Chilmark, Menemsha & Squibnocket Ponds:
NUTRIENT LOADING AND RECOMMENDED MANAGEMENT PROGRAM
JANUARY 2001

Edits, corrections and notes from 2010 are added to this version and are highlighted to identify them as such.

PREPARED BY THE MARTHA'S VINEYARD COMMISSION

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THE MARTHA'S VINEYARD COMMISSION

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NOTE: Task 1 Quality Assurance Plan not included in all copies

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EXECUTIVE SUMMARY:

This study was undertaken to assess the potential impact of residential development in the watersheds of the three ponds. The components of the study that were used to make this determination include: the amount of residential development expected in each watershed, the volume of each pond, its tidal circulation and the desired water quality goal. In the course of developing the basis for an impact assessment, a large amount of new or never before assembled information about these three coastal salt ponds and their watersheds was established. Following is a summary of the specific findings about the hydrology of the ponds, the nature of their watersheds today and projections of the probable ultimate buildout and its impact.

Pond and Watershed Parameters:

Size of the ponds:

Chilmark Pond at Low Water	178 acres	7.754 million square feet
Chilmark Pond at High Water	241 acres	10.498 " "
Menemsha Pond System	790 acres	34.412 " "
Squibnocket Pond	603 acres	26.267 " "

Volume of the Systems:

Chilmark Pond	35.94 million cubic feet	268.85 million gallons
Squibnocket Pond	175 million cubic feet	1.31 billion gallons
Menemsha Pond	179 million cubic feet	1.34 billion gallons (mid tide)

Tide Range & Tidal Volume (on a daily basis):

Chilmark Pond	0 to 0.45 feet	0 to 3.63 million cubic feet
Squibnocket Pond	0 to 0.47 feet	0.22 to 12.35 million cubic feet
Menemsha Pond	2.9 to 3 feet	166 million cubic feet

Watershed Size:

Chilmark Pond Upper (western)	2122 acres
Chilmark Pond Lower (eastern)	1051 acres
Squibnocket Pond	1303 acres
Menemsha Pond	1856 acres

Daily Fresh Water Input (average):

Chilmark Pond	0.875 million cubic feet
Squibnocket Pond	0.493 million cubic feet
Menemsha Pond	0.647 million cubic feet (year long average)

Estimated Time for 95 % Flushing of Pond Water to the Sea:

Chilmark Pond	25 days	14.9 days when open to the ocean
Squibnocket Pond	354 days	43 days when tidal
Menemsha Pond	3.2 days	

Nitrogen Loading Limit and Projected High and Low Loading at Buildout:

Pond	Load Limit kg/yr.	High Load	Low Load
Chilmark Pond	3802	6551	5015
Squibnocket Pond	3037	4059	2295
Menemsha Pond	31618	10608*	6700*

* Note this figure includes the load from Squibnocket

Projected Watershed Buildout as Number of Dwelling Units:

Pond	Now	High Growth Scenario	Low Growth Scenario
Chilmark Pond	437	1098 (200)*	859 (100)
Squibnocket Pond	101	433 (83)	302 (47)
Menemsha Pond	374	767 (125)	615 (75)

**** Note: Numbers in parentheses indicate number of guest dwellings included in the buildout number***

Water Resource Uses:

Menemsha Pond is an important shellfish resource to the Towns of Aquinnah and Chilmark. Herring, returning to spawn in Squibnocket Pond, pass through it in the spring. The Wampanoag Tribe has a new shellfish aquaculture program based in the Pond. There is a mooring field in the Pond used by recreational boaters. Menemsha Basin is an active commercial and recreational fishing port as well as a destination port for recreational boaters. The Pond is also an aesthetic and wildlife resource.

Squibnocket Pond is a spawning site for a large herring population and a wildlife and aesthetic resource. The Wampanoag Tribe manages a commercial herring fishery at the inlet to Squibnocket Pond. The Tribe hopes to open an oyster fishery in the Pond in the future. Before the system can be open to oyster harvest, the Division of Marine Fisheries must acquire enough samples for bacterial analyses to determine the health risks are minimal.

