and there is some taking of rainbow smelt, river herring and American eel on a commercial basis. The estuary is very popular for recreational fishing and shellfishing. There are several sportsmen's groups that actively fish the estuary, as well as many individuals - from the area and from out-of-state who fish and/ or harvest the oysters, clams and mussels.

Although limited public access to the shoreline, particularly in the upper estuary, does restrict hunting somewhat, duck hunting is a significant seasonal activity. The Bay is also a very popular area for birdwatching. More intensive boating activity in the estuary is mainly outside of the Great Bay Research Reserve boundary - in the lower portions of Little Bay, the Piscataqua River and Portsmouth Harbor. While there is boating in the upper estuary, the extensive mud flats in Great Bay and the shallow channels in the rivers at low tide tend to discourage all but the most experienced boaters. There is a small marina in Greenland and five public boat launches in the estuary (see regional setting section).

With the exception of seasonal homes, such as those at Brackett and Weeks Points, the character of the shoreline around Great Bay is predominantly a mixture of residential property, agricultural land and woodlands.

There are three main reasons for the pattern of development around the estuary: local land use controls that place certain restrictions on shoreline development, the ability and conviction of many landowners to retain large parcels of land, and the recreational limitations of the Great Bay estuary at low tide (mud flats, narrow channels) . The towns, via their land use controls, have classified shoreline uses for residential, agricultural and conservation purposes only. Many of these parcels, despite subdivision pressure, are still 50-100 acres or more because many of the landowners are deeply committed to preserving their own homestead and the open character of the area.

Projections for future use and development of the estuary indicate a moderate rate of growth for the area (see Table 5). From 1970 to 1980 the eight-town region grew from 38,721 to 44,475, an increase of 15 percent during the decade. From 1980-1990, it is projected to grow another 24 percent to 55,020, and by the year 2000, an additional 22 percent growth in population is expected, bringing the population to 67,036. The Department of Transportation expects a doubling of the average daily traffic across the General Sulivan Bridge by the year 2000. A Recreational Boating Needs Assessment carried out for the State in 1981 projected a need for approximately 100 additional moorings in the estuary by 1990. This growth translates into more construction activity, more housing and more use of the estuary for recreational purposes. While these changes do not necessarily represent a serious threat to the health of the estuary, the impact on the system points directly to the importance of establishing the GBNERR.

3. RESEARCH AND EDUCATION

The special qualities of the estuary have attracted many different organizations and government agencies who have conducted several scientific and educational activities. Detailed histories of both these areas are located in the research and education sections respectively.

4. MILITARY

The location of Pease Air Force Base (PAFB) encompasses approximately 3,000 acres of Newington lands, 1,500 of Portsmouth, and several hundred acres in Greenland. The site includes what was once farmland, forestry, and a 300 acre airport which opened in the early 1930's to serve as a city airport for Portsmouth. In early 1951, the Air Force began considering the construction of a large bomber base in New Hampshire. After several years of controversy, and a cessation of work on the project due to a cutback in federal funds, the base was completed in 1956. The addition of many jobs to the local economy is often noted as one of the benefits of PAFB. Recent developments have occurred concerning closure and final disposition of Pease Air Force Base. On January 5,1989 the Secretary of Defense accepted tthe Commission's recommendations and the Air Force has initiated implementation of this decision. For purposes of this document references to Pease remain unchanged as the property will remain in its present status for the next few years. Reserve staff will continue to be available to state, federal and local officials for technical information and support on the ecological significance of the Pease shoreline.

TABLE 5 POPULATION GROWTH IN GREAT BAY COMMUNITIES					
	United States Census				Projections
	1960	1970	1980	1990	2000
Dover	19,131	20,850	22,377	25,042	30,534
Greenland	1,196	1,784	2,129	2,900	3,884
Madbury	556	704	987		1,658
Newfields	737	843	817		1,330
Newington	1,045	798	716		1,069
Newmarket	3,153	3,361	4,290	7,190	7,983
Stratham	1,033	1,512	2,507	5,000	5,992
Total	32,033	38,721	44,475		67,036

(Source: 1960, 1970, 1980, 1990 U.S. Census NH Office of State Planning (For projections.)

