TISBURY GREAT POND WATERSHED STUDY

MAY 1996

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UMASS EXTENSION
MARTHA'S VINEYARD COMMISSION

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EXECUTIVE SUMMARY

The report which follows represents the second step in assessing the water quality status of Tisbury Great Pond. The first step was a study of the water quality of the Pond itself completed in 1992. The present study was devoted to establishing the water quality of the watershed by testing newly installed monitoring wells, streams and existing private wells during 1994 and early 1995.

The acreage of the watershed is determined as 10841 acres based on new information about the water table contours north of the Pond.

The test results are used to derive a good approximation of the nitrogen load moving into the Pond from groundwater, streams and acid rainfall. A total of 8509 kilograms per year was determined based on the test results. A range of figures is developed using standard figures for septic effluent on a per capita basis, lawns and farms where fertilizer is applied. These figures give a range of from 7551 to 11648 kilograms per year that agree with the load as determined by the test results. From these test results, it appears that the groundwater carries about 71 percent of the nitrogen introduced to the Pond, the streams carry 20 percent and rainfall provides 10 percent.

Projections based on those standard figures are made for buildout in the watershed. These figures range from a high of 17307 to a low of 10622 kilograms per year. A nitrogen loading limit is estimated from a generic formula at between 12000 and 15000 kilograms per year. While not tailored to the Great Pond, the formula results when compared with the buildout projections strongly suggest the need to move forward in deriving a better nitrogen loading limit for the Pond.

Approximately two thirds of the wells tested exceeded the background level of nitrogen (0.05 mg/L) expected in areas unaffected by mans activities. None of the wells exceeded 50 percent of the standard for nitrate for drinking water. Nitrogen to phosphorus ratios in wells near more intensive land uses are much higher than those values in the streams which, in turn, are higher than those in the Pond itself. It appears that the Pond itself varies from being nitrogen deficient to being short on phosphorus. More data is needed to try to pin this issue down.

This report was made possible by a collaboration between the Martha's Vineyard Shellfish Group, the Martha's Vineyard Commission and the UMASS Extension with funding support from the Edey Foundation.

INDEX

Acknowledgements 4
Conceptual description.. 4
Geology and Hydrology...................................... 6 - 8
General Land Use.. 9
Data Summary.. 9 - 22
Nitrogen Budget.. 22 - 23
Groundwater Nitrogen Load.................................... 24 - 25
Stream Nitrogen Load... 25 - 27
Rainfall Nitrogen Load.. 27
Formulae Based Nitrogen Load Calculations.................. 27 - 30
Some Implications for the Pond.................................. 30
Summary and Conclusions....................................... 30 - 31
References Cited.. 32

Tables

Table 1 Groundwater Nitrogen Loads.................... 24
Table 2 Stream Derived Nitrogen Loads................. 26
Table 3 Formula Based Nitrogen Loads............... 28
Table 4 Summary of Nitrogen Load Calculations..... 29

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CONCEPTUAL PROJECT DESCRIPTION
During 1991, a surface water study of Tisbury Great Pond was conducted by Fugro-McClelland and funded by the Towns and the Tisbury Great Pond Think Tank(TGPTT). This study considered the inputs of nutrients to the Pond by the streams and groundwater but did not collect extensive information in these areas as there was inadequate funds to support more than a surface water testing program. It is generally understood that the Pond receives tremendous flows of water from the groundwater and the streams. It follows that the chemistry and bio-cycles of the Pond may be greatly affected by the quality of the water discharging from these sources. The goal of this study was to collect information on the nature of the water quality from these two sources over the course of a year.

It was decided that the heads of the coves were likely points of discharge of large volumes of groundwater. The monitoring wells were planned for the heads of the coves to acquire some insight into the nature of the groundwater flowing to the coves. In addition, regular samples of the Tiasquam, Mill Brook and Sepiessa stream were planned to investigate these waters. Existing wells off New Lane, behind the Up Island gas station and at the head of Deep Bottom were used to round out the picture.

During the course of the study it became clear that the monitoring wells chosen might not be giving a complete picture of the entire watershed water quality due to their shallow depth and proximity to the Pond. It was decided to supplement the regular rounds of sample collection with testing for nitrate from private wells in the watershed. The first round was conducted in August 1994. A follow up round was conducted in October on those wells where elevated nitrate levels were found to be sure that the readings were accurate. In addition, wells were added near those where nitrate levels were found to be higher than expected to gain a clearer picture of the situation. A total of 22 private wells were tested in the first round and 19 in the second of which 9 were repeats of the first round. See Figure 1.

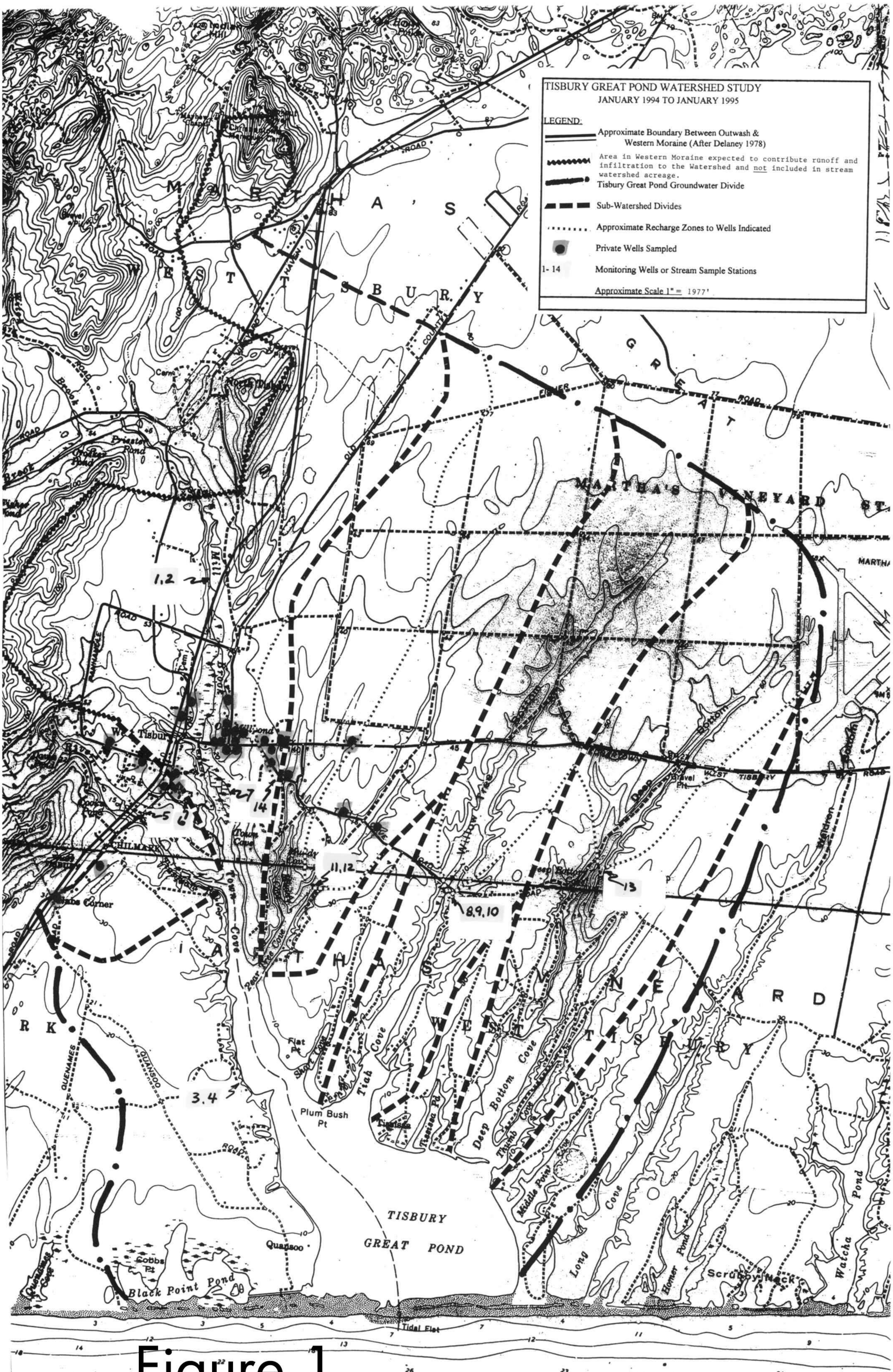

TISBURY GREAT POND WATERSHED STUDY
JANUARY 1994 TO JANUARY 1995
LEGEND:
Approximate Boundary Between Outwash & Western Moraine (After Delaney 1978)
Area in Western Moraine expected to contribute runoff and infiltration to the Watershed and not included in stream watershed acreage.
Tisbury Great Pond Groundwater Divide
Sub-Watershed Divides
Approximate Recharge Zones to Wells Indicated
Private Wells Sampled
1- 14 Monitoring Wells or Stream Sample Stations
Approximate Scale 1" = 1977'
MARTHA'S VINEYARD ST.
WEST TISBURY
GREAT
TISBURY GREAT POND
Black Point Pond
Plum Bush Pt
Quansoo
Tiah Cove
Deep Bottom Cove
Long Cove
Middle Point Cove
Scrubby Neck
Homer Pond
Watcha Pond
Town Cove
Tidal Flat
1,2
3,4
5
6
7
8,9,10
11,12
13
14

Figure 1

The focus of this effort was on sample collection and analysis. Little of the available funds were allocated for evaluation of the data. This was decided based on the quantity of funds available and the scope of the sampling program required to adequately assess the groundwater.

Geology and Hydrology of the Watershed:

A vast area contributes water to the Pond. This includes that portion of the groundwater system in the outwash plain which flows to the Pond as well as the watersheds of the two streams that drain portions of the western moraine. The watershed for the Great Pond was estimated by Saunders & Associates at 12,000 acres based on the Delaney (1978) groundwater map and surface topography.

A recent evaluation of the aquifer north and east of the Pond has allowed a fairly precise contour of the water table between the Airport property and Old County Road. This survey included 9 monitoring wells. The contour map prepared was done by graphical interpolation and is included in Appendix C as Figure C-1. From this survey, the watershed divide is established north and northeast of the Pond. Using this divide and the Gay Head Moraine/Outwash Plain as boundaries, the watershed (See Figure 1) was planimetered and an acreage of 5856 acres determined.

The stream watersheds were previously determined above Warren's Pond (WP on Fig. 1) and Albert's Pond (AP) by the MVC's 208 program at 4128 acres. In addition, there is an area within the Gay Head Moraine not included in the stream watersheds and, in my opinion, very likely to contribute recharge or runoff to the watershed. This acreage is 857 acres (See Fig. 1). The total watershed area of the Great Pond is estimated at 10841 acres. The primary reason for an acreage less than Saunders Associates is the placement of the northern limit to the watershed.

The outwash aquifer is comprised of stream deposited sands and gravel. Outwash plain sediments deposited by braided stream systems result in laterally discontinuous lenses of sand and gravel elongated in the direction of the stream axis (roughly north-south). In some instances, migration of the stream channel will create sheets of sand and gravel with generally similar grain size and sorting characteristics.

While there is uniformity of groundwater flow through such a deposit on a macro-scale, on a smaller scale there is a wide range of variability. David Delaney, USGS, in his 1978 report on the outwash plain aquifer, estimated hydraulic conductivity in the range of 200 feet per day (14,000 ft square per day divided by a 70 foot thick aquifer). Masterson and Barlow (USGS 1994) estimated 35000 feet square per day.

In addition, the watersheds of the two streams contribute overland flow and seepage from the groundwater into the Tiasquam and Millbrook which flow to the Pond. The watershed area was estimated at 1925 acres for the Tiasquam above Warren's Pond and 2203 acres above Albert's Pond for the Millbrook in a study of the flow of the two streams completed in 1976 by the MVC

208 program. The western moraine is a confusing, contorted and broken, repetitious sequence of strata that includes Cretaceous clays, Pleistocene tills, kames and other sedimentary collapse structures. It is not possible to define the nature of the aquifer in this moraine let alone determine what quantity of the groundwater may reach the streams. The topographic divides were used as the best approximation of the watershed boundaries that we have for these streams. The volume of water reaching the Pond through both systems was estimated by Fugro-McClelland (1992). They used stream gauge readings and flow meter measurements to calculate the following water budget:

groundwater flow to the Pond	5 to 15 mgd (million gallons per day)
stream flow to the Pond	5.5 mgd
rainfall directly to the Pond	2.5 mgd
Total inputs to the Pond	13 to 23 mgd
discharge through the barrier beach	10.0 mgd
evaporation from the Pond	1.3 mgd
Total outflow from the Pond System	11.3 mgd

The net difference, 1.7 to 11.7 mgd, gradually fills the Pond once the breach in the barrier is closed.

Streamflow measurements by the 208 study in 1976, for the period August through November 1975, indicated an average flow of 1.49 mgd for the Mill Brook and 0.98 for the Tiasquam for that period. As that year was a dry year with 14% below the average rainfall, the average flow in a typical year was estimated at 2.05 and 1.14 mgd respectively or a total of 3.3 mgd. This was only a partial year study and the gauging station on Millbrook did not include the lower reaches of the stream, and therefore, the results are expected to be on the low end.

Kent Healy monitored streamflow from the two streams over the course of 1993 and 1994 from which he calculated an average flow of 5.1 mgd for 1994 and 5.95 mgd for 1993. See Figure 2.

From these figures, it is clear that the fresh water input exerts a major influence on the Ponds water budget. Using the Fugro figures, groundwater comprises a minimum of just under 38% of the input to the Pond, streamflow just over 42% and rainfall just over 19%. On the upper end, the groundwater input may comprise up to 65% of the total input. If we can characterize the quality of the groundwater and the streams flowing into the Pond, we can make a generalized model of those potential sources of nutrients in the Pond's overall nutrient budget.

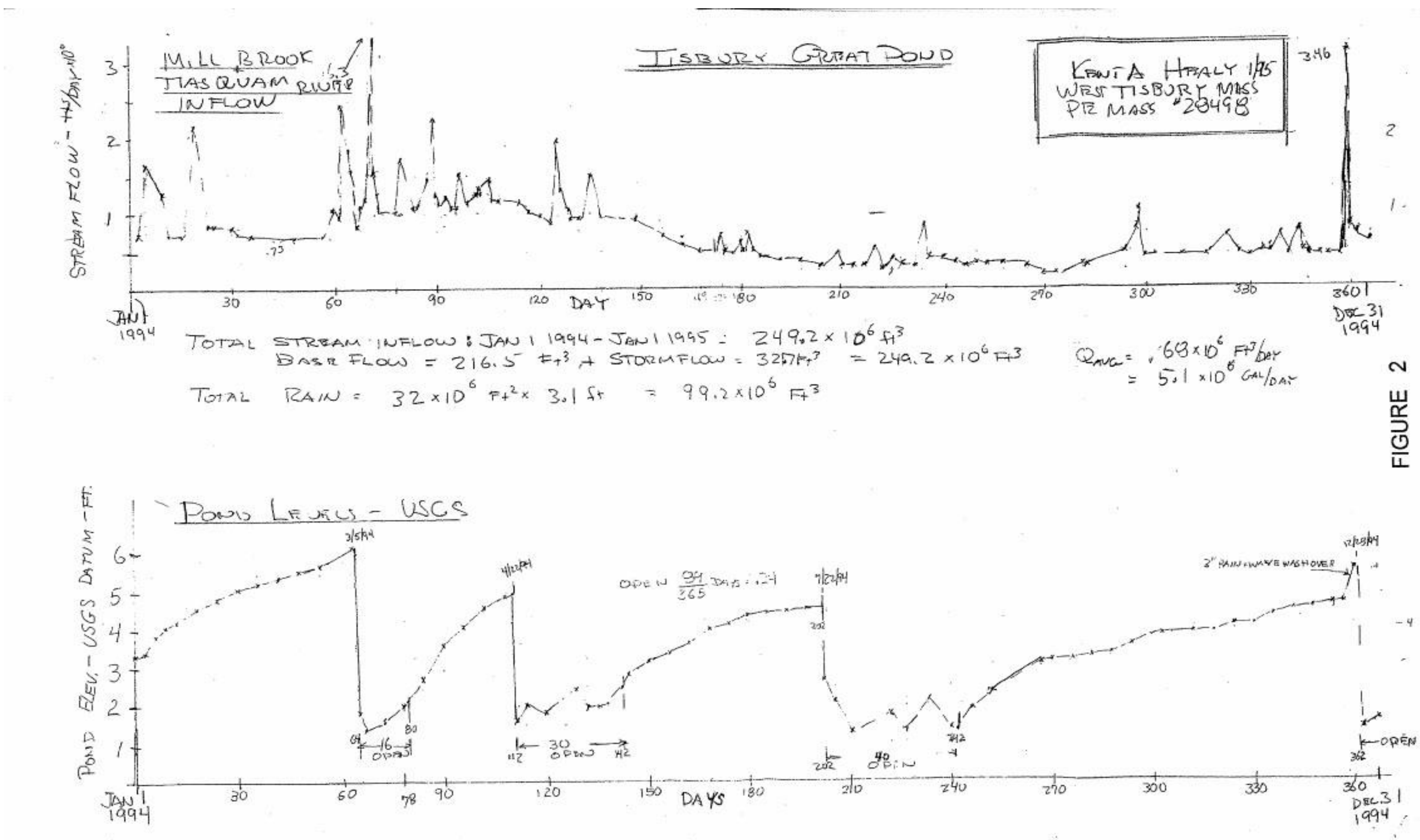

MILL BROOK
TIASQUAM RIVER
INFLOW
TISBURY GREAT POND
KENT A HEALY 1/95
WEST TISBURY MASS
PE MASS #28498
STREAM FLOW - FT³/DAY×10⁶
DAY
JAN 1 1994
DEC 31 1994
TOTAL STREAM INFLOW: JAN 1 1994 - JAN 1 1995 = 249.2 × 10⁶ ft³
BASE FLOW = 216.5 ft³ + STORMFLOW = 32.7 ft³ = 249.2 × 10⁶ ft³
Q AVG = .68 × 10⁶ FT³/DAY
= 5.1 × 10⁶ GAL/DAY
TOTAL RAIN = 32 × 10⁶ ft² × 3.1 ft = 99.2 × 10⁶ ft³
POND LEVELS - USGS
POND ELEV. - USGS DATUM - FT.
OPEN 94/365 DAYS = .24
16 OPEN
30 OPEN
40 OPEN
OPEN
DAYS
JAN 1 1994
DEC 31 1994
FIGURE 2

FIGURE 2

GENERALIZED LAND USE

Approximate watersheds were devised for each sampling well based on expected direction of groundwater and topography. Within these areas, land uses are summarized below. See also Figure C-2 in Appendix C.