Chilmark Pond is an important wildlife habitat and aesthetic resource. Two small beds of oysters were found along the barrier beach indicating there is some potential for oyster restoration. Before the system can be open to oyster harvest, the Division of Marine Fisheries must acquire enough samples for bacterial analyses to determine the health risks are minimal. It is used by riparian owners for small boat access for recreation and as a means to access the South shore. The Martha's Vineyard Land Bank owns an access to the Pond where small boats may be launched to cross to a South shore swimming beach.

Recommended Short Term Pond Management Program:

Menemsha Pond appears to be a strongly flushed water body with the capacity to withstand the projected nitrogen loading. The most intensive land use area, Menemsha Basin, is a seasonal use situated near the inlet to the pond where nutrient loading is either removed with the ebb tide or diluted with the strong influx of Vineyard Sound water on the flood tide. Management activities in the form of shellfish enhancement programs aimed at increasing the economic benefits to the shellfish industry will also positively impact water quality by removing nitrogen and other nutrients from the system. Similarly, dredging done to maintain recreational and commercial boating access and safety will also maintain a strong tidal flow which flushes nutrients from the system. As we are only just beginning (through the Wampanoag Tribe of Gay Head -Aquinnah (referred to as the Tribe) water resource studies) to get a good understanding of the water quality of the pond, it still makes sense to continue with the low density development pattern provided by current zoning. However, the new nitrogen removing on lot sewage systems allow flexibility as to lot size. Nitrogen removal from wastewater is best focused in areas of higher density in order to take advantage of economies of scale.

Additional Information Needs/Recommended Actions:

- Eelgrass survey and health assessment
- Deep water, overnight dissolved oxygen/water column stratification
- Data on Menemsha Pond level compared to Squibnocket and interchange between the two ponds
- Correct stormwater discharge into the Herring Creek on State Road
- Evaluate runoff from State Road at Hariph's Bridge
- Encourage use of nitrogen removing sewage technology.
- Enhance shellfish productivity as a means to remove nutrients
- Dredge the channel as needed for boating activity.

Squibnocket Pond is a more complex system as indicated by the changing tidal pattern discussed in this report and by the substantial fresh water component of the water column. Squibnocket today shows some poor water quality symptoms which must be attributed primarily to natural eutrophication as the current development pattern is minimal. We can only predict that these symptoms will worsen as the watershed builds out and groundwater brings more nutrients into the pond. Some further study is in order to determine whether the large phytoplankton blooms result in low oxygen levels in the deeper portions of the pond overnight. In addition, the nature and persistence of stratification of salt water in the pond bottom should be studied in detail. Stratified systems can result in low quality bottom water which can adversely affect shellfish confined to those waters and the rest of the water column when winds cause the system to mix. The Town of Aquinnah should look closely at adopting a Squibnocket Pond District similar to that on the Chilmark side as a means to provide guidance or regulation regarding residential nitrogen loading from lawns and septic systems.

The simplest approach to meeting nitrogen loading limits may be to adjust zoning in this District to require a loading limit of 2.33 kilograms per acre on average over the watershed (the loading limit divided by the acreage in the watershed). However, when the existing fixed sources such as acid rain are taken into account, the average loading allowed from residential uses falls to about 0.9 kilograms per acre. We estimate that a year round dwelling produces about 5.3 kilos of nitrogen per year from septic leachate and 1.5 from the lawn for a total of 6.8 kilos. However, when the seasonal dwellings are brought into consideration, the average nitrogen loading per dwelling is 3.45 kilos from septic leachate and 1.5 from lawns or 5 kilos per dwelling. On average at build out, across existing and future dwellings, lot sizes should average 5.4 acres. An alternative might be to require that advanced denitrifying septic systems reduce nitrogen loading on any lots less than 5.4 acres in size.

Other short term suggestions include a study of the herring population in the pond to determine if there are steps that can be taken to enhance the size of the run. Similarly, the oyster production from the pond should be managed to produce large quantities of vigorous young oysters which utilize nitrogen. The oysters can then be exported to Menemsha Pond to prepare them for market.

The connection between Squibnocket and Menemsha pond is the weak link regarding the flushing of the pond. The Herring Creek should be surveyed to determine if there are any environmentally safe steps that can be taken to increase the exchange of water and increase the rate of flushing. Any increase in salt water into the system will have ecological and circulation effects which should be evaluated before taking steps to increase the flow through the Herring Creek. On the plus side, this could be a cost effective means to loosen the growth restrictions discussed in the previous paragraphs.