[1] SPNEA, in-house report, Piscataqua Planning Project,phase I Report, (April, 1981)

[2] John P. Adams, Drowned Valley- The Piscaraqua River Rasin, (Hanover, 1976)

[3] Charles E. Clark, The Eastern Frontier: the Settlement of Northern New England 1610-1763 (New York,1970)

[4] Adams, Drowned Valley

CAT. NO. 1071

MATERIAL SAFETY DATA SHEET

POS: UAX5GR02
HACH ORDER#: 164602

MSDS DATE: 5/18/95
CHANGE NO.: 16074

For Assistance, Contact:
Regulatory Affairs Dept.
PO Box 907 Ames, IA 50010
(800) 227-4224

HACH COMPANY
PO BOX 907
AMES, IA 50010

Emergency Telephone #
Rocky Mountain Poison Ctr.
(303) 623-5716

I. PRODUCT IDENTIFICATION

PRODUCT NAME: Manganous Sulfate
CAS NO.: 7785-87-7 CHEMICAL NAME: Manganese Sulfate
FORMULA: MnSO4 CHEMICAL FAMILY: Inorganic Salts
MSDS NUMBER: M08029

II. INGREDIENTS

Manganous Sulfate
PCT: 100 CAS NO.: 7785-87-7 SARA: LISTED
TLV: 5 mg/m3 as Mn PEL: C: 5 mg/m3 as Mn
HAZARD: Systemic poison by inhalation.

III. PHYSICAL DATA

STATE: Solid APPEARANCE: Pink powder ODOR: Not determined
SOLUBILITY IN: WATER: Soluble ACID: Not determined
OTHER: Not determined BOILING POINT: NA MELTING PT.: >400°C
SPEC GRAVITY: ND pH: of 5% soln. = 3.7 VAPOR PRESSURE: Not applicable
VAPOR DENSITY (air=1): NA EVAPORATION RATE: NA
METAL CORROSIVITY - ALUMINUM: 0.002 in/yr STEEL: ND STABILITY: Stable
STORAGE PRECAUTIONS: Store in a cool, dry place.

IV. FIRE, EXPLOSION HAZARD AND REACTIVITY DATA

FLASH PT.: Not applicable METHOD: NA
FLAMMABILITY LIMITS - LOWER: NA UPPER: NA
SUSCEPTIBILITY TO SPONTANEOUS HEATING: None
SHOCK SENSITIVITY: None AUTOIGNITION PT.: ND
EXTINGUISHING MEDIA: Use media appropriate to the surrounding fire conditions.
FIRE/EXPLOSION HAZARDS: None reported
HAZARDOUS DECOMP. PRODUCTS: May emit toxic fumes of sulfur oxides and manganese oxides in fire
OXIDIZER: No NFPA Codes: Health: 2 Flammability: 0 Reactivity: 1
CONDITIONS TO AVOID: Extreme temperatures; contact with oxidizers or powdered metals

V. HEALTH HAZARD DATA

THIS PRODUCT MAY BE: Irritating to eyes, skin and respiratory tract.
ACUTE TOXICITY: Moderately toxic
ROUTES OF EXPOSURE: inhalation
TARGET ORGANS: lungs
CHRONIC TOXICITY: Cumulative poison
ROUTES OF EXPOSURE: inhalation
TARGET ORGANS: central nervous system, blood
CANCER INFORMATION: experimental mutagen and experimental teratogen
ROUTES OF EXPOSURE: Not determined
TARGET ORGANS: Not determined
OVEREXPOSURE: Chronic inhalation may cause psychiatric disorders characterized by irritability, difficulty walking, speech disturbances and compulsive behavior. May also cause mask-like facial expression, cirrhosis of the liver, and Parkinson's-like symptoms.
MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: Persons with pre-existing respiratory, liver, or central nervous system conditions may be more susceptible to the effects of manganese poisoning.

VI. PRECAUTIONARY MEASURES

Avoid contact with eyes and skin.
Do not breathe dust.
Wash thoroughly after handling.
PROTECTIVE EQUIPMENT: adequate ventilation, lab grade goggles, disposable latex gloves

VII. FIRST AID

EYE AND SKIN CONTACT: Immediately flush eyes with water for 15 minutes. Call physician. Flush skin with plenty of water.
INGESTION: Give large quantities of water or milk. Induce vomiting by sticking finger down throat. Never give anything by mouth to an unconscious person. Call physician.
INHALATION: Remove to fresh air. Give artificial respiration if necessary. Call physician.