Wells 1 and 2 are situated within an agricultural use area. Vegetable crops are grown within about 250 feet. There are no residences within 500 feet to the north and 1200 to 1500 feet to the west.

Wells 3 and 4 are situated in a very low density residential setting. There are residences within 400 feet to the north and 200 feet to the south. To the west, the expected direction from which groundwater flows, there are no residences within 1500 feet. The vegetation is woodland and meadows.

Well 6 is sited in a moderate density residential area south of the Up-Island Gas Station. The size of the contributing area to this well is difficult to determine as it is close to a suspected groundwater divide between the Tiasquam to the south and Millbrook to the north. Within 1000 feet to the north there are 6 residences. Further to the north, is the relatively high density Music Street area at a distance of 1000 to 2000 feet. There is a small hay field in the Music Street area also.

Wells 9 and 10 are sited off Tiah's Cove Road in a very small area of relatively high density. There are 5 residences within 500 feet in the expected direction of groundwater flow. Within 2000 feet, there are 8 residences and 40 within 4000 feet.

Wells 11 and 12 are sited in a rural agricultural area at the base of a steep slope descending from a hayfield of some 20 acres. To the north there are three houses within 500 feet.

Well 13 is situated in Deep Bottom in a wetland near the impoundment created where the road crosses the head of the Pond. There are no houses within 1000 feet and 8 within 2000 feet. There is approximately 7 acres of hay/pasture to the north at about 1200 to 2000 feet.

Well 14 is sited on New Lane in an area of moderate density. Within 500 feet there are 4 houses, 7 more within 1000 feet and another 7 within 1500 feet. A portion of the pasture and holding area for horses at Blackthorn Farm is included within the watershed also.

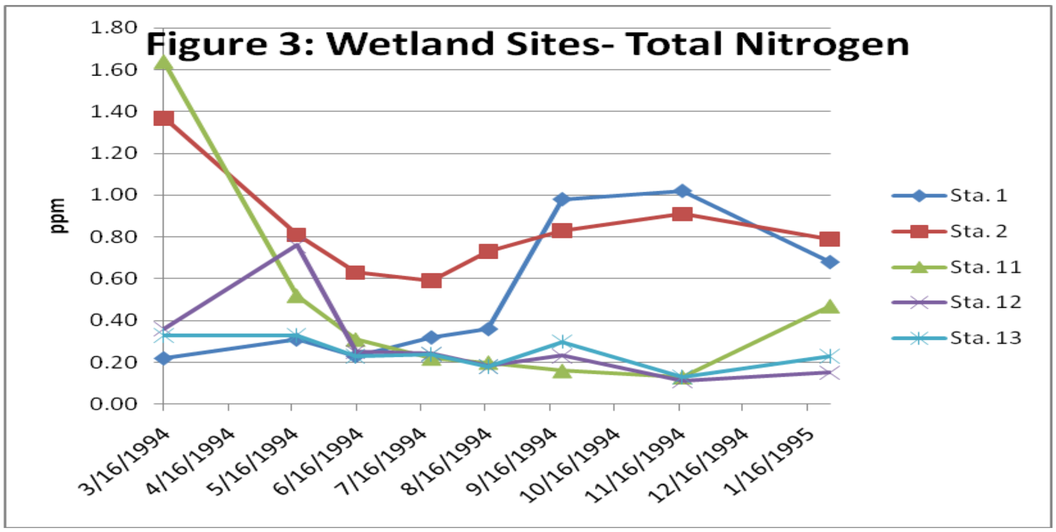
DATA SUMMARY:

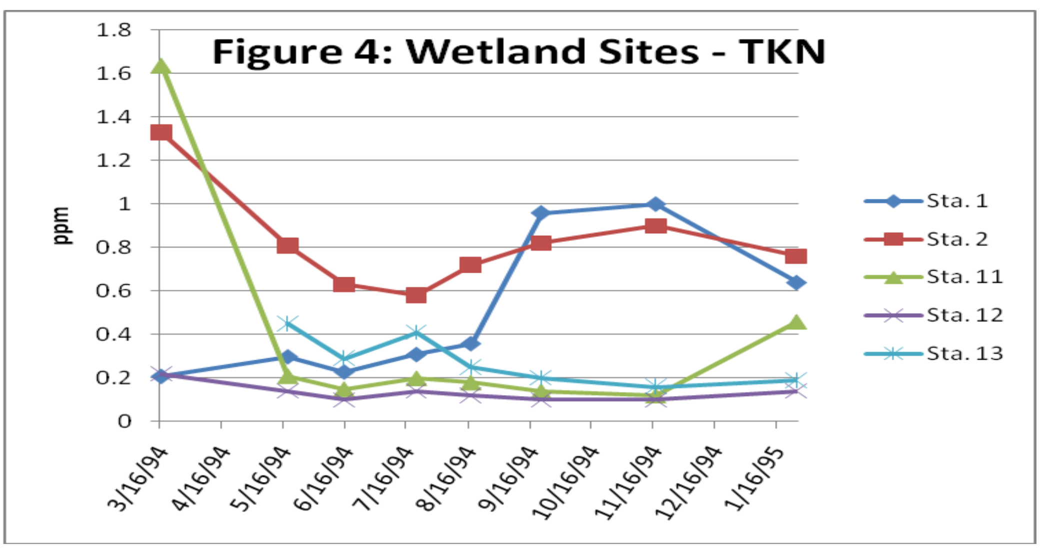
Test results are summarized by month in Tables A-1 through A-8 and by station in Tables B-1 through B-14 situated in Appendix A and B in the back of this report. The wells sited in wetlands include 1, 2, 11, 12 and 13. Of these, 1 and 2 at Hillside Farm are in or just below true wetland muck soils, 11 and 12 are in a seasonal wetland site and 13 is well below the expected depth of organic wetland soils.

TEST RESULTS:

Average values of ammonia and TKN were highest at the monitoring wells at Hillside Farm (Well 1 with an average of 0.50 mg/l and well 2 at 0.82 mg/l). See also Figures 3, 4, 5 and 6. Nitrate levels were low throughout the sampling period at this location, probably reflecting the anaerobic conditions of the soils. Generally, ammonia levels were below 0.1 mg/l at all sites

except the Hillside wells and the Board of Health well (well #6 see Appendix B averages and Figure 1 for locations). In general, TKN values were highest in the wetland wells which are shallow. Compare values in Figure 4 for well 1 (deeper) and 2 (shallow) with 11 (shallow 4 feet) with 12 (deeper, 10 feet). Of the wells sited in upland areas, only at the Board of Health well site (6) were TKN values (average of 0.48 mg/l) in the range of the shallow wetland wells.

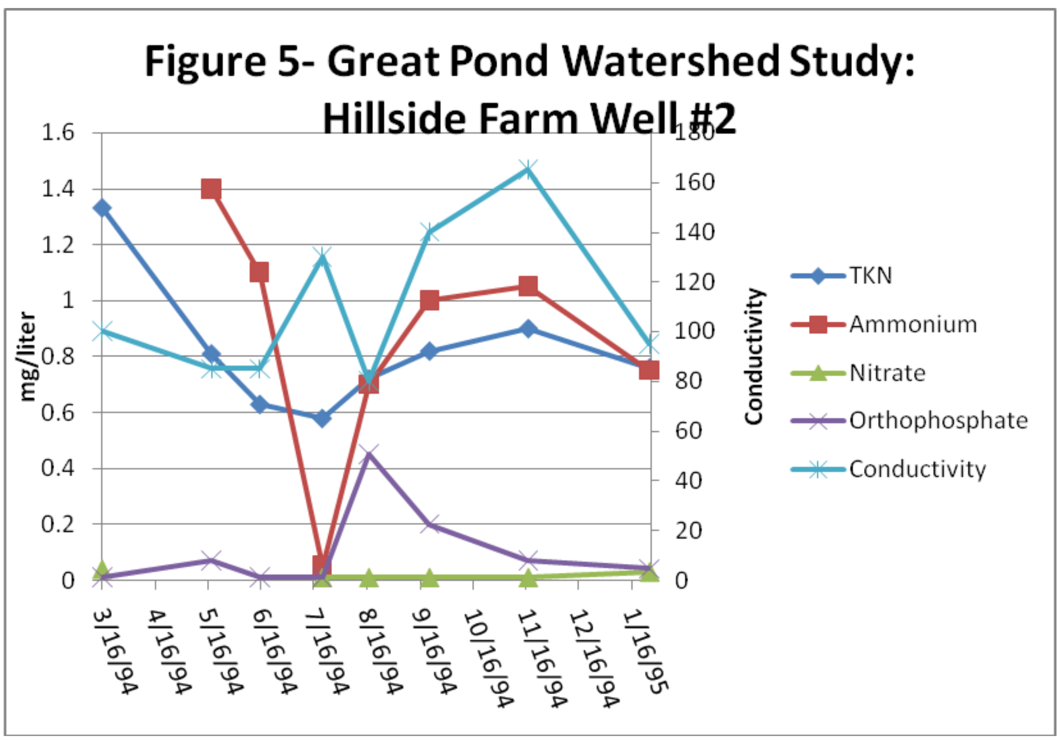




Wells 1 and 2 were placed in wetland soils with significant organic matter content and low chroma colors in the mineral soils reflecting a water table near the surface year round causing variably anaerobic conditions. Conductivity levels were elevated throughout the year and probably reflect dissolved minerals such as ferrous iron and manganese that were not tested (chloride levels were generally low in the Hillside wells throughout the study). Both of these metals are considered to be benign to freshwater life.

At the Deep Bottom site (13) the well penetrates several feet of organic, wetland soils and is screened at a depth of 12.5 feet. Although no well log is available, I suspect the screen is well into mineral soils at that depth. The separation of the intake of this well from organic, wetland soils may account for the lower values of TKN and Total Nitrogen which are only 30 percent of the values at the Hillside site (Figures 3 & 4). The Flat Point wells are also sited in wetland soils but these have a much more limited organic matter content and higher chroma than at Hillside. Both Flat Point wells finish in medium to coarse silty sand.

In Figure 3, we see elevated nitrogen levels at the two farm wetland sites that decline through the growing season at Flat Point Farm but climb to a second peak in September at Hillside. The late summer peak at Hillside is comprised about equally of TKN and ammonia (Fig. 5). It is not clear whether this peak is related to the siting of the wells in a wetland or fertilizer losses from crop production. Urea is often used for side dressing sweet corn (contains no chloride). There is no chloride peak seen in the late summer sampling at the Hillside wells. However, it seems unlikely that ammonia from fertilizers applied to the fields some 30 feet in elevation above the wells and over 200 feet horizontally away would reach the wells without oxidation to the nitrate form. Nitrate levels remain very low throughout the study period (see Figures 5 and 6).



At Flat Point Farm (wells 11 & 12) the values of TKN and total nitrogen are more like those found at Deep Bottom with the exception of the January and March test results. See Figures 3 and 4. The average TKN value in well 11(shallow 4 foot well) is elevated by a high measurement in March (see Figure 7). A spike in the nitrate concentration is seen in the deeper well (Figure 8) in May. There are hay fields in the watershed of these wells that are within about 300 feet of the wells. Conductivity levels are similar across all three sites although the average for wells 11 and 12 are raised by high readings in June (well 11) and July (well 12). This may result from higher Pond levels and lower rainfall (see Fig. 2 and page 45).

A **possible** explanation for the results described above is that the wetland sites release ammonia and organic nitrogen (TKN) in the breakdown of organic matter in an anaerobic setting. At Hillside Farm, the wells more fully intercept this release either by virtue of their siting or because this wetland is more productive. At Deep Bottom, the well penetrates well below the expected level of wetland muck and is reflecting non-wetland nutrient additions from further away. At the Flat Point site, the wetland is more seasonal (controlled by the height of the Pond or the seasonal water table rise) and the wells finish in mineral sands with higher chroma colors.
There is a greater opportunity for oxidation alternating with anaerobic conditions to either convert the nitrogen to gas which is lost or to nitrate.

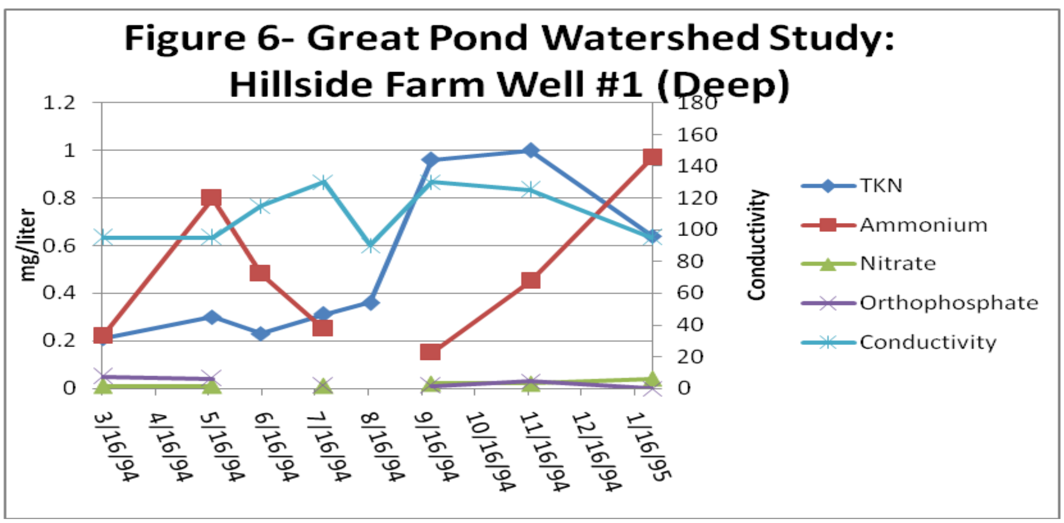


Figure 6- Great Pond Watershed Study: Hillside Farm Well #1 (Deep)