Information Needs/Recommended Actions:

- Correct stormwater runoff into Herring Creek at State Road
- Collect data on pond stratification and dissolved oxygen cycling during late summer
- Continue periodic water chemistry and phytoplankton sampling
- Collect longer term tidal cycle data as a means to refine flushing time and adjusting nitrogen loading limits
- Survey herring and other fin fish populations in the system
- Survey benthic organisms and aquatic plant distribution
- Survey the Herring Creek to determine if tidal flow can be increased
- Evaluate the possible impacts of increasing tidal flow through the Creek.
- Implement oyster production program.
- With this information in hand, consider adjusting development density through DCPC or zoning changes or reduce nitrogen loading as needed by requiring advanced nitrogen removing on lot sewage disposal systems
- Work toward average future lot size of 5.4 acres through open space within a subdivision and through an active open space acquisition program.
- Encourage the use of nitrogen removing on lot sewage treatment for small lots (5.4 acres or less). Focus on systems that take advantage of natural processes to reduce nitrogen loading.
- Encourage small managed turf areas and use of slow release nitrogen fertilizers at minimal application rates. Use native grasses to maximize open vistas.
- Begin a database on nitrogen content of local rainfall.

Chilmark Pond is somewhat more complex than Squibnocket in that it alternates between cycles when it fills with ground and stream discharges and becomes more fresh and times when it is drained down and becomes saltier. The duration of the opening to the ocean determines how much exchange occurs while the pond is open. About 15 days are needed for a 95 percent exchange. The length of time that the pond is open depends on the weather, being shortened by southerly winds particularly under stormy conditions that generate waves that fill the channel with sand closing the pond. This is not a predictable phenomenon and so we cannot predict a reliable flushing period for each opening. An alternative way to estimate the time required to flush the system is to utilize the time required for the streams and groundwater to discharge a volume of water equal to the pond volume. While not completely satisfying as far as removing nitrogen from the water column, this 25 day period seems to be a reasonable basis for devising a nitrogen loading limit. That said, the Buzzard's Bay formula for determining the loading limit is best used for fully tidal ponds like Menemsha. The limit we have derived is not a perfect fit for this system.

Some consideration should be given to what is the desired use for this pond. The Pond is currently rated as an SA resource. However, the future nitrogen loading will exceed the recommended limit for this rating. For recreational boating and wildlife only, the SB water quality rating is probably appropriate. This rating may also be suitable if the Town would like to promote the establishment of shellfish, probably oysters, as a means to somewhat improve water quality and provide some economic benefit. However, even with the nitrogen limit based on a lower quality SB goal, the ultimate loading at buildout from the watershed will probably exceed it. Because it is limited by the available nitrogen, the added loading at buildout will probably cause some increased rooted vegetation in the western portion of the Upper Pond and, in the eastern end more frequent and intense phytoplankton blooms. It appears that the water quality of the Lower pond is partially determined by the input of nutrients and biomass in the form of fresh water phytoplankton mainly from the Upper Pond. The Lower pond would probably also experience more frequent and intense algae blooms and possibly increased macroalgae (sea lettuce or *Ulva*, *Enteromorpha* etc.).

Eelgrass is not presently found in the Lower pond and may well not have been present for at least the past 60 years as recalled by pond users (Wakeman, 2000). Other rooted macrophytes are infrequent in the Lower pond resulting in less cover and nursery grounds for fish that might either be found in the pond or potentially be stocked. A resident recalls a substantial fishery for herring and perch in the early part of this century with the product exported to off Island markets (Cottle, 2000). A survey of the fish population in these ponds should be a priority to determine what are the components of the system for which we need to plan. A similar study was completed in Edgartown Great Pond and is planned for Tisbury Great Pond. Continuation to Chilmark Pond is a natural next step.

The Lower Pond needs longer lasting, mid-summer openings to the ocean. An examination of the possibility to improve the circulation of the pond by cutting out some of Long Point to widen the channel along the beach at low pond should be carried out. It is unlikely that this would prolong the lifetime of an opening to the ocean but it should increase internal circulation patterns and, depending on the amount of dredging done, increase the volume of the basin itself which will increase flow.