VIII. SPILL AND DISPOSAL PROCEDURES

IN CASE OF SPILL OR RELEASE: Sweep up powder. Avoid breathing material. Dissolve in water. Flush down the drain with excess water.
DISPOSE OF IN ACCORDANCE WITH ALL FEDERAL, STATE, AND LOCAL REGULATIONS.

IX. TRANSPORTATION DATA

D.O.T. PROPER SHIPPING NAME: Not Currently Regulated
HAZARD CLASS: NA ID: NA GROUP: NA

I.C.A.O. PROPER SHIPPING NAME: Not Currently Regulated
HAZARD CLASS: NA ID: NA GROUP: NA

I.M.D. PROPER SHIPPING NAME: Not Currently Regulated
HAZARD CLASS: NA ID: NA GROUP: NA

X. REFERENCES

1) TLV's Threshold Limit Values and Biological Exposure Indices for 1988-1989. American Conference of Governmental Industrial Hygienists, 1988.
2) Air Contaminants, Federal Register, Vol. 54, No. 12, Thursday, January 19, 1989. pp. 2332-2983.
3) Sax, N. Irving. Dangerous Properties of Industrial Materials, 6th Ed. New York: Van Nostrand Reinhold Co. 1984.
4) Gosselin, R.E. et al. Clinical Toxicology of Commercial Products, 5th Ed. Baltimore: The Williams and Wilkins Co., 1984.
5) Vendor information.
6) Technical judgment
7) Casarett and Doull's Toxicology, 3rd Ed. New York: Macmillan Publishing Co., Inc. 1986.
8) NIOSH Registry of Toxic Effects of Chemical Substances, 1985-86. Cincinnati: U. S. Department of Health and Human Services, April, 1987.
9) List of Dangerous Substances Classified in Annex I of the EEC Directive (67/548) - Classification, Packaging and Labelling of Dangerous Substances, Amended November, 1986.

SARA: This product contains a chemical or chemicals subject to the reporting requirements of section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 and 40 CFR Part 372.

CAT. NO. 1072

MATERIAL SAFETY DATA SHEET

POS: UAXSGR02
HACH ORDER#: 166602

MSDS DATE: 4/11/95
CHANGE NO.: 15858

For Assistance, Contact:
Regulatory Affairs Dept.
PO Box 907 Ames, IA 50010
(800) 227-4224

HACH COMPANY
PO BOX 907
AMES, IA 50010

Emergency Telephone #
Rocky Mountain Poison Ctr.
(303) 623-5716

I. PRODUCT IDENTIFICATION

PRODUCT NAME: Alkaline Iodide-Azide Reagent
CAS NO.: NA CHEMICAL NAME: Not applicable
FORMULA: Not applicable CHEMICAL FAMILY: Not applicable
MSDS NUMBER: M00026

II. INGREDIENTS

Lithium Hydroxide, Monohydrate
PCT: <65 CAS NO.: 1310-66-3 SARA: NOT LISTED
TLV: Not established PEL: Not established
HAZARD: Very toxic; corrosive

Potassium Iodide
PCT: <40 CAS NO.: 7681-11-0 SARA: NOT LISTED
TLV: Not established PEL: Not established
HAZARD: May cause irritation

Sodium Azide
PCT: <5 CAS NO.: 26628-22-8 SARA: LISTED
TLV: C: 0.11 ppm PEL: C: 0.3 ppm(NaN3)
HAZARD: Extremely toxic; May cause irritation; Explosion hazard

III. PHYSICAL DATA

STATE: solid APPEARANCE: White crystals ODOR: None
SOLUBILITY IN: WATER: Soluble ACID: Not determined
OTHER: Not determined BOILING POINT: NA MELTING PT.: 110°C(230°F)
SPEC GRAVITY: 1.94 pH: of 5% soln. = 12.6
VAPOR PRESSURE: Not applicable VAPOR DENSITY (air=1): NA
EVAPORATION RATE: NA METAL CORROSIVITY - ALUMINUM: 0.248 in/yr
STEEL: ND STABILITY: Stable
STORAGE PRECAUTIONS: Store in a cool, dry place.