Figure 7- Great Pond Watershed Study: Flat Point Well #11

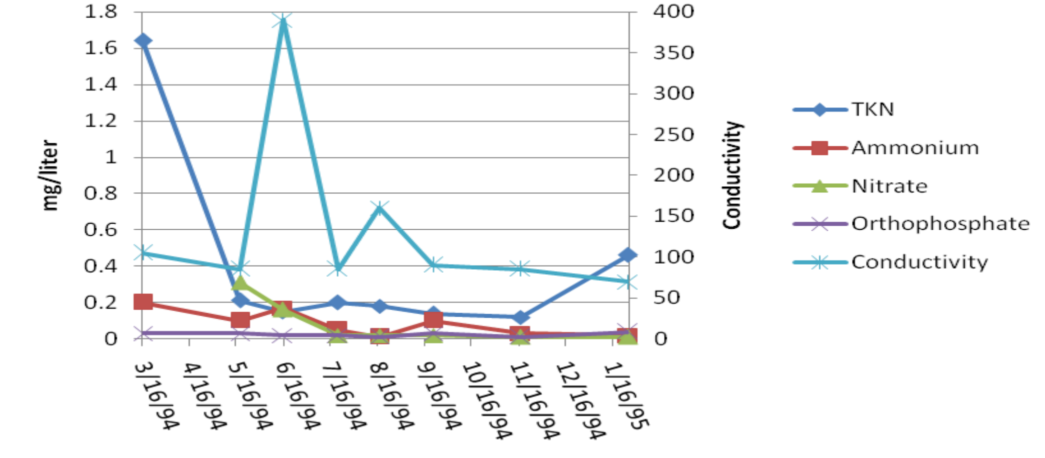
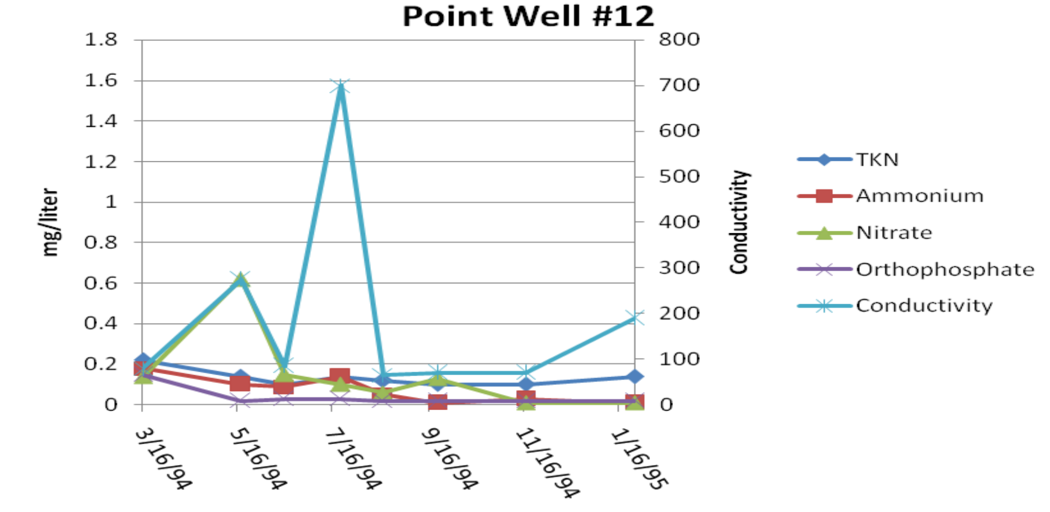
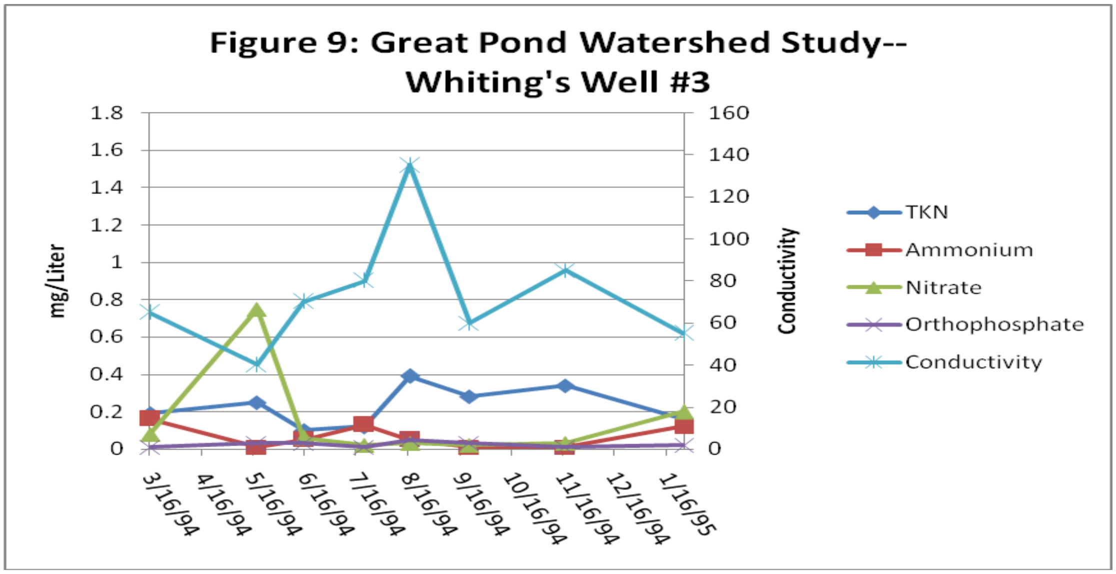


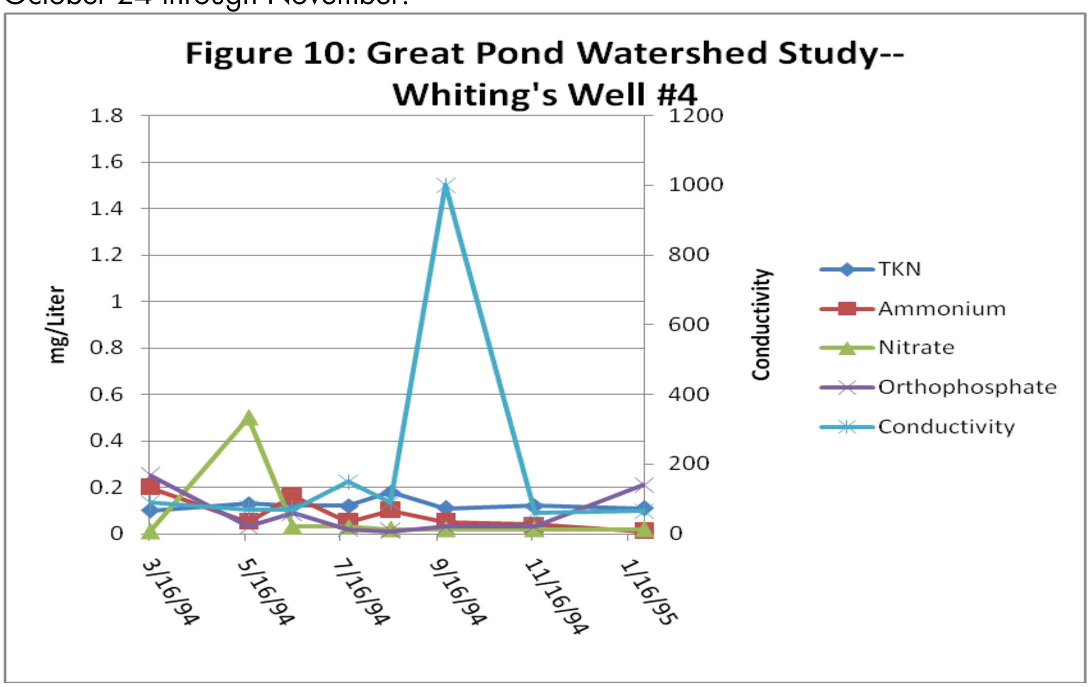
Figure 8: Great Pond Watershed Study--Flat Point Well #12



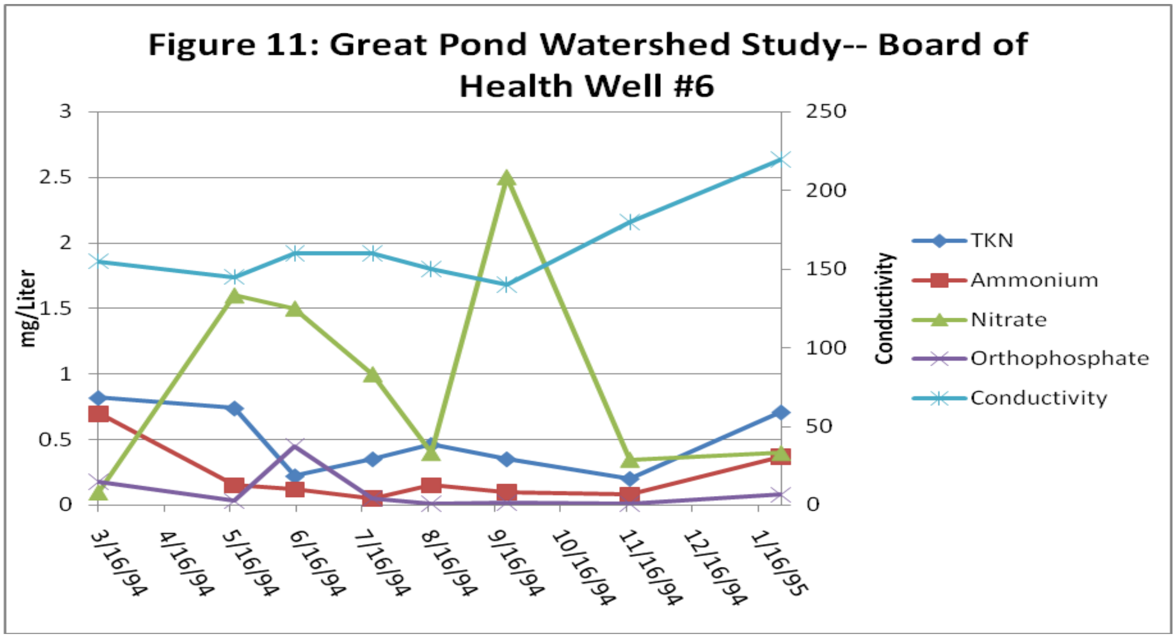
Wells 3 and 4 at the Whiting property were planned as representing background levels of all nutrients. These wells are sited in mineral soils with good aeration. There are no nearby septic systems that might impact the nutrient levels. There is a croquet course in the proximal watershed and its fertilization might be reflected in the May data which show elevated nitrate levels (see Tables A-8, B-3, B-4 and Fig. 9). Rising conductivity levels from June through August in the shallow well (Figure 9) probably reflect low rainfall as well as rising Pond levels following the April 22 to May 22 opening (Fig. 2). Rainfall at West Tisbury averaged less than 3 inches per month during those months.



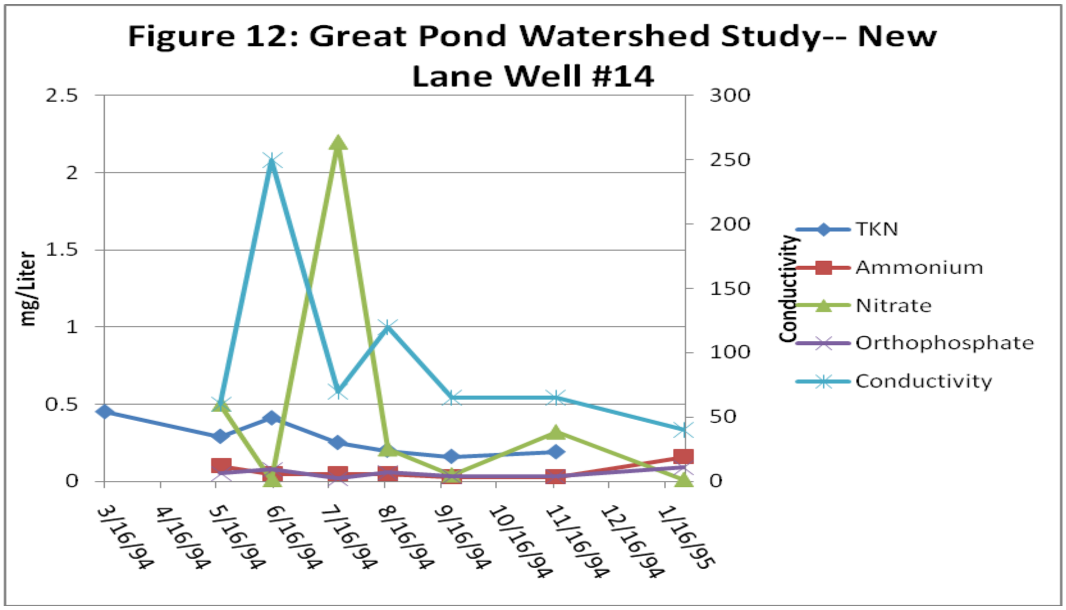
The high conductivity level recorded in the deeper well (# 4 Fig. 10) in September, may reflect the rising pond level which was at 3 feet above NGVD. The November reading in this well when the Pond was nearly at 4 feet elevation (NGVD) was less than 10 percent of the September reading (Figure 10) resulting from recharge from rains averaging over an inch per week from October 24 through November.



Wells 6 and 14 are representative of a more residential setting. At well 6, nitrate levels averaged 0.98 mg/l but showed much higher levels during late spring and late summer peaks during the course of the study. See Table B-6 and Figure 11. The wide range in nitrate levels is reflected by a standard deviation that nearly equals the average. Ammonia levels were also elevated at this site during the March and January readings.

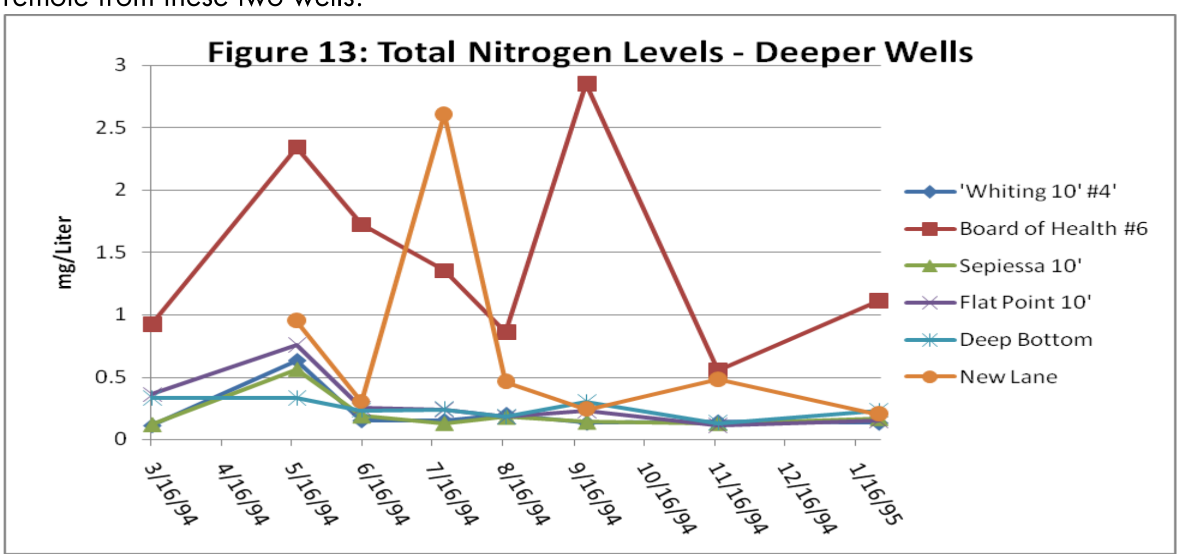


Conductivity levels were consistently elevated at this well site through the course of the study but peaking in January. Main (1986) concluded that the background specific conductance levels in the Edgartown area were between 45 and 60 (micromhos/cm) and levels in the sewage effluent plume (from the Treatment Plant) ranged from 100 to 400. Background chloride levels were considered to be in the range of 22 to 36. Conductivity at the Whiting well (3) and at Deep Bottom (13) averaged 75 and 73 respectively (good control sites). At Well 6, the average Conductivity of 164 and chloride levels averaging 36 mg/l coupled with the periodically elevated nitrogen levels implies the possibility of septic effluent as the source. Keep in mind that this well is screened some 20 feet into the water table. Although there is <u>no</u> clear proof in this instance, contaminant zones from septic systems are often concentrated near the top of the water table and the well samples may be missing the most contaminated portion of the water table.

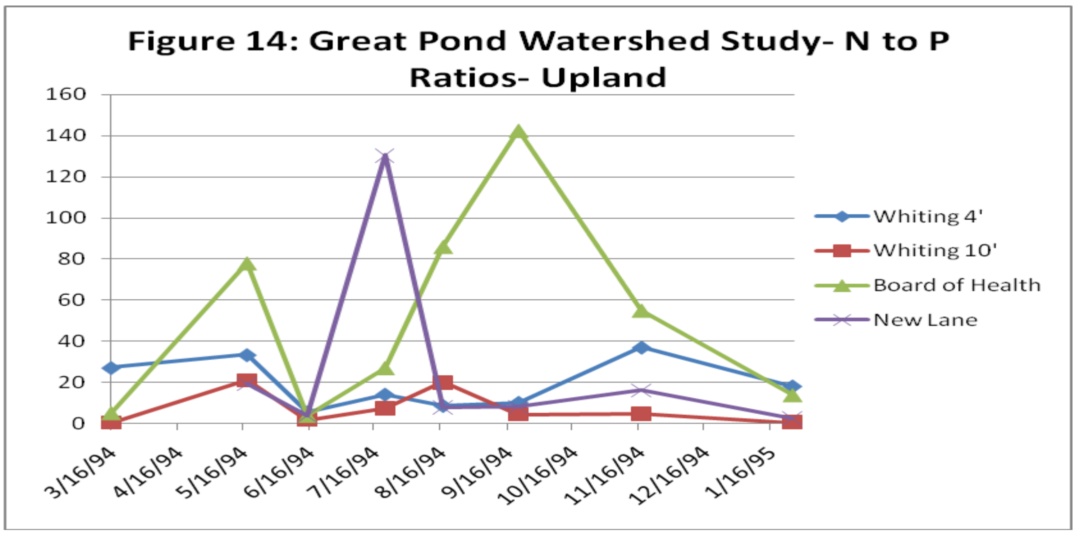


Well 14, situated on New Lane shows a peak in nitrate levels in July and a much lower peak late in the season. See Figure 12 and Table B-14. Conductivity levels are elevated in the June through August time period and average 96 through the course of the study. Elevated chloride levels coincide with the June and August conductivity peaks. Ammonia levels are somewhat higher in May and January.

If we examine the deeper wells, situated well below organic wetland soils or in upland sites, over the course of the study, there are two fairly distinct cycles of Total nitrogen seen (Figure 13). In this plot, the New Lane and Board of Health wells are clearly separated from the other wells which consistently have Total N levels around or below 0.5 mg/l. This is a likely display of the effect of nutrient inputs outside natural cycles. Potential sources include septic systems and to a lesser certainty, agricultural fields which are remote from these two wells.



Relative proportions of nitrogen and phosphorus available in ponds affect the growth of algae and phytoplankton which require large amounts of these two nutrients (along with readily available carbon, hydrogen and oxygen) for growth. Generally a ratio of 15 to 1 (nitrogen to phosphorus) is seen as a break point between systems where nitrogen limits growth (less than 15 to 1) and those where phosphorus limits growth (greater than 15 to 1). As phosphorus is preferentially retained in soils (compared to nitrogen) septic effluent typically has high N/P ratios.



If we compare wells that are likely to be less affected by natural release of nitrogen (i.e. not wetland), a breakout similar to that seen in Figure 13 is apparent (Figure 14). In this Figure, the Board of Health and New Lane wells display much higher N/P ratios at times than the Whiting wells which are considered to represent background levels.

Input of groundwater to the Pond characterized by high N/P ratios would reduce nitrogen as a limiting nutrient for Pond plankton and algae growth while stimulating productivity provided there were adequate levels of the other nutrients required. A likely scenario is that the growth of macrophytes and phytoplankton is fed by inputs of nitrogen from the groundwater, streams and rainfall and by phosphorus from the ocean. We will examine this scenario in the paragraphs which follow.