Coastal Great Pond systems are not simple and need study over a number of years for a complete understanding of their nutrient loading limits. The results of this study do not lead to an obvious conclusion regarding the ultimate use of the watershed. They do send up some warning flags that the Lower Pond will exceed its nitrogen loading limit unless proactive steps are taken to reduce the final buildout loading. These steps can be taken through conservation easements or fee title purchase to reduce land available for development. They can also take the form of requirements for use of nitrogen removing septic systems to lower the loading to acceptable per acre limits. The calculations are similar to those explained for Squibnocket Pond. The suggested limit for Chilmark Lower Pond is also about 0.9 kilograms per acre. The average nitrogen load from sewage and lawn is about 5 kilograms per dwelling (average of both year round and seasonal) which implies the need for an average lot size of 5.4 acres. This is within the range of some recent subdivision proposals when open space is included. Where a denitrification sewage treatment system is used, the lot size could be reduced to 4.1 acres.

Information Needs/Recommended Actions:

- Survey fish populations and assess timing of openings to enhance herring
- Investigate feasibility and desirability of oyster production
- Evaluate pond circulation and options to enhance water quality through better circulation/flushing including dredging shoals and the role Doctor's Creek plays in carrying nutrients into the Lower Pond.
- Develop a good record system for timing and duration of pond openings. Attempt a trial run program to maintain the inlet for 15 days over a period of several months by repeat excavation of the inlet.
- Encourage small managed lawn areas with remainder grown as native grasses with no fertilizer applications. Encourage use of slow releases fertilizers.
- Identify and acquire conservation lands in the watershed
- Encourage the use of nitrogen removing on lot sewage treatment.
- Continue the low density growth pattern as per zoning and by Planning Board subdivision review. Work toward an average lot size of 5.4 acres for future subdivisions through open space in the subdivision as well as an active acquisition program.
- Identify and correct any remaining direct stormwater discharges to streams in the watershed
- Begin a database on the nitrogen content of local rainfall.

Phosphorus Loading to All Ponds:

As phosphorus is not typically a limiting nutrient to coastal pond systems, it is not addressed to the same level as nitrogen in this document. The discussion is included as Appendix B. An evaluation of phosphorus sources within the watersheds indicates that, on an annual basis, phosphorus additions to the ponds from watershed sources is a small part of the annual budget. This is particularly true for steady rate sources such as septic system leachate. Episodic, event type additions such as runoff from streets and pastures may be significant on a short term basis and are very difficult to predict or quantify. Recommendations for phosphorus reduction focus on runoff diversion into vegetated buffer strips and set backs of sewage disposal systems to allow soil retention of phosphorus to renovate wastewater.

Introduction and Summary:
This study was undertaken to assess the likely impact of residential development in the watersheds of the three ponds. The data available for Squibnocket Pond indicated that, at times, the Pond experienced low water quality. Squibnocket Pond was also identified as being a concern due to nutrient loading by the Office of Watershed Management, DEP in 1995. Chilmark Pond was identified under section 303d of the Clean Water Act as an impaired pond due to bacterial contamination. Menemsha Pond was identified by the Basin Team as a key area to concentrate resources. Under the Watershed Initiative, a determination of acceptable levels of nutrient loading to coastal ponds was seen as an important next step.

This document has been assembled with the best available information. In developing the recommendations I have adhered to the Precautionary Principle which was presented by the Newsletter of the Science and Environmental Health Network in March, 1998. The basis for this statement was compelling evidence that damage to humans and the worldwide environment was of such magnitude and seriousness that new principles for conducting human activities are now necessary. Waiting for scientific proof of a cause and effect relationship often results in taking action after problems have developed. The Principle states:

When an activity raises threats of harm to the environment or human health, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically.

Study Goals and Objectives: This study has been conducted to assemble the data necessary to determine the tolerance of these ponds for nutrient loading. We have determined as closely as possible what area contributes ground water to the ponds. High and Low build out scenarios for the watersheds are described both of which we believe have a real possibility of occurring. The nitrogen loading to the pond systems are calculated for each scenario. Nitrogen loading limits are detailed. Options available to the Towns to limit the projected nitrogen loading are described. A series of recommendations have been developed to provide guidance to the Towns.