IV. FIRE, EXPLOSION HAZARD AND REACTIVITY DATA

FLASH PT.: Not applicable METHOD: NA
FLAMMABILITY LIMITS - LOWER: NA UPPER: NA
SUSCEPTIBILITY TO SPONTANEOUS HEATING: None
SHOCK SENSITIVITY: Not determined AUTOIGNITION PT.: ND
EXTINGUISHING MEDIA: dry chemical. DO NOT USE WATER
FIRE/EXPLOSION HAZARDS: Contact with metals may give off flammable hydrogen gas
HAZARDOUS DECOMP. PRODUCTS: Toxic fumes of potassium oxides, NOx, sodium oxides, and iodine & iodine compounds
OXIDIZER: No NFPA Codes: Health: 3 Flammability: 1 Reactivity: 1
CONDITIONS TO AVOID: Exposure to heat or flames, excess moisture; contact with acids or oxidizers.

V. HEALTH HAZARD DATA

THIS PRODUCT MAY BE: corrosive to eyes, skin and respiratory tract.
ACUTE TOXICITY: Oral rat LD50 = 350 mg/kg = Very toxic
ROUTES OF EXPOSURE: ingestion, inhalation, skin absorption
TARGET ORGANS: central nervous system, liver, kidneys, spleen, lungs, bone marrow
CHRONIC TOXICITY: Not determined
ROUTES OF EXPOSURE: ingestion, inhalation, skin absorption
TARGET ORGANS: central nervous system, liver, kidneys
CANCER INFORMATION: An ingredient of this mixture is an experimental mutagen.
ROUTES OF EXPOSURE: ingestion
TARGET ORGANS: Not determined
OVEREXPOSURE: Causes severe burns; hypotension. May cause respiratory stimulation then depression, nausea, central nervous system depression, coma, death. Chronic iodide overdose may cause skin rash, runny nose, headaches, fever and irritation of mucous membranes.
MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: Pre-existing: eye, skin, kidney, liver, or respiratory conditions; may cause a larger drop in blood pressure in hypotensive persons than in normotensive persons

VI. PRECAUTIONARY MEASURES

Avoid contact with eyes, skin and clothing
Do not breathe dust.
Wash thoroughly after handling.
PROTECTIVE EQUIPMENT: fume hood, lab grade goggles, rubber gloves, lab coat

VII. FIRST AID

EYE AND SKIN CONTACT: Immediately flush eyes and skin with water for 1 minutes. Remove contaminated clothing. Call physician.
INGESTION: Do NOT induce vomiting. Give 1 - 2 glasses of water. Call a physician immediately. Never give anything by mouth to an unconscious person.
INHALATION: Remove to fresh air. Give artificial respiration if neces Call physician.

VIII. SPILL AND DISPOSAL PROCEDURES

IN CASE OF SPILL OR RELEASE: Scoop material into a beaker and dissolve water. Neutralize to a pH between 6 and 9 with an acid such as hydrochloric acid. Flush neutralized waste to the drain with excess
DISPOSE OF IN ACCORDANCE WITH ALL FEDERAL, STATE, AND LOCAL REGULATION

IX. TRANSPORTATION DATA

D.O.T. PROPER SHIPPING NAME: Lithium Hydroxide, Solid Mixture
HAZARD CLASS: 8 ID: UN2680 GROUP: II

I.C.A.O. PROPER SHIPPING NAME: Lithium Hydroxide Monohydrate Mixture
HAZARD CLASS: 8 ID: UN2680 GROUP: II

I.M.O. PROPER SHIPPING NAME: Lithium Hydroxide Monohydrate Mixture
HAZARD CLASS: 8 ID: UN2680 GROUP: II

X. REFERENCES

1) TLV's Threshold Limit Values and Biological Exposure Indices for 1 1989. American Conference of Governmental Industrial Hygienists, 1
2) Air Contaminants, Federal Register, Vol. 54, No. 12, Thursday, Ja 19, 1989. pp. 2332-2983.
3) In-house information
4) Technical judgment
5) Outside testing.
6) Patty, Frank A. Industrial Hygiene and Toxicology, 3rd Revised E Volume 2. New York; A Wiley-Interscience Publication, 1981.
7) Sax, N. Irving. Dangerous Properties of Industrial Materials, 6t New York: Van Nostrand Reinhold Co. 1984.
8) NIOSH Registry of Toxic Effects of Chemical Substances, 1985-86. Cincinnati: U. S. Department of Health and Human Services, April

SARA: This product contains a chemical or chemicals subject to the re requirements of section 313 of Title III of the Superfund Amendment Reauthorization Act of 1986 and 40 CFR Part 372.