The streams are an important source of fresh water input to the Pond and the nutrients carried are less likely to be removed from the system by bottom sediments than are the nutrients carried by groundwater which must pass through these sediments before entering the Pond. Bottom sediments may play an important role in removing nitrate from groundwater as the action of anaerobic bacteria in the sediments may convert the nitrate to nitrogen gas lost from the system to the atmosphere. Total N content of the streams is plotted in Figure 15. The May/June peak in Sepiessa Brook is comprised largely of nitrate. This is also true of the May peak in the Tiasquam.

While there is a nitrate peak in the Mill Brook in May also, this peak is at only 0.11 mg/l compared to 0.81 in Sepiessa and 0.45 in the Tiasquam. See Figures 16, 17 and 18 as well as Tables B-5, B-7 and B-8. Peaks of a readily absorbed and used nutrient like nitrate during the growing season imply a significant source that exceeds uptake capability of the rooted macrophytes and algae in the streams. As used here, Total N is the sum of TKN (which includes ammonia) and nitrate in mg/l.

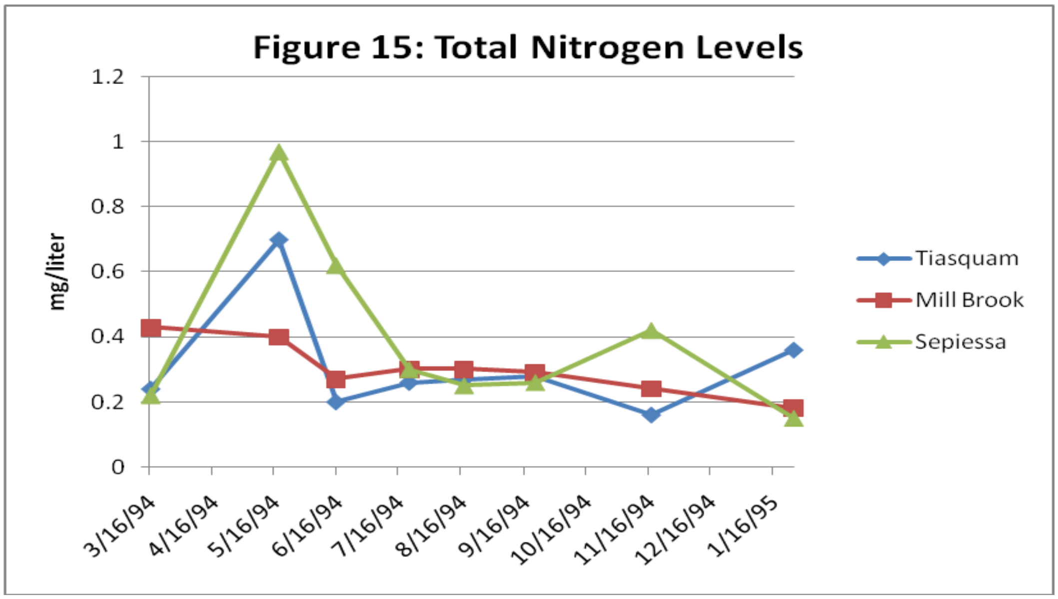


Figure 15: Total Nitrogen Levels

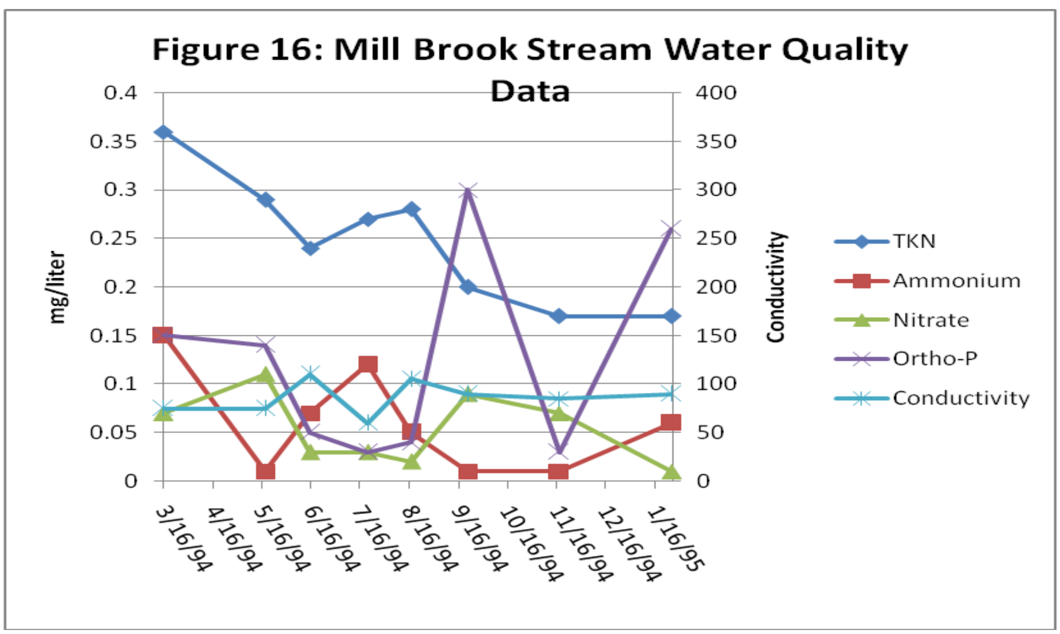
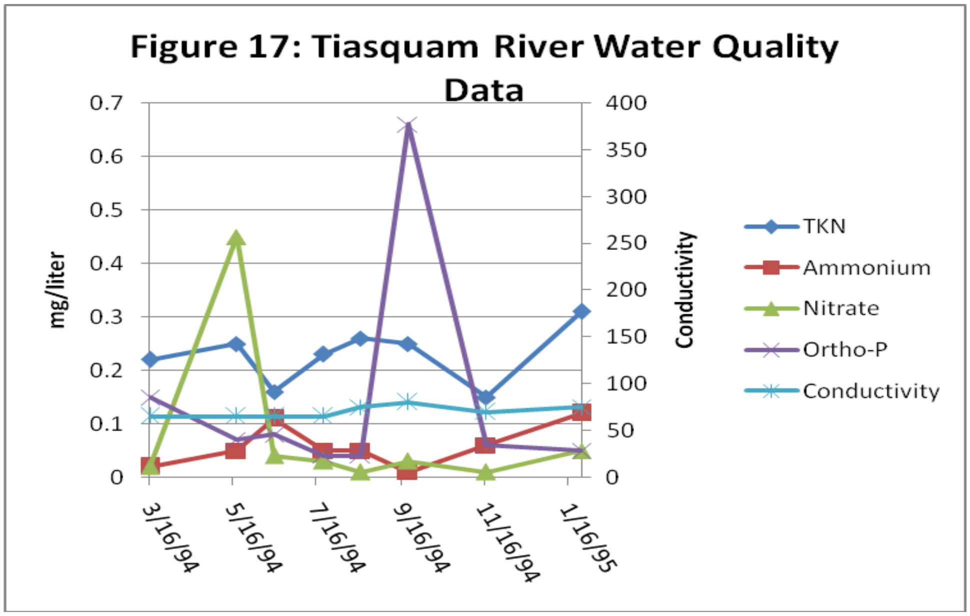
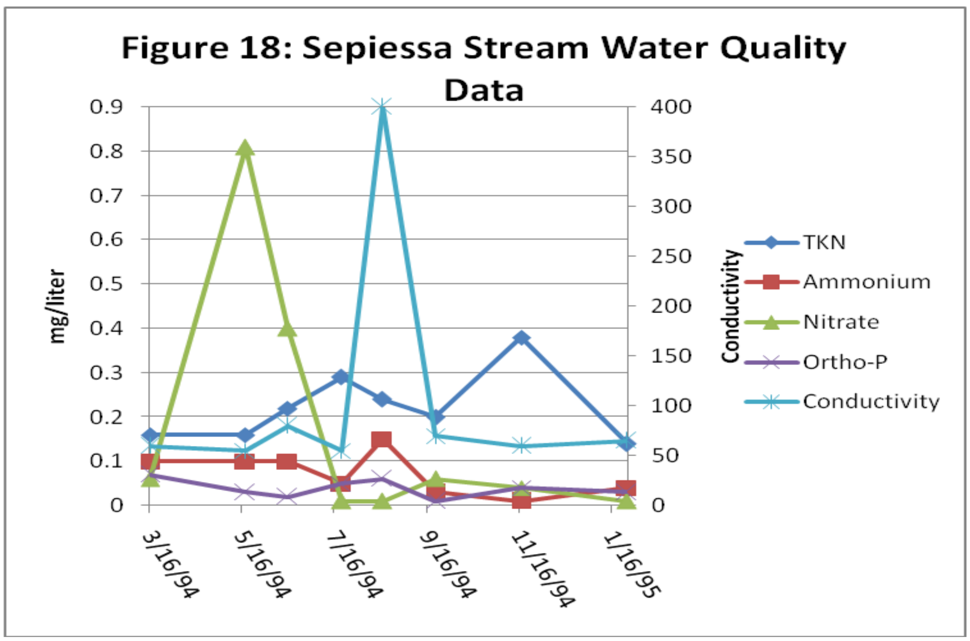
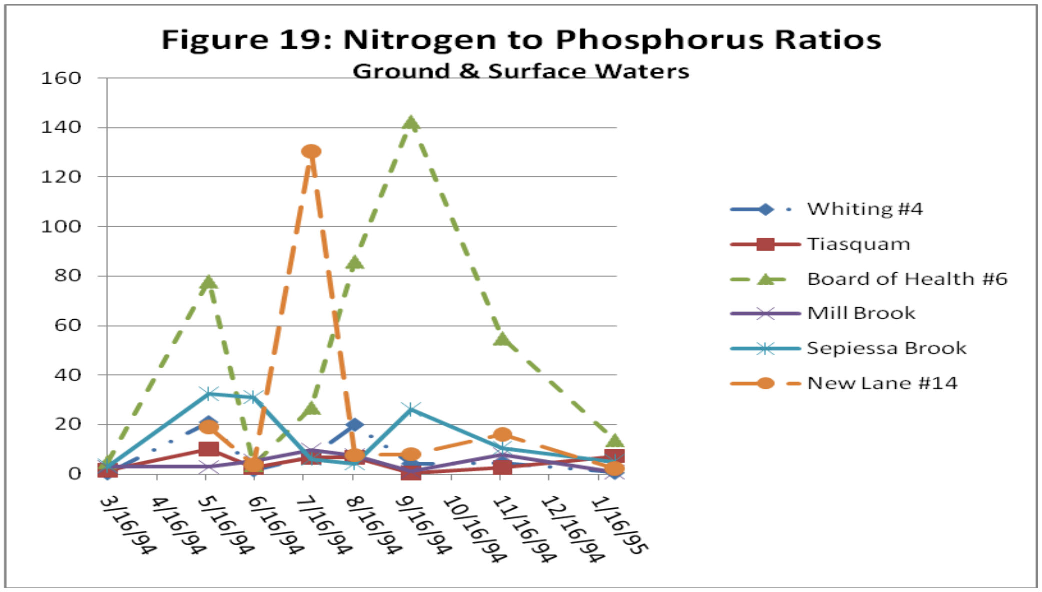


Figure 16: Mill Brook Stream Water Quality Data



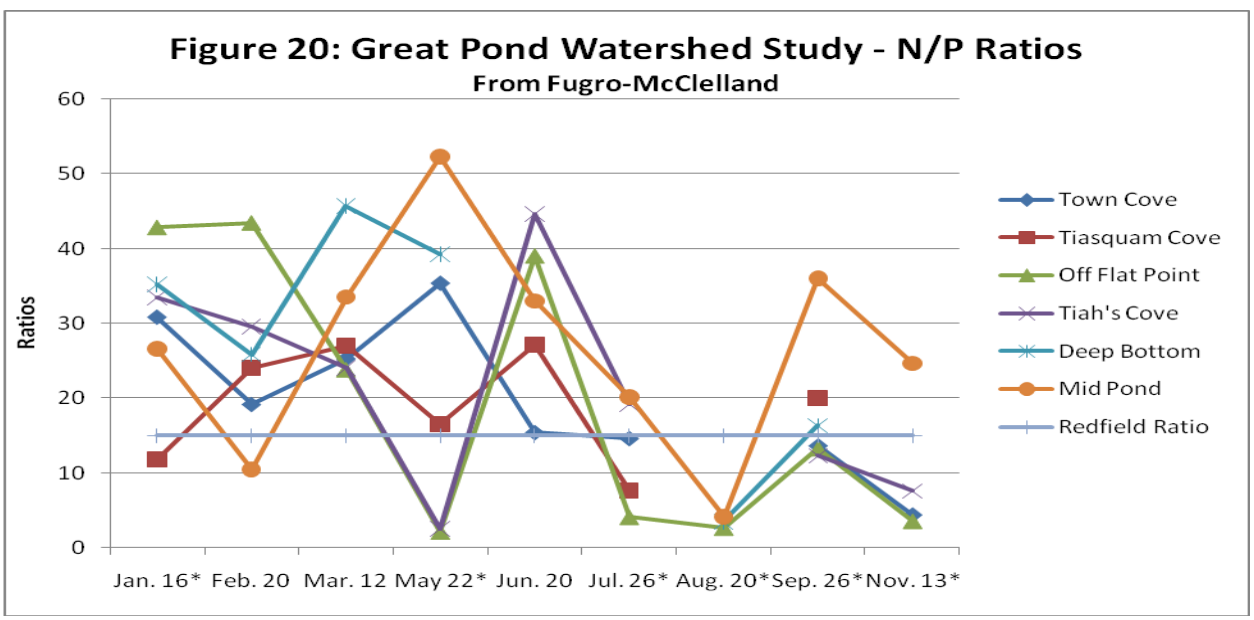


Comparing N/P ratios in the stream systems with those in the groundwater indicates that significant uptake of nitrogen is probably occurring in the stream systems (Figure 19). The Board of Health well is at the divide between groundwater flowing to the Tiasquam and the Mill Brook. Both streams show N/P ratios well below those found in this well and below the 15 to 1 ratio which indicates that they may well be nitrogen limited.



Sepiessa Brook N/P ratios are intermediate between residential groundwater and the other streams. This may reflect greater influence of groundwater bearing nitrogen on this stream than on the other two.

If we look at the N/P ratios in the Pond itself as developed from data collected by Fugro-McClelland in 1991, (Figure 20) there is a confused pattern of ratios at the six stations sampled. This pattern lead them to conclude that the Pond was not apparently either nitrogen or phosphorus limited. The Pond was open from approximately January 18 to January 29, 1991, March 26 to May 7 and July 26 through February 4, 1992. I offer the following descriptive model to explain the fluctuating N/P ratios.



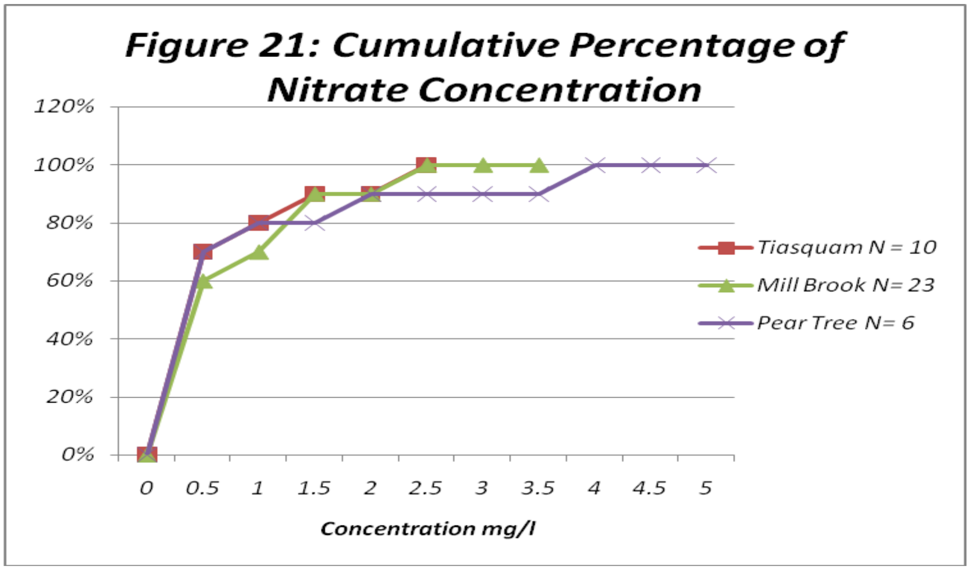
Openings in all likelihood, enrich the system with phosphorus as the ocean is a major source. During openings, somewhat increased discharge of groundwater containing elevated N/P ratios into a lowered Pond occurs, adding nitrogen to the system. Declining N/P at Flat Point Farm and Tiah's Cove from March through May reflect input of P to the system from the opening. After the Pond closed in early May, the N/P ratios rise at these locations as a result of input of fresh waters bearing N.

Conversely, the N/P ratios in Town Cove and in the middle of the southern basin rise following the March opening. This may result from the movement of N enriched waters from the Town Cove area into the southern part of the Pond following the opening as the Pond drains.

Low N/P late in the summer results from the long lasting opening caused by Hurricane Bob. The secondary peak at all stations in late September may result from the decline of aquatic vegetation late in the season as well as the extensive loss of trees and foliage in the watershed caused by the Hurricane which would input nitrogen as it decayed.