Previous Work in the Ponds:
In 1978, the Wampanoag Tribe studied the Menemsha and Squibnocket systems collecting data on water chemistry, chlorophyll *a* and circulation in Menemsha Pond as part of a shellfish aquaculture project (Walsh 1979). The bathymetry of Squibnocket Pond was also mapped. This study was a baseline data collection project. The data indicated that Menemsha and Squibnocket had low levels of phytoplankton (chlorophyll *a* 0.1 to 3 micrograms per liter (parts per billion) and dissolved oxygen at or near saturation.

In 1990, Arthur Gaines of the Woods Hole Oceanographic Institute performed an initial study of the Squibnocket Pond system including estimates of groundwater input, tidal exchange and nutrient levels in the system. This study was undertaken to provide technical information toward the management of the pond. The data collected indicated low levels of dissolved inorganic nitrogen and abundant dissolved oxygen. Nitrogen loading was estimated from groundwater and stream data. In October 1990, the Squibnocket Pond Critical District regulations were adopted into the Chilmark zoning bylaws. These regulations added lot size requirements for a guest house and adjusted setbacks of septic systems from the pond.

In 1995, the Wampanoag Tribe funded a water quality survey of 10 stations in Menemsha Pond and 4 in Squibnocket to determine the nutrient status, water column physical oceanography and phytoplankton and chlorophyll *a* content (Wilcox, 1999). Menemsha Pond was found to contain low levels of nutrients, chlorophyll *a* and phytoplankton. Water column transparency was good throughout the growing season. Squibnocket was found to have high levels of total dissolved nitrogen and, at times, chlorophyll *a*. Water column transparency was low at times.

Primer on Coastal Pond Eutrophication:

NOTE: Technical terms used throughout this document are defined in the Glossary included as Appendix C. Eutrophication carries a wide range of meaning. It is generally associated with an increase in productivity (the cycling of carbon into living matter) and high concentrations of nutrients (Wetzel, 1983). The term was devised to indicate the extreme end of a range of conditions in lakes from clear and unproductive on one extreme to overly productive on the eutrophic end. The eutrophic state is characterized by a number of conditions that are undesirable from the human use perspective. These include excess phytoplankton, sometimes abundant aquatic plants, low oxygen levels in the water sometimes to the point of causing a die off of animals, a reduction in the number of species living in the system with a shift from filter feeders (scallops and clams) to detritus feeders like snails and, under extreme conditions, burrowing worms. The eutrophic state can develop under natural conditions where nutrients released from the surrounding uplands enter the pond and stimulate the productivity in the system. However, the process is hastened by man made nutrients which are released in concentrations far in excess of the natural process. These nutrients are released from development in the watershed by runoff of stormwater, erosion of soil from farmland, disposal of sewage by septic systems or by treatment facilities and by fertilizers applied to farmland and landscaping. The nutrients are also added from outside the watershed by acid rain which is contaminated through the stack emissions of power plants, manufacturing processes and auto exhaust.

One nutrient that all of these activities release and which is necessary for plant growth, is nitrogen. The other major nutrients required for growth of phytoplankton and algae include phosphorus, carbon, hydrogen and oxygen. Generally, the last three are sufficiently available in coastal waters so that they do not hinder growth of these aquatic plants. In phytoplankton, nitrogen and phosphorus are required in the approximate ratio of 16 to 1. While other less important nutrients may also affect growth rates, these two are of primary importance and, by their availability alone, usually determine the amount of growth of biomass in the system. In ocean waters, it is generally agreed that nitrogen is the deficient nutrient and phosphorus is usually present in sufficient quantities for growth of phytoplankton (Valiela, 1995). For this reason, marine waters are often spoken as being nitrogen limited. This means if nitrogen is added to the water, phytoplankton can reproduce to take advantage of the supply and the amount of organisms in the water column can increase until once again limited by availability of nitrogen or another necessary nutrient.

While nitrogen from the sources mentioned is a soluble nutrient that moves readily through the environment, phosphorus is strongly bonded to soil particles and does not travel far as a dissolved nutrient. Potential phosphorus sources include direct runoff from pastures and roads draining into the ponds when there is inadequate filtration by heavily vegetated borders. The flood tide may carry in phosphorus although data in Vineyard Sound (Wilcox, 1999) indicate orthophosphate is at low concentrations (about 0.5 micromoles per liter). In addition, during times where the lower part of the water column in a pond becomes anaerobic or when wind mixing suspends sediment, phosphorus may be released from the sediment where it is stored in large amounts (Wetzel, 1983).