CAT. NO. 1073

MATERIAL SAFETY DATA SHEET

POR: UAX5GR02
HACH ORDER#: 164602

MSDS DATE: 1/01/95
CHANGE NO.: 12068

For Assistance, Contact:
Regulatory Affairs Dept.
PO Box 907 Ames, IA 50010
(800) 227-4224

HACH COMPANY
PO BOX 907
AMES, IA 50010

Emergency Telephone #
Rocky Mountain Poison Ctr.
(303) 623-5716

I. PRODUCT IDENTIFICATION

PRODUCT NAME: Sulfamic Acid Powder Pillows
CAS NO.: 5329-14-6 CHEMICAL NAME: Sulfamic acid
FORMULA: H2NSO3H CHEMICAL FAMILY: Inorganic Acids
MSDS NUMBER: M00007

II. INGREDIENTS

Sulfamic Acid
PCT: <100 CAS NO.: 5329-14-6 SARA: NOT LISTED
TLV: Not established PEL: Not established
HAZARD: Causes eye burns; causes skin irritation, moderately toxic

Other component
PCT: <1 CAS NO.: NA SARA: NOT LISTED
TLV: Not applicable PEL: Not applicable
HAZARD: Not applicable

Any component of this mixture not specifically listed (eg. "other components") is not considered to present a carcinogen hazard.

III. PHYSICAL DATA

STATE: solid APPEARANCE: White crystalline powder ODOR: None
SOLUBILITY IN: WATER: 1:2 @ 80 C ACID: Soluble
OTHER: Slightly soluble alc., methanol BOILING POINT: NA
MELTING PT.: 205°C decomp SPEC GRAVITY: 2.15 pH: of 1% soln = 1.18
VAPOR PRESSURE: Not applicable VAPOR DENSITY (air=1): NA
EVAPORATION RATE: NA METAL CORROSIVITY - ALUMINUM: ~0.212 in/yr
STEEL: ~0.814 in/yr STABILITY: Stable
STORAGE PRECAUTIONS: Store tightly closed in a dry place.

IV. FIRE, EXPLOSION HAZARD AND REACTIVITY DATA

FLASH PT.: Not applicable METHOD: NA
FLAMMABILITY LIMITS - LOWER: NA UPPER: NA
SUSCEPTIBILITY TO SPONTANEOUS HEATING: None
SHOCK SENSITIVITY: None AUTOIGNITION PT.: ND
EXTINGUISHING MEDIA: water or dry chemical
FIRE/EXPLOSION HAZARDS: Reacts violently with chlorine, fuming nitric acid, metal nitrates, metal nitrites
HAZARDOUS DECOMP. PRODUCTS: May emit toxic fumes of sulfur oxides, nitrogen and ammonia oxides in fire
OXIDIZER: No NFPA Codes: Health: 2 Flammability: 1 Reactivity: 1
CONDITIONS TO AVOID: Contact with chlorine or fuming nitric acid, metal nitrates, metal nitrites, oxidizers, bases; extreme heat or flame; excess moisture

V. HEALTH HAZARD DATA

THIS PRODUCT MAY BE: corrosive to eyes, irritating to skin and respiratory tract.
ACUTE TOXICITY: Oral rat LD50 = 3160 mg/Kg = Moderately toxic
ROUTES OF EXPOSURE: ingestion, inhalation
TARGET ORGANS: Not determined
CHRONIC TOXICITY: Not determined
ROUTES OF EXPOSURE: Not determined
TARGET ORGANS: Not determined
CANCER INFORMATION: Not applicable
ROUTES OF EXPOSURE: Not applicable
TARGET ORGANS: Not applicable
OVEREXPOSURE: Causes eye burns. May cause irritation of the skin, respiratory tract, mouth, esophagus, and gastrointestinal tract.
MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: Pre-existing eye, skin and respiratory conditions

VI. PRECAUTIONARY MEASURES

Avoid contact with eyes, skin and clothing
Do not breathe dust.
Wash thoroughly after handling.
Keep away from heat, sparks and open flame.
PROTECTIVE EQUIPMENT: adequate ventilation, lab grade goggles, rubber gloves, lab coat

VII. FIRST AID

EYE AND SKIN CONTACT: Immediately flush eyes and skin with water for 15 minutes. Remove contaminated clothing. Call physician.
INGESTION: Do NOT induce vomiting. Give 1 - 2 glasses of water. Call a physician immediately. Never give anything by mouth to an unconscious person.
INHALATION: Remove to fresh air.