<u>Private Well Test Results:</u>
To gain a greater perspective on the distribution of nitrogen in the groundwater, the scope of the sampling effort was increased to include a large number of private wells. These wells were sampled on August 24, 1994, and some were retested on October 20, 1994. Samples were stored on ice and delivered and analyzed at the lab the same day. The samples were tested for nitrate levels only as this was expected to be the most likely nitrogen species to be found in these wells and to keep costs within budget.

The results are shown graphically in Figure 21. This is a cumulative frequency curve of the results which shows what percent of the wells have less or more nitrate than a selected concentration. For example, about 57% of the Millbrook, 67% of the Pear Tree Cove and 70% of the Tiasquam watershed samples were less than 0.5 mg/l. The curve is strongly skewed toward the higher concentrations of nitrate. This means that although the preponderance of the data is concentrated at lower concentrations, there are some instances of much higher concentration which stretch the curve to the upper end of the scale. I interpret this skewness to indicate that the wells sampled randomly intersect zones of the water table that contain elevated nitrate levels. This could result from the well intake point missing the contamination in either the vertical or horizontal planes. This follows from the generally accepted pattern of dispersal of contaminants from their source into the water table which commonly shows little lateral dispersal and gradual deepening in the water table down gradient.



For the three watersheds sampled adequately, the data indicates that 43 percent of the wells tested in the Millbrook watershed, 33 percent of the wells in the Pear Tree watershed and 30 percent in the Tiasquam watershed have nitrate levels that exceed 0.5 mg/l. How does this compare to what might be found in a natural setting with no human input of nitrogen?

Two wells drilled on the M.V. Airport property are representative of groundwater recharging from the State Forest with no human input. Well M-1 is sited in the northwest corner of the Airport property. Well M-2 is sited on the western edge of the property mid-way along the north-south property line. Both wells were screened at the water table. The wells were tested (1988) and all had nitrate reported at 0.0 mg/l and chloride of 5 mg/l in M-1 and 7mg/l in M-2 (Dufresne-Henry, 1990). On Cape Cod, the USGS found ambient nitrate levels near a septage treatment facility at < 0.1 mg/l. Weiskel and Howes (1991) report dissolved inorganic nitrogen background levels on Cape Cod at 1 to 4 uM/L (0.01 to 0.06 mg/L). Also on Cape Cod, Nelson et al estimated the background nitrate level of 0.05 mg/l. Until better information is available, I would suggest we use a 0.05 mg/l value for the background nitrate level. About one third of the <u>private</u> well sample results were at or below 0.06 mg/L (14 out of 40) but were tested only for nitrate. None of the wells tested approached the drinking water limit of 10 mg/l of nitrate. The data provide a statistical picture of the observed nitrogen content of the groundwater discharge to the Pond.

<u>HYPOTHETICAL NITROGEN BUDGET</u>

Introduction:

The following discussion is intended to provide a framework within which we can view the cycling of nitrogen in Tisbury Great Pond and its watershed. The model devised is necessarily based on some approximations as there are components of the model which are not yet clearly spelled out. These deficiencies include the following:

1. Location of the groundwater divide that coincides with the Western Moraine/Outwash

Plain contact. The location shown in Figure 1 follows Delaney (1978). In my opinion, it is highly likely that there is groundwater flow from the area west and north of this line into the Town Cove sub-watershed. With the method used in the model, increased size of this sub-watershed would increase the flow and nitrogen load to the Pond. The additional acreage that, I feel, more closely reflects the actual size of the Town Cove watershed is 857 acres. The data presented includes the extra nitrogen load from this area for this sub-watershed in parentheses.

2. We do not yet understand the nutrient removal effect exerted on groundwater flowing through pond bottom sediments. Most groundwater flow into a pond occurs near the shoreline. Nitrogen removal by the pond bottom mud may reduce nitrogen loads entering the Pond. Further research in this area is necessary.
3. The total volume of groundwater moving to the Pond is not precisely known. It has been suggested that much of the groundwater from the watershed may enter the Atlantic Ocean without ever passing through the Pond system. Recent work in the Edgartown Great Pond Watershed (Whitman & Howard, 1996) indicates this is unlikely unless there is very different geology under the Pond. If we assume 1.67 feet (20 inches) of recharge on an annual basis, in a 5856 acre watershed we derive a figure of 3.2 billion gallons per year moving to the Pond. If we add the additional acreage that I suspect should be in the watershed, the total flow would increase to 3.65 billion gallons per year. These figures are used in the calculations which follow. These flows approach the average flow estimated by Fugro McClelland of 10 million gallons per day (3.65 billion gallons per year). Apportioning groundwater flow to the Sub-watersheds based on their acreage as a percent of the total watershed is reasonable but may not be highly accurate as it was based on surface topography. If the recharge rate is greater than 20 inches per year, the volume of groundwater and the nitrogen load moving to the Pond will be proportionately larger.
4. Despite the sampling program carried out, we can only approximate the nitrogen content of the groundwater moving into the Pond. Contaminant plumes from septic systems, farms and lawns evidently have limited lateral and vertical mixing. The analyses therefore at best represent an average that is dependent on the completeness of the sampling program in characterizing the watershed.
5. Much of the growth on the lower portion of Old County Road and along Tiah's Cove Road occurred in the 1980s. While the Tiah's Cove development is close to the groundwater sampling sites, lower County Road is not. At an approximate distance of 4000 to 10000 feet at the nearest and 1 foot/day travel time, the load from the County Road area may be just beginning to reach the sampling sites. This adds uncertainty to the comparison of measured nitrogen loads versus calculated loads using estimated values for nitrogen sources. This implies that the nitrogen load estimated below is probably a minimum figure.

Groundwater Flows and Nitrogen Loads:

Total groundwater flow to the Pond was estimated at between 5 and 15 million gallons per day (mgd) by Fugro-McClelland. The average flow would be 3.65 billion gallons per year. In Table 1, high (3.65 billion gallons/year) and low (3.2 billion) flow figures were selected. These figures are converted to liters and apportioned to each sub-watershed based on its percent of the total watershed area. **The expanded Town Cove watershed figures (the high flow scenario) and resulting changes in other watersheds are shown in parentheses.** Using mean concentrations of Total Nitrogen, nitrogen loads in the groundwater are calculated. Total Nitrogen is the sum of TKN (which includes ammonia) and nitrate. In examining these figures keep in mind that 1 kilogram is one million milligrams.

In this Table, nitrogen figures are derived from two sources: private drinking water wells and monitoring wells driven near the shoreline. Portions of the sub-watershed that are estimated to contribute to a particular monitoring well are broken out for the Tiasquam where the nitrate value tested in the monitoring well is different from the private wells in the same watershed. These sub watersheds are shown in Figure 1. For example, in the Tiasquam sub-watershed, well 6 had a mean Total Nitrogen concentration of 1.03 mg/l. It was felt that this well did not accurately represent that portion of the watershed southwest of the Tiasquam River. This area is low density residential and agricultural and a much lower concentration was used for this area.

Table 1 Estimated Subwatershed Flows and Nitrogen Loads

		Acreage	**% of Total**	**Total N mg/l**	**Flow liters X10^9**	**Total N Kilos X 10^3**
Chilmark		740	12.64 (11.02)	0.34	1.53 (1.52)	0.520 (0.517)
Tiasquam		243	4.15 (3.62)			
Sub	Well 6	65	1.11 (0.97)	1.03	0.135 (0.134)	0.139 (0.138)
Sub	Outside 6	178	3.04 (2.65)	0.05*	0.369 (0.366)	0.018 (0.018)
Town Cove		760 (1617)	12.98 (24.09)	0.798	1.574 (3.332)	1.256 (2.659)
Pear Tree		1335	22.8 (19.89)	0.604	2.766 (2.751)	1.671 (1.662)
Tiah's Cove		977	16.68 (14.55)	0.191	2.023 (2.012)	0.386 (0.384)
Deep Bottom		1096	18.72 (16.33)	0.246	2.271 (2.258)	0.559 (0.555)
Remainder		705	12.04 (10.5)	0.05*	1.46 (1.452)	0.073 (0.073)
TOTAL all		5856 (6713)			12.13 (13.83	4.622 (6.006)

Notes: * Expected background levels

The nitrogen loads calculated used the private well test results to fill out the picture. These wells were tested for nitrate only and do not include TKN which was a substantial part of the Total Nitrogen in the monitoring wells. The derived average nitrogen concentrations used in Table 1 are probably on the low side for this reason. In well aerated soils typical of this area, nitrogen should be oxidized to nitrate by the time it reaches the water table. Elevated ammonia levels were found mostly in the monitoring wells that were placed in wetland sites. There may be some nitrogen reaching the water table in the form of ammonia from septic systems near the shore where water tables are high and the opportunity to oxidize the effluent is limited. Natural release of ammonia from wetlands should not be discounted but it is not possible to quantify it from the data collected. Ammonia in the stream inputs is included below and probably accounts for the majority of the total from wetlands.
NOTE: the wells sited in wetland soils (wells 1 and 2) were not used in setting average Total Nitrogen levels for these watersheds.

The figure used for nitrogen loading in the discussion that follows is 6.006 billion milligrams per year or 6006 kilograms. The 4662 kilogram loading does provide a low side range for the loading rate.

Farm inputs to the watershed nitrogen load are partially included in the data collected, however, this source is not fully clear. The wells at Hillside Farm did show a second peak of ammonia in the late summer when the other wells sited in wetlands did not (eg. Deep Bottom and Flat Point Farm). However, this is not the expected form of farm-derived nitrogen where application of fertilizer to the surface of the soil provides ample opportunity for oxidation to occur. Estimates of farm nitrogen have been made using standard rates of application and losses to the groundwater (Saunders Associates). These estimates indicate that farms could potentially be a significant source of nitrogen that could approach 15% of the total calculated in Table 1. See also Tables 3 and 4 on this subject.

Stream Derived Nitrogen:
Stream flows were calculated by Kent Healy throughout the course of the sampling study. The total flow for the year averaged 5.1 million gallons per day (mgd). The total flow was partitioned 60 percent to the Millbrook and 40 percent to Tiasquam and further to assume that 65 percent of the flow occurs during the January to May period with the remainder equally spread through the remaining seven months.

In Table 2, monthly flow and estimated concentration of nitrate and ammonia are used to calculate total dissolved nitrogen input. The nitrogen input from the Tiasquam is doubled by a huge delivery of nitrate in May. If this is in error, the total nitrogen delivered by the Millbrook would be over twice the Tiasquam delivery. The same magnitude of nitrate delivery was seen in May in the Sepiessa stream which may indicate the figures are reliable. An estimation of the input of nitrogen from Sepiessa stream is given below.

The streams were sampled in March, May, June, July, August, September, November and

January. Values of the nitrogen species used in Table 2 for months not sampled were estimated from adjoining months nitrogen levels.

Delivery of nitrogen from Sepiessa stream is uncertain as there are no flow estimates for this stream. I would estimate the flow as being in the range of 5 gallons per minute but, even if the flow were in the range of one percent of the total Tiasquam and Millbrook flows (35.4 gpm), the nitrogen input from this source is less than two percent of that from the other streams.

Using a flow of 3.55 gallons per minute (1/10 of 1 percent of Millbrook and Tiasquam flows), I estimate the input of nitrogen from Sepiessa Stream at 1.58 million milligrams (kilograms) per year.

Table 2 : Stream Derived Nitrogen

	Time frame	Liters $X10^6$	NH4 mg/l	Total N from NH4 kilograms	NO3 mg/l	Total N from NO3 kilograms	Total N Load kilos
MillBrook							
	Jan-Feb	1100.6	0.1	110.1	0.03	33.0	
	Mar	550.3	0.1	55.0	0.09	49.5	
	Apr	550.3	0.05	27.5	0.09	49.5	
	May	550.3	0.05	27.5	0.11	60.5	
	Jun-Aug	635.1	0.1	63.5	0.04	25.4	
	Sep-Nov	635.1	0.03	19.1	0.09	57.2	
	Dec	211.7	0.03	6.4	0.03	6.4	
Sub total		4233.4					590.6
Tiasquam							
	Jan	366.9	0.12	44.0	0.04	14.7	
	Feb-Apr	1100.7	0.03	33.0	0.04	44.0	
	May	366.9	0.05	18.4	0.45	165.1	
	Jun	141.1	0.12	16.9	0.04	5.6	
	Jul-Nov	705.5	0.05	35.3	0.04	28.2	
	Dec	141.1	0.12	16.9	0.04	5.6	
Sub total				164.5		263.2	427.7
TOTAL		7055.6		473.6		544.7	1018.3

The total nitrogen load from the three streams is about 1020 kilograms per year.
If TKN is substituted for NH4 in Table 2, the total stream nitrogen load is 2374 Kilograms including an estimate for Sepiessa. As these samples were not filtered and may have included some particulates that would add to the TKN value but might not affect the

NH4 values, I am not sure how to handle this factor. This factor further emphasizes the conservatively low figure that we are working toward. In the estimation of the total nitrogen load below, an average of these two figures is used for the stream contribution. This figure is 1697 kilograms per year.

Rainfall Nitrogen Load:

The other source of nitrogen input to the Pond is from rainfall containing air pollution from the industrial midwest. Reduction of this source is outside the realm of local level action, requiring on-going improvement of federal and state standards. Nevertheless, this source is substantial. In the figures which follow, it is assumed that nitrate bearing rainfall that lands on vegetated ground is absorbed into the vegetative growth cycle and does not enter either the groundwater or the Pond. See page 22. It is possible that the added nitrogen from rainfall may overload the uptake capacity or increase the end of season, decay-driven release of nitrogen into the groundwater. I know of no scientific evaluation of this issue. Assuming that a nitrogen concentration of 0.05 mg/L is carried with infiltrating rainwater over the entire 10841 acre watershed, there would be a total of 1117.9 kilograms added to the system each year from this source. This addition should be included in the groundwater and stream nitrogen test results in Tables 1 and 2.

However, rain falling directly on the Pond and bearing nitrogen is an obvious source of this nutrient not yet counted. Total average rainfall multiplied by the average area of the Pond yields a total volume of 3.1 billion liters per year. Gay and Melching, USGS (1995) reported that a study of rainfall water quality conducted at Truro from 1983 to 1985 found nitrogen levels varied with storm type and path. Oceanic cyclones contained 0.15 mg/l nitrate-nitrogen and 0.08 NH4-nitrogen. Continental cyclones contained 0.11 and 0.08 of the two nitrogen species and cold front storms carried 0.24 and 0.06 mg/l. The USGS arrived at a volume weighted mean of 0.26 mg/l which is used below. Multiplying by the total rainfall directly on the Pond, indicates a total of 806 kilograms per year from rainfall directly to the Pond.

All together, a total load of 7703 kilograms per year are added from the groundwater and stream inputs. The figure of 7703 uses the expanded Town Cove watershed acreage and flow. With the contributions from rain falling directly on the Pond, a total of 8509 kilograms are added to the Pond from all sources each year. About 10 percent is from rain directly to the Pond, 20 percent from the streams and 71 percent from the groundwater. In comparison, Nixon (1982) found that the percentages for Rhode Island coastal ponds broke down as follows: precipitation ranged from 1.2 to 9 percent; groundwater from 71.2 to 94 percent and runoff from 3.6 to 20 percent. Six ponds were studied.

Calculated Nitrogen Load Using a Formula Based Approach:

Calculated nitrogen loading from the number of houses (with assumptions about occupancy rates) and acreage of farmland (with assumptions about nitrogen applied and lost to the groundwater) yield a general model against which we can compare our partially calibrated model.

In Table 3, I have made considerable modification to the nitrogen inputs reported by Saunders

Associates (1989) in acreage figures for farms and nitrogen application and leaching rates based on personal knowledge and recent reports. In addition, I have adjusted lawn application rates and acreage as discussed below. Finally, I use the Gay and Melching (1995) figure and a leaching loss rate of 0.05 mg/l.

Table 3: Calculated Total Watershed Nitrogen Load Using a Formula-Based Approach

Sources	Number	Amount	Loss to System	Total Input kilograms
Farm (hay)	200 acres*	9.1 kg/acre	20%	**91**
Farm (veg.)	90 acres	34.1	40%	**1227.6**
Farm (pasture)	350 acres	2 kg/ac (avg.)	20%	**151.2**
Rainfall (inland	22.36 $X10^9$ liters**	0.05 mg/l		**1117.9**
Rainfall (pond)	3.1 $X10^9$ liters	0.26 mg/l	100%	**806**
Septic wastewater	811 residences	2.27 kilos/person	100%	**3995**
Lawns	811 X1000 s.f.	1 kg/1000 s.f.	20%	**162.2**
TOTAL				**7550.9**

* Assumes 75% is alfalfa hay with 0 nitrogen applied
** Represents recharge on the entire 10,841 acre watershed

In their calculations, Saunders Associates estimated 2.17 people per residence based on one half of the residences being seasonal and occupancy rates of 2.84 per year round and 6 per seasonal residence. Saunders Associates, calculated a total load (in 1988) of 10411 kilograms per year. In addition, they estimated that 20 percent of the nitrogen in rainfall (0.87 mg/L) reached the groundwater resulting in an additional 7619 kilograms per year (see Table 4).

As discussed on page 21, I feel this load is not supported by the background nitrogen levels and by the nitrogen concentration in rainfall (Gay & Melching). Therefore, I suggest modifying their figure for nitrogen from rainfall in the watershed to reflect a concentration of 0.05 mg/L, which results in an added 1237 kilograms (from their 12000 acre watershed). The total annual calculated load is 11648 kilograms. Saunders Associates used lawn areas of 5000 square feet per lot and a loss of 60% per year of the nitrogen fertilizer applied. My impression is that the area estimates may be high and the leaching losses, while varying from 1 to 75 percent in the literature, should be lower (see Petrovic, 1990, Table 5). In Table 3, I have adjusted Saunders Associates figures to reflect lawn areas of 1000 square feet per residence and leaching losses to 20 percent of the 1 kilogram applied per year.