Nitrogen and Its Potential Impact: Nitrogen is an important component of all living organisms. It comprises about 78 percent of our atmosphere but is not very soluble as a gas in water. It is converted to a soluble form by three main sources. Lightning can oxidize nitrogen to form water soluble nitrogen by products. Nitrogen fixing organisms such as blue green algae can convert atmospheric nitrogen gas into compounds usable in their systems. Soluble nitrogen is also created and released by living animals particularly man. Once soluble, nitrogen is most directly usable by phytoplankton and larger aquatic plants in the form of nitrate, nitrite or ammonium. As they cannot create their own soluble nitrogen, these plants are therefore dependent on availability of these forms of nitrogen in order to grow. Sources of these forms of nitrogen include septic system leachate, sewage effluent, acid rain, fertilizers and release from pond bottom deposits following bacterial breakdown of organic matter. In the sandy soils present in the recharge area, most forms of nitrogen are oxidized to nitrate before they reach the ground water. Nitrate is highly soluble in water and generally not reduced or eliminated by any substantial process once it is in the ground water. For this reason, we can closely estimate the loading to the pond by making reasonable estimates of the quantity of nitrate from the land uses in the watershed reaching the ground water.

While some increase in the phytoplankton population is not necessarily a problem, with enough nutrients the population can explode. High populations of phytoplankton (often called an algae bloom) cloud the water reducing light transmission. In large numbers, overnight oxygen uptake by these living organisms or the die off and decay of phytoplankton can reduce oxygen levels to the point where other organisms are stressed or killed. This may have occurred in Edgartown Great Pond in 1993, when the oyster population died out following a late summer bloom.

Reduced light limits the vigor of eelgrass which requires sunlight as does any green plant. Eelgrass beds may have existed at one time in Chilmark Pond. They have not been present in the 60 year memory of people familiar with the pond (Wakeman, personal communication). It is possible that beds were lost during the 1930's wasting disease devastation throughout the northeast and never reestablished. It is also possible that eelgrass never existed due to low salinity. Eelgrass is common in Menemsha Pond but was not found in Squibnocket Pond. Eelgrass is an important component of the ecosystem providing cover for bait fish, scallops, blue crabs and eels as well as food and a substrate for the growth of a myriad of aquatic plants and animals. It also acts as a sediment stabilizer through its dense root system.

Numerous studies of coastal ponds by researchers have concluded that nitrogen loading from shoreline development may have adverse impacts on these waters. Waquoit Bay, Cape Cod, has been thoroughly studied over 30 years. It is a coastal pond with a fixed inlet through a barrier beach. As residential land use increased in the recharge area, the pond has steadily lost formerly extensive eelgrass beds. The loss was attributed to nutrient loading from septic systems in the watershed (Kennish, 1996). The damage to eelgrass beds in response to nutrient loading occurs in two ways as a result of the eelgrass plants requirement for light.

While seagrasses like eelgrass are limited by the available light level, both phytoplankton and large macro-algae (wrack algae) are limited by the availability of nutrients rather than light (Valiela, 1995). In other words, when nitrogen is added to the water column, it stimulates the growth of undesirable algae but does not increase the growth of eelgrass. In more marine waters, wrack algae include *Ulva*, *Enteromorpha* and *Cladophora*. The differing growth limitations set up a situation where, as nutrients are added to the system, phytoplankton and wrack algae increase, reduce the light penetrating to the bottom and cause a decline of eelgrass which may eventually be replaced entirely by macro-algae. Nutrient stimulation of phytoplankton blooms reduces available light to the eelgrass beds at the bottom particularly where the water depth is 2 or more meters. Nutrients also increase the growth of single cell and chain algae (e. g. diatoms) which grow on the surface of the eelgrass blades further blocking the sun light. Reduced light may stress the eelgrass making it more susceptible to wasting disease or may just reduce its vigor and lead to thinning of the eelgrass and eventual loss of entire beds. The macro-algae also tend to break loose late in the season or after a storm and gather into large mats which may smother desirable, filter feeding shellfish such as clams, scallops and oysters, encourage detritus (debris) feeders such as snails and, in severe cases, cause anoxia (lack of dissolved oxygen), aquatic animal die off and odors.