VIII. SPILL AND DISPOSAL PROCEDURES

IN CASE OF SPILL OR RELEASE: Cover contaminated surfaces with soda ash or sodium bicarbonate. Mix and add water if necessary. Use litmus paper to make sure pH of slurry is neutral or add neutralizer until mixture stops bubbling. Scoop up the slurry and wash the neutral waste down the drain with excess water. Wash the site with soda ash solution.
DISPOSE OF IN ACCORDANCE WITH ALL FEDERAL, STATE, AND LOCAL REGULATIONS.

IX. TRANSPORTATION DATA

D.O.T. PROPER SHIPPING NAME: Sulphamic Acid
HAZARD CLASS: 8 ID: UN2967 GROUP: III

I.C.A.O. PROPER SHIPPING NAME: Sulphamic Acid
HAZARD CLASS: 8 ID: UN2967 GROUP: III

I.M.O. PROPER SHIPPING NAME: Sulphamic Acid
HAZARD CLASS: 8 ID: UN2967 GROUP: III

X. REFERENCES

1) TLV's Threshold Limit Values and Biological Exposure Indices for 1988-1989. American Conference of Governmental Industrial Hygienists, 1988.
2) Air Contaminants, Federal Register, Vol. 54, No. 12, Thursday, January 19, 1989. pp. 2332-2983.
3) In-house information
4) Sax, N. Irving. Dangerous Properties of Industrial Materials, 6th Ed. New York: Van Nostrand Reinhold Co. 1984.
5) Technical judgment
6) Outside testing.
7) Gosselin, R.E. et al. Clinical Toxicology of Commercial Products, 5th Ed. Baltimore: The Williams and Wilkins Co., 1984.
8) List of Dangerous Substances Classified in Annex I of the EEC Directive (67/548) - Classification, Packaging and Labelling of Dangerous Substances, Amended November, 1986.

CAT. NO. 24093

MATERIAL SAFETY DATA SHEET

POR: HAX5GR02
HACH ORDER#: 164692

MSDS DATE: 4/25/95
CHANGE NO.: 15948

For Assistance, Contact:
Regulatory Affairs Dept.
PO Box 907 Ames, IA 50010
(800) 227-4224

HACH COMPANY
PO BOX 907
AMES, IA 50010

Emergency Telephone #
Rocky Mountain Poison Ctr.
(303) 623-5716

I. PRODUCT IDENTIFICATION

PRODUCT NAME: Sodium Thiosulfate Standard Solution, Stabilized, 0.0250 N
CAS NO.: NA CHEMICAL NAME: Not applicable
FORMULA: Not applicable CHEMICAL FAMILY: Not applicable
MSDS NUMBER: M00371

II. INGREDIENTS

Propylene Glycol
PCT: 20 TO 30 CAS NO.: 57-55-6 SARA: NOT LISTED
TLV: Not established PEL: Not established
HAZARD: Causes mild irritation

Sodium Sulfate
PCT: 1 TO 5 CAS NO.: 7757-82-6 SARA: NOT LISTED
TLV: Not established PEL: Not established
HAZARD: May cause irritation

Sodium Thiosulfate
PCT: <1 CAS NO.: 7772-98-7 SARA: NOT LISTED
TLV: Not established PEL: Not established
HAZARD: May cause irritation

Other components, each
PCT: <1 CAS NO.: NA SARA: NOT LISTED
TLV: Not applicable PEL: Not applicable
HAZARD: Not applicable

Demineralized Water
PCT: to 100 CAS NO.: 7732-18-5 SARA: NOT LISTED
TLV: Not applicable PEL: Not applicable
HAZARD: None

Any component of this mixture not specifically listed (eg. "other components") is not considered to present a carcinogen hazard.