The amount of nitrogen from septic systems that reaches the groundwater is still not thoroughly established. It should vary with rates of application, percolation rates of the soils, development of an organic mat in the leaching zone etc. Removal of nitrogen in the leaching zone may reach to 50 to 75 percent of the total concentration from the septic tank. If 50 percent removal is applied to the figures in Table 3, then a total of 5553.4 kilograms is calculated for the watershed. This reduction might well be offset by changes in the inputs from farms, rain and/or lawns.

The 8509 kilograms per year as calculated from water test results falls midway between the value derived from Table 3 and the 11648 kilograms as modified from Saunders Associates. This indicates to me that the field data provide a reasonable loading figure. It also implies that the build out scenario projected by Saunders Associates based on reasonable estimates of land use nitrogen loads, is within the right range.

At buildout, Saunders Associates projected 2717 residences with 5896 occupants. Assuming the same inputs from farms, rain and the same size lawns and rates of nitrogen loss, a total of 17307 kilograms of nitrogen is released per year. I feel this is a reasonable projection as it is modified by the assumptions in Table 3 that resulted in a loading figure (7551 kilograms) that is within about 11 percent of that derived from field testing. Assuming 50 percent nitrogen removal by the leaching systems for septic effluent, we derive a low end estimate of 10622 kilograms. These figures include the same acreage and loss rates for the farmland and the same assumptions about lawn area and loss rates as well as the same additions of nitrogen from rainfall as in Table 3. I am using conservative leaching rates for fertilizers in all cases. The projected load is an increase over the existing situation by some 25 to 103 percent.

Table 4 summarizes estimated present day and buildout nitrogen loads as discussed above. The range of figures that results from the application of various formulae indicates the difficulty that exists in trying to pin down what the load actually is. Depending on assumptions, we have a four fold range in nitrogen loads from rainfall and a twenty fold range from lawns. It is precisely for this reason that the testing program is so important because it indicates what is actually there.

Table 4 Summary: Nitrogen Loading in Kilograms per Year

Derived from Sampling Program				Estimated by Formulae			
SOURCE	HIGH	LOW		SOURCE	S.A.	S.A.2	TABLE 3
Groundwater	6006	4622		Septic	3991	3991	3995
Streams	2372	1018		Lawns	3310	3310	162
Rain	806	806		Farms	751	751	1470
				Rain	9978	3596	1924
TOTAL N	9184	6446			18030	11648	7551
Projections					35189	17307	

NOTES:

S.A. Taken from Saunders Associates Inc.- no modifications

S.A.2 Modified to adjust rainfall addition only

Projected load at buildout: S.A. revised figure adjusts rainfall, lawn and farm loads to figures or rates used in Table 3 column

What impact would an increase of this magnitude have on the Pond? To fully answer this question, we must first characterize the nitrogen in the Pond system and determine how the Pond flushes to the ocean.

Some Implications For The Pond:

The effect of nitrogen loading on the Pond depends on a number of factors which are not yet fully understood. Assuming the loading figures are close, we still need to know the flushing rate of the Pond in order to establish an appropriate limit to the amount of nitrogen which can safely be added to the Pond on a yearly basis. We can estimate that the Pond is flushed on about a 3 to 4 month interval based on the frequency of Pond openings. This leads to an estimated minimum flushing interval of 90 days.

In Buzzard's Bay, nitrogen loading limits were derived for coastal embayments in a generic fashion which we can use as guidance for Tisbury Great Pond. The limit set for shallow ponds, defined as having 40 percent of their area at less than 1 meter at low water, with flushing intervals greater than 4.5 days fits Tisbury Great Pond. For waters rated as Outstanding Resource Waters, a limit of 5 grams per square meter per year was set (Buzzard's Bay Project, 1991).

At low water, the Pond has 595 acres and 743 at high water. Converting to square meters results in limits of 12 to 15,000 kilograms per year. Our calculated loading of 8509 puts us at 57 to 71 percent of the limit. The high buildout scenario load of 17307 kilograms exceeds the upper limit while the low projection approaches the lower limit. While these nitrogen limits are not based on a detailed analysis of the nutrient cycling in the Pond, they do indicate the importance of getting this information in light of the projected nitrogen loads.

Nitrogen loads to the Pond can be reduced by several approaches:

- limit the number of houses with on-site sewage that are built through purchase of easements or fee title or by zoning changes.
- reduce the nitrogen loads from sewage effluent by requiring on-site sewage disposal units to have advanced treatment removing additional nitrogen.
- reduce nitrogen loads from lawn fertilization by encouraging more naturalized landscaping and the use of water insoluble nitrogen or other slow release nitrogen fertilizers.
- reduce nitrogen applications on vegetable operations through the use of the Umass Extension nitrogen reduction program.

Summary and Conclusions

The ground and stream waters flowing into Tisbury Great Pond were studied over the course of a year from March 1994, to January 1995. It appears that release of ammonia from wetland areas is an important source of nitrogen that is largely accounted for by the stream analyses. However, release from fringing marshes around the Pond was not accounted for. Upland drinking water wells and monitoring wells show nitrogen levels that exceed the background level

(0.06 mg/L) in about two thirds of the wells tested. None exceeded drinking water standards for nitrate (10 mg/l). It was determined that nitrogen additions to the Pond from groundwater are three and one half times that of streams and seven to eight times that resulting from rainfall.

In general, the ratio of total nitrogen to phosphorus is greatest in the groundwater, significantly reduced in the streams and approximates the Redfield limit of 15:1 in the Pond (although the values range widely depending on presence of an opening). This information is interpreted to mean that the groundwater is a source of nitrogen to the Pond and probably to the streams. The streams bind some of the nitrogen in living tissue but still are a source of nitrogen to the Pond. The fact that the streams contain fairly significant amounts of dissolved nitrogen during the growing season implies a source that exceeds uptake capability.

It is not known what role denitrification in the bottom sediments plays in reducing the impact of groundwater percolating through them into the Pond. This phenomenon is accepted as occurring in anaerobic bottom sediments but the extent to which it operates is not known. It may be offset by remineralization (release) of nutrients from the sediments into the upwelling groundwater. In a Pond with a well developed organic muck bottom, this could be a significant source.

Agreement within 11 percent of a general nitrogen loading model with the partially calibrated model derived from this study implies that projections based on buildout scenarios are reasonable. The buildout nitrogen loading based on some modification to the work by Saunders Associates, leads to the conclusion that total nitrogen loading to the Pond will approximately double at buildout. Using man made cuts through the barrier beach to flush out the nutrient load is dependent on raising sufficient head to establish a good opening. Filling the Pond enough for a successful breach to occur is a time dependent process. It is unlikely that any more than four openings per year is possible as is currently the practice. If it is determined that limitations on nutrient inputs to the Pond are required, another course of action is necessary.

What remains to be done? We need to thoroughly describe the nitrogen levels in the Pond and the plankton blooms that are dependent on nutrient inputs from all sources. The tidal flux and resulting flushing rate of the Pond must be accurately determined so that residence time of nutrients entering the Pond can be estimated. From this information, a recommended nitrogen loading limit can be determined for the watershed and on this the Towns can bring into place appropriate land use controls that will maintain nitrogen levels below this level. There are many different approaches available ranging from purchase, purchase of development rights, use of nitrogen removing sewage systems, zoning density to public education on such topics as slow release fertilizers and the value of vegetated buffers.

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Weiskel, Peter and B. Howes (1991) Quantifying Dissolved Nitrogen Flux through a Coastal Watershed, Water Resources Research, V. 27, #11, pp. 2929-2939

Whitman & Howard, Inc.(1996) Letter Report on Second Phase of the Nitrate Plume Investigation

Wilcox, William-Martha's Vineyard Commission(1977)Draft Plan/EIS Water Quality Management Plan for Martha's Vineyard

APPENDIX A

WELL LOCATIONS & WATER LEVEL DATA

For information on well materials, installation and well logs, see Appendix C.

Water table levels in the monitoring wells through the course of the study are provided below. The wells were not surveyed to establish precise elevations. The following elevations are approximate, taken from quad sheets.

Wells 1 and 2 Hillside Farm-	25 feet
Wells 3 and 4 Whiting property-	5 feet
Well 6 Board of Health-	30 feet
Wells 9 and 10 Sepiessa-	8 feet
Wells 11 and 12 Flat Point Farm-	8 feet
Well 13 Deep Bottom-	8 feet
Well 14 New Lane-	20 feet

Depths to the screen on each well are as follows:

Well 1-	14 feet	Well 9-	9 feet
Well 2-	4 feet	Well 10-	14 feet
Well 3-	4 feet	Well 11-	4 feet
Well 4-	9 feet	Well 12-	9 feet
Well 6-	40 feet	Well 13-	10 feet
		Well 14-	13 feet

Tisbury Great Pond Watershed								
	Well Levels Below T.O.C. 1994-95							
Well #	3/16/1994	5/18/1994	6/15/1994	7/20/1994	8/16/1994	9/20/1994	11/16/1994	1/25/1995
1	0.78	0.98	1.37	2.31	1.97	2.52		2.25
2	1.12		1.51	2.20	1.92	2.18		1.65
3	4.41	4.67	3.13	2.48	5.15	4.19	3.01	4.03
4	3.98	4.08	2.70	2.08	4.60	3.73	2.61	3.58
6	28.17	28.78	28.50	28.30	29.37	29.32	28.87	29.06
9	1.77	2.15	1.53	1.20	2.52	2.30	1.67	2.23
10	1.76	2.13	1.51	1.17	2.49	2.28	1.64	2.23
11	2.48	2.86	2.37	1.91	3.18	2.98	2.34	2.88
12	2.39	2.78	2.23	1.85	3.14	2.91	2.26	3.82
13	0.88	1.01	0.78	0.76	2.55	1.76	1.64	1.86
14		11.88	11.64	11.57	12.48	12.65	12.59	12.70
	NOTE:	Well Levels in Feet Below Lip of Well Pipe						

Data Summary by Date Sampled

TABLE A-1	TISBURY GREAT POND WATERSHED NUTRIENT STUDY									
		MARCH 1994 SAMPLING ROUND								
Sample	TKN	NH4-N	NO3-N	PO4	Cond.	Tot. N	N/P Ratio	Chloride	Alk.	pH
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm	ppm	
1	0.21	0.22	0.01	0.05	95	0.22	4.3	14.5		6.14
2	1.33		0.04	0.01	100	1.37	137	23		6.32
3	0.19	0.16	0.08	0.01	65	0.27	27	13	0.6	6.02
4	0.1	0.2	0.01	0.25	90	0.11	0.42	23	3	6.33
5	0.22	0.02	0.02	0.15	65	0.24	1.6	14	3	6.43
6	0.82	0.7	0.1	0.18	155	0.92	5.111	38	8.8	6.12
7	0.36	0.15	0.07	0.15	75	0.43	2.833	16	3.8	6.23
8	0.16	0.1	0.06	0.07	60	0.22	3.143	15	0	5.57
9	0.11	0.1	0.01	0.02	90	0.12	5.75	25.5	2.3	6.24
10	0.18	0.12	0.01	0.02	80	0.19	9.25	22	2.7	6.22
11	1.64	0.2		0.03	105	1.64	54.667	27	3.8	6.47
12	0.22	0.18	0.14	0.15	80	0.36	2.4	18	0.7	6.04
13	0.29	0.05	0.04	0.05	100	0.33	6.6	26	0.6	5.4

TABLE A-2	TISBURY GREAT POND WATERSHED NUTRIENT STUDY									
		MAY 1994 SAMPLING ROUND								
Sample	TKN	NH4-N	NO3-N	PO4	Cond.	Tot N	N/P Ratio	Chloride	Alk.	pH
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm	ppm	
1	0.3	0.8	0.01	0.04	95	0.31	7.75	13		6.01
2	0.81	1.4		0.07	85	0.81	11.57	17		5.97
3	0.25	0.01	0.75	0.03	40	1	33.33	7		5.34
4	0.13	0.05	0.5	0.03	70	0.63	21	16		5.95
5	0.25	0.05	0.45	0.07	65	0.7	10	12.5		6.13
6	0.74	0.15	1.6	0.03	145	2.34	78	13		5.74
7	0.29	0.01	0.11	0.14	75	0.4	2.86	16		6.29
8	0.16	0.1	0.81	0.03	55	0.97	32.33	12		5.49
9	0.11	0.05	0.45	0.03	60	0.56	18.67	13.5		5.67
10	0.1	0.1	0.01	0.01	55	0.11	11	11		5.77
11	0.21	0.1	0.31	0.03	85	0.52	17.33	19		5.1
12	0.14	0.1	0.62	0.02	275	0.76	38	15		3.07
13	0.32	0.15	0.01	0.01	55	0.33	33	13.5		5.2
14	0.45	0.1	0.5	0.05	60	0.95	19	11		6.05

TABLE A-3	TISBURY GREAT POND WATERSHED NUTRIENT STUDY									
		JUNE 1994 SAMPLING ROUND								
Sample	TKN	NH4-N	NO3-N	PO4	Cond.	Total N	N/P Ratio	Chloride	Alk	pH
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm	ppm	
1	0.23	0.48			115	0.23	#DIV/0!		16.8	6.08
2	0.63	1.1		0.01	85	0.63	63	20	15.8	5.86
3	0.1	0.05	0.06	0.03	70	0.16	5.333	15	0.9	5.02
4	0.12	0.16	0.03	0.09	70	0.15	1.667	12.6	2.6	6.16
5	0.16	0.11	0.04	0.08	65	0.2	2.5		2.8	5.86
6	0.22	0.12	1.5	0.45	160	1.72	3.822	26	8.1	5.67
7	0.24	0.07	0.03	0.05	110	0.27	5.4	17	16	6.12
8	0.22	0.1	0.4	0.02	80	0.62	31	20.6		5.84
9	0.16	0.08	0.03	0.03	70	0.19	6.333	16		5.92
10	0.1	0.14	0.06	0.04	65	0.16	4	17.5		6.24
11	0.15	0.17	0.16	0.02	390	0.31	15.5	85	0.4	4.92
12	0.1	0.09	0.15	0.03	85	0.25	8.333	17	7.1	6.1
13	0.17	0.09	0.06	0.02	80	0.23	11.5	19	0.7	4.58
14	0.29	0.05	0.01	0.08	250	0.3	3.75	60.5	2.7	6.64

TABLE A-4	TISBURY GREAT WATERSHED NUTRIENT STUDY								
		JULY 1994 SAMPLING ROUND							
Sample	TKN	NH4-N	NO3-N	PO4	Cond.	Tot N	N/P Ratio	Chloride	Alk.	pH
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm	ppm	
1	0.31	0.25	0.01	0.01	130	0.32	32	25	2.2	6.13
2	0.58	0.05	0.01	0.01	130	0.59	59	26	14.7	6.42
3	0.12	0.13	0.02	0.01	80	0.14	14	19	0.2	5.3
4	0.12	0.05	0.03	0.02	150	0.145	7.25	42	1.1	6.53
5	0.23	0.05	0.03	0.04	65	0.26	6.5	13	3.4	6.9
6	0.35	0.05	1	0.05	160	1.35	27	35	9.8	5.88
7	0.27	0.12	0.03	0.03	60	0.295	9.833	16	8	6.4
8	0.29	0.05	0.01	0.05	55	0.3	6	16	0.2	5.6
9	0.12	0.15	0.01	0.01	60	0.13	13	16	0.8	5.9
10	0.14	0.15	0.02	0.02	60	0.16	8	20.4	0.8	5.73
11	0.2	0.05	0.02	0.02	85	0.22	11	25.6	0	5.02
12	0.14	0.14	0.1	0.03	700	0.24	8	18.5		2.73
13	0.23	0.05	0.01	0.02	55	0.24	12	14.5	0	4.81
14	0.41	0.05	2.2	0.02	70	2.61	130.5	15	0.3	5.04

TABLE A-5	TISBURY GREAT POND WATERSHED NUTRIENT STUDY									
		AUGUST 1994 SAMPLING ROUND								
SAMPLE	TKN	NH4-N	NO3-N	PO 4	COND.	TOT. N	N/P	CHLORIDE	ALK.	pH
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm	ppm	
1	0.36				90	0.36	#DIV/0!		0	5.47
2	0.72	0.7	0.01	0.45	80	0.73	1.62	60	10.6	6.03
3	0.39	0.05	0.03	0.05	135	0.42	8.40	38	0.4	5.38
4	0.18	0.1	0.02	0.01	90	0.2	20.00	24	0	4.56
5	0.26	0.05	0.01	0.04	75	0.27	6.75	18	1.1	5.32
6	0.46	0.15	0.4	0.01	150	0.86	86.00	40	4.9	5.44
7	0.28	0.05	0.02	0.04	105	0.3	7.50	34	7	5.81
8	0.24	0.15	0.01	0.06	400	0.25	4.17	112	1.6	5.75
9	0.16	0.05	0.02	0.02	95	0.18	9.00	20	2	5.08
10	0.38	0.15	0.03	0.01	80	0.41	41.00	20.5	2.7	5.45
11	0.18	0.01	0.02	0.01	160	0.2	20.00	32	0.5	4.76
12	0.12	0.05	0.06	0.02	65	0.18	9.00	17	4.4	5.06
13	0.15	0.05	0.03	0.03	75	0.18	6.00	52	0	4.81
14	0.25	0.05	0.21	0.06	120	0.46	7.67	28	2	5.04

TABLE A-6	TISBURY GREAT POND WATERSHED NUTRIENT STUDY									
		SEPTEMBER 1994 SAMPLING ROUND								
Sample	TKN	NH4-N	NO3-N	PO4	Cond.	Tot N	N/P Ratio	Chloride	Alk.	pH
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm	ppm	
1	0.96	0.15	0.02	0.01	130	0.98	98	32	0	6.43
2	0.82	1	0.01	0.2	140	0.83	4.15	18.5	9.7	6.28
3	0.28	0.01	0.02	0.03	60	0.3	10	12.5	1	5.9
4	0.11	0.05	0.02	0.03	1000	0.13	4.33	17.5	0	2.94
5	0.25	0.01	0.03	0.66	80	0.28	0.42	14.5	2.6	5.05
6	0.35	0.1	2.5	0.02	140	2.85	142.5	28	5.7	5.28
7	0.2	0.01	0.09	0.3	90	0.29	0.97	20.5	7.1	5.72
8	0.2	0.03	0.06	0.01	70	0.26	26	14	3.4	5.8
9	0.1	0.01	0.04	0.01	60	0.14	14	16	1.1	5.67
10	0.11	0.01	0.02	0.02	60	0.13	6.5	18	1.3	5.66
11	0.14	0.1	0.02	0.03	90	0.16	5.33	20	0	4.47
12	0.1	0.01	0.13	0.02	70	0.23	11.5	19	3	5.23
13	0.27	0.01	0.03	0.01	85	0.3	30	24	0	4.45
14	0.2	0.03	0.04	0.03	65	0.24	8	15.5	0.4	4.79

TABLE A-7	TISBURY GREAT POND WATERSHED NUTRIENT STUDY									
		NOVEMBER 1994 SAMPLING ROUND								
SAMPLE #	TKN	NH4-N	NO3-N	PO 4	COND.	TOT. N	N/P	CHLORIDE	ALK.	pH
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm	ppm	
1	1	0.45	0.02	0.03	125	1.02	34	27	17	6.65
2	0.9	1.05	0.01	0.07	165	0.91	13	20		6.28
3	0.34	0.01	0.03	0.01	85	0.37	37	22	0.1	5.5
4	0.12	0.04	0.02	0.03	60	0.14	4.667	16	2.6	5.88
5	0.15	0.06	0.01	0.06	70	0.16	2.667	19	3.7	6.06
6	0.2	0.08	0.35	0.01	180	0.55	55	45	5	5.79
7	0.17	0.01	0.065	0.03	85	0.235	7.833	18	7	6.18
8	0.38	0.01	0.04	0.04	60	0.42	10.5	17	1.8	6.14
9	0.11	0.01	0.02	0.03	60	0.13	4.333	18	22	6.05
10	0.1	0.01	0.01	0.06	75	0.11	1.833	14		4.52
11	0.12	0.03	0.01	0.01	85	0.13	13	24	0	5.03
12	0.1	0.03	0.01	0.02	70	0.11	5.5	15	3.6	5.66
13	0.1	0.05	0.03	0.15	70	0.13	0.867	19	0	4.95
14	0.16	0.03	0.32	0.03	65	0.48	16	11	1.4	5.1

TABLE A-8	Tisbury Great Pond Watershed Nutrient Study									
	January 1995 Sampling Round									
SAMPLE #	TKN	NH 4	NO 3	PO 4	COND.	TOT. N	N/P	CHLORIDE	ALK.	pH
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm	ppm	
1	0.64	0.97	0.04	0	95	0.68	#DIV/0!	18		4
2	0.76	0.75	0.03	0.04	95	0.79	19.75	33		5.95
3	0.16	0.12	0.2	0.02	55	0.36	18	15		6.2
4	0.11	0.01	0.02	0.21	65	0.13	0.62	21		6.4
5	0.31	0.12	0.05	0.05	75	0.36	7.2	43		6.21
6	0.71	0.37	0.4	0.08	220	1.11	13.88	64		6.01
7	0.17	0.06	0.01	0.26	90	0.18	0.69	23		6.25
8	0.14	0.04	0.01	0.03	65	0.15	5	28		6.24
9	0.13	0.02	0.04	0.02	65	0.17	8.5	16		6.16
10	0.15	0.05	0.01	0.01	60	0.16	16	17		6.04
11	0.46	0.02	0.01	0.04	70	0.47	11.75	15		5.02
12	0.14	0.01	0.01	0.02	190	0.15	7.5	21		3.85
13	0.21	0.06	0.02	0.04	65	0.23	5.75	14		5.81
14	0.19	0.16	0.01	0.09	40	0.2	2.22	12		6.64

APPENDIX B

Data Summary by Sample Location

TABLE B-1	TISBURY GREAT POND WATERSHED NUTRIENT STUDY						
SUMMARY OF DATA FROM STATION NUMBER					Well 1	Hillside deep	
DATE	TKN	NH4-N	NO3-N	PO4	Cond.	TOT. N	N/P	Chloride
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm
3/16/94	0.21	0.22	0.01	0.05	95	0.22	4.3	14.5
5/18/94	0.3	0.8	0.01	0.04	95	0.31	7.75	13
6/15/94	0.23	0.48			115	0.23		
7/21/94	0.31	0.25	0.01	0.01	130	0.32	32	25
8/17/94	0.36				90	0.36		
9/21/94	0.96	0.15	0.02	0.01	130	0.98	98	32
11/17/94	1	0.45	0.02	0.03	125	1.02	34	27
1/26/95	0.64	0.97	0.04	0	95	0.68		18

TABLE B-2	TISBURY GREAT POND WATERSHED NUTRIENT STUDY							
SUMMARY OF DATA FROM STATION NUMBER						Well 2 Hillside shallow		
DATE	TKN	NH4-N	NO3-N	PO4	Cond.	Total N	N/P	Chloride
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm
3/16/94	1.33		0.04	0.01	100	1.37	137	23
5/18/94	0.81	1.4		0.07	85	0.81	11.57	17
6/15/94	0.63	1.1		0.01	85	0.63	63	20
7/21/94	0.58	0.05	0.01	0.01	130	0.59	59	26
8/17/94	0.72	0.7	0.01	0.45	80	0.73	1.62	60
9/21/94	0.82	1	0.01	0.2	140	0.83	4.15	18.5
11/17/94	0.9	1.05	0.01	0.07	165	0.91	13	20
1/26/95	0.76	0.75	0.03	0.04	95	0.79	19.75	33

TABLE B-3	TISBURY GREAT POND WATERSHED NUTRIENT STUDY							
SUMMARY OF DATA FROM STATION NUMBER						3	Whiting's 4 foot well	
DATE	TKN	NH4-N	NO3-N	PO4	Cond.	TOT. N	N/P	Chloride
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm
3/16/94	0.19	0.16	0.08	0.01	65	0.27	27	13
5/18/94	0.25	0.01	0.75	0.03	40	1	33.33	7
6/15/94	0.1	0.05	0.06	0.03	70	0.16	5.33	15
7/21/94	0.12	0.13	0.02	0.01	80	0.14	14	19
8/17/94	0.39	0.05	0.03	0.05	135	0.42	8.4	38
9/21/94	0.28	0.01	0.02	0.03	60	0.3	10	12.5
11/17/94	0.34	0.01	0.03	0.01	85	0.37	37	22
1/26/95	0.16	0.12	0.2	0.02	55	0.36	18	15

TABLE B-4	TISBURY GREAT POND WATERSHED NUTRIENT STUDY							
SUMMARY OF DATA FROM STATION NUMBER						4	Whiting's 10 foot well	
DATE	TKN	NH4-N	NO3-N	PO4	Cond.	TOT. N	N/P	Chloride
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm
3/16/94	0.1	0.2	0.01	0.25	90	0.11	0.42	23
5/18/94	0.13	0.05	0.5	0.03	70	0.63	21	16
6/15/94	0.12	0.16	0.03	0.09	70	0.15	1.67	12.6
7/21/94	0.12	0.05	0.03	0.02	150	0.15	7.25	42
8/17/94	0.18	0.1	0.02	0.01	90	0.2	20	24
9/21/94	0.11	0.05	0.02	0.03	1000	0.13	4.33	17.5
11/17/94	0.12	0.04	0.02	0.03	60	0.14	4.67	16
1/26/95	0.11	0.01	0.02	0.21	65	0.13	0.62	21

TABLE B-5	TISBURY GREAT POND WATERSHED NUTRIENT STUDY							
SUMMARY OF DATA FROM STATION NUMBER						5	Tiasquam River	
DATE	TKN	NH4-N	NO3-N	PO4	Cond.	TOT. N	N/P	Chloride
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm
3/16/94	0.22	0.02	0.02	0.15	65	0.24	1.6	14
5/18/94	0.25	0.05	0.45	0.07	65	0.7	10	12.5
6/15/94	0.16	0.11	0.04	0.08	65	0.2	2.5	
7/21/94	0.23	0.05	0.03	0.04	65	0.26	6.5	13
8/17/94	0.26	0.05	0.01	0.04	75	0.27	6.75	18
9/21/94	0.25	0.01	0.03	0.66	80	0.28	0.42	14.5
11/17/94	0.15	0.06	0.01	0.06	70	0.16	2.67	19
1/26/95	0.31	0.12	0.05	0.05	75	0.36	7.2	43

TABLE B-6	TISBURY GREAT POND WATERSHED NUTRIENT STUDY								
SUMMARY OF DATA FROM STATION NUMBER					6	Board of Health well behind up-island gas			
DATE	TKN	NH4-N	NO3-N	PO4	Cond.	TOT. N	N/P	Chloride	
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm	ppm
3/16/94	0.82	0.7	0.1	0.18	155	0.92	5.11	38	
5/18/94	0.74	0.15	1.6	0.03	145	2.34	78	13	
6/15/94	0.22	0.12	1.5	0.45	160	1.72	3.82	26	
7/21/94	0.35	0.05	1	0.05	160	1.35	27	35	
8/17/94	0.46	0.15	0.4	0.01	150	0.86	86	40	
9/21/94	0.35	0.1	2.5	0.02	140	2.85	142.5	28	
11/17/94	0.2	0.08	0.35	0.01	180	0.55	55	45	
1/26/95	0.71	0.37	0.4	0.08	220	1.11	13.88	64	

TABLE B-7	TISBURY GREAT POND WATERSHED NUTRIENT STUDY							
SUMMARY OF DATA FROM STATION NUMBER						7	Mill Brook @ Doane's	
DATE	TKN	NH4-N	NO3-N	PO4	Cond.	TOT. N	N/P	Chloride
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm
3/16/94	0.36	0.15	0.07	0.15	75	0.43	2.83	16
5/18/94	0.29	0.01	0.11	0.14	75	0.4	2.86	16
6/15/94	0.24	0.07	0.03	0.05	110	0.27	5.4	17
7/21/94	0.27	0.12	0.03	0.03	60	0.3	9.83	16
8/17/94	0.28	0.05	0.02	0.04	105	0.3	7.5	34
9/21/94	0.2	0.01	0.09	0.3	90	0.29	0.97	20.5
11/17/94	0.17	0.01	0.07	0.03	85	0.24	7.83	18
1/26/95	0.17	0.06	0.01	0.26	90	0.18	0.69	23

TABLE B-8	TISBURY GREAT POND WATERSHED NUTRIENT STUDY							
SUMMARY OF DATA FROM STATION NUMBER					8	Sepiessa Brook @ New Lane		
DATE	TKN	NH4-N	NO3-N	PO4	Cond.	TOT. N	N/P	Chloride
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm
3/16/94	0.16	0.1	0.06	0.07	60	0.22	3.14	15
5/18/94	0.16	0.1	0.81	0.03	55	0.97	32.33	12
6/15/94	0.22	0.1	0.4	0.02	80	0.62	31	20.6
7/21/94	0.29	0.05	0.01	0.05	55	0.3	6	16
8/17/94	0.24	0.15	0.01	0.06	400	0.25	4.17	112
9/21/94	0.2	0.03	0.06	0.01	70	0.26	26	14
11/17/94	0.38	0.01	0.04	0.04	60	0.42	10.5	17
1/26/95	0.14	0.04	0.01	0.03	65	0.15	5	28

TABLE B-9	TISBURY GREAT POND WATERSHED NUTRIENT STUDY							
SUMMARY OF DATA FROM STATION NUMBER						9	Sepiessa 10' well	
DATE	TKN	NH4-N	NO3-N	PO4	Cond.	TOT. N	N/P	Chloride
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm
3/16/94	0.11	0.1	0.01	0.02	90	0.12	5.75	25.5
5/18/94	0.11	0.05	0.45	0.03	60	0.56	18.67	13.5
6/15/94	0.16	0.08	0.03	0.03	70	0.19	6.33	16
7/21/94	0.12	0.15	0.01	0.01	60	0.13	13	16
8/17/94	0.16	0.05	0.02	0.02	95	0.18	9	20
9/21/94	0.1	0.01	0.04	0.01	60	0.14	14	16
11/17/94	0.11	0.01	0.02	0.03	60	0.13	4.33	18
1/26/95	0.13	0.02	0.04	0.02	65	0.17	8.5	16

TABLE B-10	TISBURY GREAT POND WATERSHED NUTRIENT STUDY							
SUMMARY OF DATA FROM STATION NUMBER					10	Sepiessa 15' well		
DATE	TKN	NH4-N	NO3-N	PO4	Cond.	TOT. N	N/P	Chloride
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm
3/16/94	0.18	0.12	0.01	0.02	80	0.19	9.25	22
5/18/94	0.1	0.1	0.01	0.01	55	0.11	11	11
6/15/94	0.1	0.14	0.06	0.04	65	0.16	4	17.5
7/21/94	0.14	0.15	0.02	0.02	60	0.16	8	20.4
8/17/94	0.38	0.15	0.03	0.01	80	0.41	41	20.5
9/21/94	0.11	0.01	0.02	0.02	60	0.13	7	18
11/17/94	0.1	0.01	0.01	0.06	75	0.11	1.83	14
1/26/95	0.15	0.05	0.01	0.01	60	0.16	16	17

TABLE B-11	TISBURY GREAT POND WATERSHED NUTRIENT STUDY							
SUMMARY OF DATA FROM STATION NUMBER					11	Flat Point farm 4 foot well		
DATE	TKN	NH4-N	NO3-N	PO4	Cond.	TOT. N	N/P	Chloride
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm
3/16/94	1.64	0.2		0.03	105	1.64	54.67	27
5/18/94	0.21	0.1	0.31	0.03	85	0.52	17.33	19
6/15/94	0.15	0.17	0.16	0.02	390	0.31	15.5	85
7/21/94	0.2	0.05	0.02	0.02	85	0.22	11	25.6
8/17/94	0.18	0.01	0.02	0.01	160	0.2	20	32
9/21/94	0.14	0.1	0.02	0.03	90	0.16	5.33	20
11/17/94	0.12	0.03	0.01	0.01	85	0.13	13	24
1/26/95	0.46	0.02	0.01	0.04	70	0.47	11.75	15

TABLE B-12	TISBURY GREAT POND WATERSHED NUTRIENT STUDY							
SUMMARY OF DATA FROM STATION NUMBER						12	Flat Point 10 foot well	
DATE	TKN	NH4-N	NO3-N	PO4	Cond.	TOT. N	N/P	Chloride
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm
3/16/94	0.22	0.18	0.14	0.15	80	0.36	2.4	18
5/18/94	0.14	0.1	0.62	0.02	275	0.76	38	15
6/15/94	0.1	0.09	0.15	0.03	85	0.25	8.33	17
7/21/94	0.14	0.14	0.1	0.03	700	0.24	8	18.5
8/17/94	0.12	0.05	0.06	0.02	65	0.18	9	17
9/21/94	0.1	0.01	0.13	0.02	70	0.23	11.5	19
11/17/94	0.1	0.03	0.01	0.02	70	0.11	5.5	15
1/26/95	0.14	0.01	0.01	0.02	190	0.15	7.5	21

TABLE B-13	TISBURY GREAT POND WATERSHED NUTRIENT STUDY							
SUMMARY OF DATA FROM STATION NUMBER					13	Deep Bottom well		
DATE	TKN	NH4-N	NO3-N	PO4	Cond.	TOT. N	N/P	Chloride
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm
3/16/94	0.29	0.05	0.04	0.05	100	0.33	6.6	26
5/18/94	0.32	0.15	0.01	0.01	55	0.33	33	13.5
6/15/94	0.17	0.09	0.06	0.02	80	0.23	11.5	19
7/21/94	0.23	0.05	0.01	0.02	55	0.24	12	14.5
8/17/94	0.15	0.05	0.03	0.03	75	0.18	6	52
9/21/94	0.27	0.01	0.03	0.01	85	0.3	30	24
11/17/94	0.1	0.05	0.03	0.15	70	0.13	0.87	19
1/26/95	0.21	0.06	0.02	0.04	65	0.23	5.75	14

TABLE B-14	TISBURY GREAT POND WATERSHED NUTRIENT STUDY							
SUMMARY OF DATA FROM STATION NUMBER					14	New Lane well		
DATE	TKN	NH4-N	NO3-N	PO4	Cond.	TOT. N	N/P	Chloride
	ppm	ppm	ppm	ppm	micromhos	ppm		ppm
3/16/94								
5/18/94	0.45	0.1	0.5	0.05	60	0.95	19	11
6/15/94	0.29	0.05	0.01	0.08	250	0.3	3.75	60.5
7/21/94	0.41	0.05	2.2	0.02	70	2.61	130.5	15
8/17/94	0.25	0.05	0.21	0.06	120	0.46	7.67	28
9/21/94	0.2	0.03	0.04	0.03	65	0.24	8	15.5
11/17/94	0.16	0.03	0.32	0.03	65	0.48	16	11
1/26/95	0.19	0.16	0.01	0.09	40	0.2	2.22	12

APPENDIX C:

Pond Watershed, Well Installation, Sampling Technique and Logs

POND WATERSHED

The water table was contoured based on elevation data collected on or near April 29, 1996 from a total of nine wells. These wells include two on Old County Road; one on Stoney Hill Road; one at Greenlands; one at Rosbeck's Pond on West Tisbury Road; one north and south of the County treatment plant; one near the old well house on the Airport property and one near the dug pond at the State Forest. The locations of these wells are shown on Figure C©1. With additional wells the water table contouring might change somewhat. The contours were crucial in placing the groundwater divide for the Great Pond to the northeast and north of the Pond. The divide is expected to extend nearly to the north-south runway. There appears to be some effect on the water table configuration from either or both Deep Bottom and Waldron's Bottom which causes some groundwater flow to the south-southwest from the Airport property.