III. PHYSICAL DATA

STATE: liquid APPEARANCE: Clear, colorless ODOR: Sweet
SOLUBILITY IN: WATER: Soluble ACID: Soluble OTHER: Not determined
BOILING POINT: 99°C MELTING PT.: freezes -7°C SPEC GRAVITY: 1.05
pH: 9.9 VAPOR PRESSURE: Not determined VAPOR DENSITY (air=1): ND
EVAPORATION RATE: 0.96 METAL CORROSIVITY - ALUMINUM: 0.004 in/yr
STEEL: 0.006 in/yr STABILITY: Stable
STORAGE PRECAUTIONS: Store in a cool, dry place away from oxidizers.

IV. FIRE, EXPLOSION HAZARD AND REACTIVITY DATA

FLASH PT.: >212°F METHOD: open cup
FLAMMABILITY LIMITS - LOWER: ND UPPER: ND
SUSCEPTIBILITY TO SPONTANEOUS HEATING: None
SHOCK SENSITIVITY: None AUTOIGNITION PT.: ND
EXTINGUISHING MEDIA: water, dry chemical, alcohol foam or carbon dioxide
FIRE/EXPLOSION HAZARDS: None
HAZARDOUS DECOMP. PRODUCTS: May emit toxic fumes of carbon oxides and sodium oxides in fire
OXIDIZER: No NFPA Codes: Health: 1 Flammability: 0 Reactivity: 0
CONDITIONS TO AVOID: Excessive heat; contact with oxidizers

V. HEALTH HAZARD DATA

THIS PRODUCT MAY BE: irritating to eyes, skin and respiratory tract.
ACUTE TOXICITY: Not determined
ROUTES OF EXPOSURE: Not determined
TARGET ORGANS: Not determined
CHRONIC TOXICITY: Not determined
ROUTES OF EXPOSURE: Not determined
TARGET ORGANS: Not determined
CANCER INFORMATION: Not applicable
ROUTES OF EXPOSURE: Not applicable
TARGET ORGANS: Not applicable
OVEREXPOSURE: May cause eye, skin, and respiratory tract irritation
MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: None reported

VI. PRECAUTIONARY MEASURES

Avoid contact with eyes, skin and clothing
Do not breathe mist or vapor.
Wash thoroughly after handling.
PROTECTIVE EQUIPMENT: adequate ventilation, lab grade goggles, disposabl latex gloves

VII. FIRST AID

EYE AND SKIN CONTACT: Immediately flush eyes with water for 15 minutes. physician. Wash skin with soap and plenty of water.
INGESTION: Give large quantities of water. Call physician immediately.
INHALATION: Remove to fresh air.

VIII. SPILL AND DISPOSAL PROCEDURES

IN CASE OF SPILL OR RELEASE: Dilute with water. Pour down the drain wit excess water.
DISPOSE OF IN ACCORDANCE WITH ALL FEDERAL, STATE, AND LOCAL REGULATIONS.

IX. TRANSPORTATION DATA

D.O.T. PROPER SHIPPING NAME: Not Currently Regulated
HAZARD CLASS: NA ID: NA GROUP: NA

I.C.A.O. PROPER SHIPPING NAME: Not Currently Regulated
HAZARD CLASS: NA ID: NA GROUP: NA

I.M.O. PROPER SHIPPING NAME: Not Currently Regulated
HAZARD CLASS: NA ID: NA GROUP: NA

X. REFERENCES

1) TLV's Threshold Limit Values and Biological Exposure Indices for 198 1989. American Conference of Governmental Industrial Hygienists, 198
2) Air Contaminants, Federal Register, Vol. 54, No. 12, Thursday, Janua 19, 1989. pp. 2332-2983.
3) In-house information
4) Technical judgment
5) Fire Protection Guide to Hazardous Materials, 10th Ed., Quincy, MA; National Fire Protection Association, 1991.
6) Sax, N. Irving. Dangerous Properties of Industrial Materials, 6th E New York: Van Nostrand Reinhold Co. 1984.
7) Gosselin, R.E. et al. Clinical Toxicology of Commercial Products, 5t Ed. Baltimore: The Williams and Wilkins Co., 1984.
8) NIOSH Registry of Toxic Effects of Chemical Substances, 1985-86. Cincinnati: U. S. Department of Health and Human Services, April, 1