Watershed Land Use:

land use map is attached as Figure C-2. determination of acreages of various land use types was beyond the scope of this study. However, Saunders Associates did determine these acreages and the percentages derived are probably reasonable approximations of the current situation. They are:

- Not subdivided 35.6%
- Permanent Conservation 12.8%
- State Forest 19.5%
- Commercial 1.7%
- Subdivided 16.1%
- Built 15.4%

Pond Openings and Elevations:

The Pond was **open** during the following times:

3/5-3/21 1994
4/22-5/22 1994
7/22-9/1 1994
12/28 1994

During sampling rounds, the **Pond elevations** were as follows:

3 /16/94	+1.5 feet	very low
5/18/94	+2.0 feet	low
6/15/94	+3.75 feet	high
7/20/94	+3.5 feet	high
8/16/94	+1.5 feet	very low
9/20/94	+2.9 feet	moderate
11/16/94	+4.0 feet	high
1/25/95	not available	

WELL INSTALLATION & MATERIALS

Wells were constructed of 1/2 inch black steel threaded pipe sections. Couplings were threaded onto the adjoining sections. The pipe was driven after a four foot hole was excavated with bucket auger. Well points were manufactured locally with approximately 1/2 by 62 millimeter apertures. Due to the nature of the installation technique, actual sediments from below the depth of the auger excavation were not directly examined.

Wells were installed in clusters of two or three to sample the groundwater at the surface of the water table, from a depth of 5 feet into the water table and, in some cases from a depth of 10 feet into the water table. The theoretical basis for this placement pattern was that the shallow wells would reflect land uses nearby and the deeper wells would be affected by land use further out. The shallow well was constructed of 4 inch pvc schedule 40 pipe. It was "jetted" into the surrounding sediment by removal of sediment from inside the pipe with periodic downward and twisting pressure applied to the pipe. With this technique, the pipe could be worked 1 to 2 feet into the water table. The assumption made was that the deeper wells would reflect inputs to the groundwater from further away while the shallow wells would reflect proximal inputs.

SAMPLING TECHNIQUE

Water samples were collected with a "Jack Rabbit" peristaltic type hand pump. The wells were purged of fines by continuous pumping. Well volumes were calculated from the length of standing water in the pipe at each sampling. Three well volumes of water were removed from each well before the sample was acquired. This technique not only purged the well of standing water but it also thoroughly flushed the pump so that there would be no concern with cross contamination from consecutive wells.

Well 8, situated behind the Up-Island Gas Station, is a 2 inch diameter pvc well placed as a monitoring well with a total depth of 50 feet below grade. Typically there was about 20 feet of standing water in this well at sampling. A bailer was used to purge this well and gather the sample for analyses. Because of the large volume of water standing in this well it was not purged as thoroughly as the other wells. One to one and one half well volumes were removed before the water sample was taken.

Water samples were collected in sterilized bottles and packed in ice until transported to the lab. For most sample rounds, all samples were delivered to the lab the same day as the collection. TKN samples which were transported by air to Aquatec Lab were acidified to Ph 2 at sampling. During the July through January sampling rounds, some samples were taken the morning after the majority were collected. All samples were kept on ice throughout.

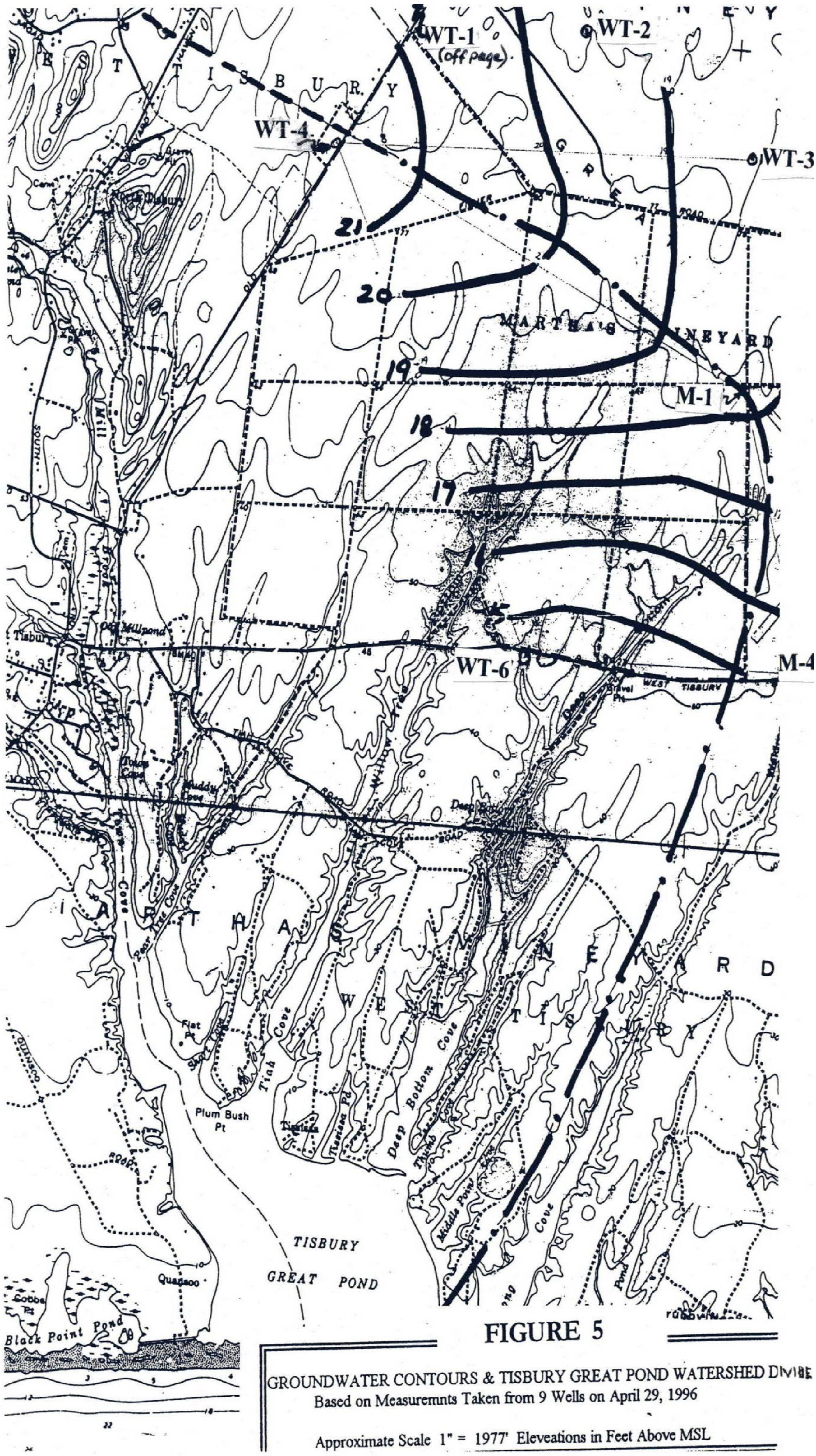

FIGURE 5

GROUNDWATER CONTOURS & TISBURY GREAT POND WATERSHED DIVIDE
Based on Measuremnts Taken from 9 Wells on April 29, 1996

Approximate Scale 1" = 1977' Eleveations in Feet Above MSL

FIGURE C-1

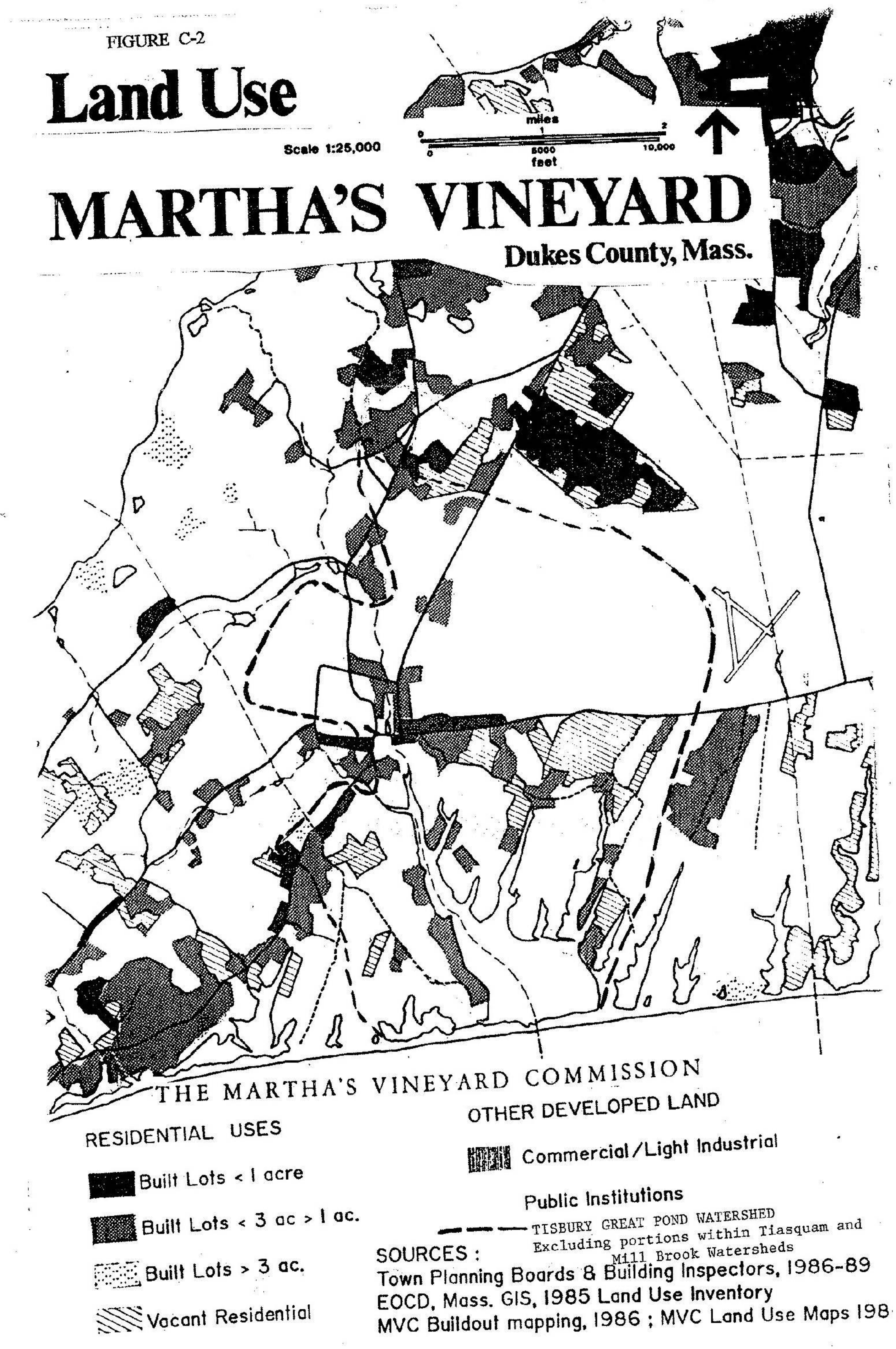
FIGURE C-2
Land Use
Scale 1:25,000
miles
feet
MARTHA'S VINEYARD
Dukes County, Mass.
THE MARTHA'S VINEYARD COMMISSION
RESIDENTIAL USES
Built Lots < 1 acre
Built Lots < 3 ac > 1 ac.
Built Lots > 3 ac.
Vacant Residential
OTHER DEVELOPED LAND
Commercial/Light Industrial
Public Institutions
TISBURY GREAT POND WATERSHED Excluding portions within Tiasquam and Mill Brook Watersheds
SOURCES :
Town Planning Boards & Building Inspectors, 1986-89
EOCD, Mass. GIS, 1985 Land Use Inventory
MVC Buildout mapping, 1986 ; MVC Land Use Maps 198

<u>SAMPLING SCHEDULE</u>

Water samples were taken from all wells and the streams on the following dates:

16 March 1994
18 May 1994
15 June 1994
20 & 21 July 1994
16 & 17 August 1994
20 & 21 September 1994
16 & 17 November 1994
25 & 26 January 1995

<u>SIMPLIFIED WELL LOGS</u>

Hillside Farm:

Wells 1 and 2 were installed at Hillside Farm in the wetland which borders Mill Brook. The wells were at the base of a steep slope at the top of which about 10 acres of vegetable crops were sited. The first foot of the soil profile included cobbles in an organic, poorly sorted, silty sand which graded into another 2 feet of silty sand with some organic matter but lacking the cobbles. From 3 to 5 feet an olive, silty, coarse sand with 1 to 5 inch pebbles and cobbles was encountered. From 5 to 10 feet a deep grey-green, micaceous, silty, very fine sand was found. This strongly resembles glauconitic greensand found elsewhere on the Island. It is not known if this deposit is autochthonous (in place as deposited) or represents a flow till or reworked deposit extracted from the Gay Head Moraine by the stream. At 10 feet, a very dense section of the same material was found and apparently continued to a depth of 15 feet. There are also reports of this material being encountered at the West Tisbury School near surface.

The upper levels of the section penetrated had dark grey to black colors indicating a strong likelihood that the section is nearly continuously anaerobic.

Permeability in this "greensand" was very limited. The two wells finished in this deposit had to be pumped down 12 to 24 hours before sample collection. These wells were purged once before sampling. The ten foot well in this deposit was abandoned as it would not recharge sufficiently to allow sampling. The source of the recharge water to the 15 foot well is uncertain although from the density of the overlying deposits, it is expected to be recharged from the depth at which it was finished.

If this greensand is laterally continuous, it has interesting implications for the relationship between the stream and the groundwater. It might be interpreted as meaning that the stream only receives input from a perched water table formed on the greensand and that the stream is exclusively effluent, that is, it does not contribute to the main aquifer. This issue should be examined in greater detail through the use of intensive streamflow monitoring at the dam sites along its length to assess changes in flow that might expose the nature of the Millbrook-groundwater relationship. The four inch diameter well was finished at a depth of 4 feet below grade.

Whiting Property:
Wells 3 and 4 were placed just north of Big Sandy on the side of a low bank. The first four feet of material encountered was a silty medium to coarse sand with some gravel. In one hole, a zone of cobbles was found at 3 feet. The remainder of the section appeared to be sand with fine gravel and some silt. This observation is based on the nature of the progress with the driven point and not on direct observation.

BOARD OF HEALTH MONITORING WELL:
This well(#6) is sited southwest of the Up Island Gas Station and was placed as a monitoring well for petroleum products. The well has a two inch casing and extends approximately 50 feet below grade. The well extends some 20 feet into the water table. The well is sited near the divide that is expected to separate groundwater flowing toward Millbrook from those moving toward the Tiasquam.

TIAH'S COVE:
Wells numbered 9 and 10 are sited 10 and 15 feet respectively below grade. The materials in the section penetrated were not directly observed as both wells were driven. From the "feel" of the driving, it is expected that a silty sand was found throughout.

FLAT POINT FARM:
Wells 11 and 12 were sited near the head of the wetland that extends from the north end of Pear Tree Cove. The wells are in a wetland although never flooded during the course of the study. They are sited at the base of a 20 foot bluff that slopes down from a hay field which is relatively flat. The shallow well is 4 inch pvc and was finished at a depth of 4 feet below grade. A 1/2 inch steel well was finished at a depth of 10 feet below grade. Soil materials penetrated included 6 inches of organic soil and root mat, 3 feet of medium, silty, sand coarsening downward. The remainder of the section penetrated with the driven well appears to continue the 3 foot section observed. It was difficult to clear the 4 inch well of the silty component by pumping. In fact, it was not until the third or fourth sampling round that the well cleared completely. The soil materials penetrated below the topsoil were all high chroma sands with brown to orange coloring indicating an oxidative environment. Although not observed, I would expect some mottling to indicate periodic flooding of the subsoil.

DEEP BOTTOM:
Well 13 was placed by the USGS in 1976 and is sited in the wetland across the road to the north from the head of Deep Bottom Cove. No well log is available for this well. It extends to a total depth of 12 feet below grade and is constructed of 1 inch i.d. black polyethylene pipe. This well was subjected to flooding at extreme high stands of the Pond.

NEW LANE:

Well 14 was placed by Kent Healy using a bucket auger. It is constructed of 4 inch pvc and has a total depth of about 12 feet below grade. It penetrates the water table by about 2 feet. Materials at the bottom of the well are clean, medium to coarse sands.

STREAM SAMPLES:

Samples were taken from the Tiasquam River(station #5) on the south side of South Road at the bridge. The Millbrook (#7) was sampled from the Doane property at the rock "dam". The stream that feeds Tiah's Cove (#8) was sampled just south of Tiah's Cove Road. In addition to nutrients, these samples were also analyzed for Fecal Coliform.