It seems clear that addition of nitrogen to our coastal ponds will lead to undesirable consequences if it exceeds a threshold known as the loading limit. One goal of this report is to establish appropriate nitrogen loading limits for each pond so that the regulatory agencies may implement the necessary steps to prevent man made eutrophication of these ponds. Because Chilmark and Squibnocket Ponds are brackish ponds which appear to alternate between times of excess nitrogen and times of deficient nitrogen (Wilcox, 1999), the right loading limit is not as clear cut a conclusion as it is for a salt pond such as Menemsha. It seems certain that there are extended periods of time during the course of each year, particularly during the growing season, when all of these ponds are nitrogen limited. We should be very concerned at what the future loading of the recharge area may do to these ponds. Once the recharge area is built out, it will take about 20 years for the system to reach equilibrium and for the full effect of the nitrogen loading to appear in the pond. If the "effect" on the pond is undesirable, changes made in the recharge area to reduce nitrogen loading will take another 20 years to reach the pond and reverse the negative impacts. For this reason we need to make every effort to anticipate possible impacts with a conservative limit on nitrogen loading within the recharge area.

Water Column Parameters: There are key chemical and physical measures that are measures of the condition of a water body under study. When collected over time, these measures can tell us whether the system is eutrophic or moving toward eutrophication. Study over time is necessary because these measures vary from year to year in response to weather patterns. The measures are described in more detail in Task 2. They include chlorophyll which is an indicator of the algae population in the water column. Light penetration is affected by the amount of algae in the water column and is measured with a Secchi disk. The amount of dissolved oxygen is a key necessity for the animals living in a pond. It is affected by the algae population but also by the amount of organic matter that is decaying in the pond. The amount of nitrogen in the water column in all forms indicates whether the system is over-productive and if the nitrogen input from the watershed is excessive. There are many other investigations which indicate the condition of a pond including population studies of the bottom dwellers, distribution and amount of aquatic plants, fish population make up and long term productivity in the system to name a few. These are more complex and costly studies which were beyond the scope of this study.

Geology: The watershed for the Upper (western) and Lower (eastern) Chilmark Great Ponds includes two distinct deposits of glacial origin (Kaye, 1964). The geology in the hilly portions of these watersheds is complex as a result of the glacier pushing up thick wedges of frozen ground comprised of coastal plain sands and clays (much like what can be seen in the Gay Head Cliffs) as the underpinnings for the watershed. These formations (called imbricated thrust sheets) make up much of the western moraine (Qgh, Kaye 1972) including most of the Squibnocket, Chilmark Upper and Menemsha Pond watersheds. These materials range from clay through sand and gravel. The thrust sheets dip steeply to the northwest creating isolated pockets of groundwater that may or may not directly connect to the Ponds. The less pervious materials also form the basis for sufficient runoff generation to support Mill Brook, an unnamed stream flowing through the Allen Farm and Fulling Mill Brook all of which flow out of the moraine into Upper Chilmark Pond. In addition Black Brook and Witch Brook flow into Squibnocket Pond from a large wetland dominated watershed. An unnamed stream originating in a large wetland near Menemsha Crossroad discharges into Menemsha Pond near Peases Point. See Figure 1 for pond locations.

The second formation is Mvo, an outwash deposit consisting of layered sand and gravel. While some of this formation occurs in the watershed of the Upper Chilmark Pond, it makes up a larger part of the Lower Chilmark Pond watershed. Within this deposit, the aquifer is closely linked to the Lower (eastern) Chilmark Pond. The divide which separates groundwater flowing into Lower Chilmark Pond from water flowing into Tisbury Great Pond is subject to some movement due to the relative level of the two ponds. The area of the contributing aquifer would expand for the Pond which is relatively lower. Typically both ponds are opened (and lowered) to the ocean on a similar schedule however, Tisbury Great Pond sometimes remains connected to the ocean for months while the Chilmark Pond opening often closes more quickly. The outwash deposit does not occur in the Squibnocket and Menemsha Pond watersheds.

Chilmark Pond was probably formed by headward erosion by sapping of groundwater spring seepage fed from a large glacial meltwater lake situated in Nantucket Sound immediately after the Wisconsin ice had vacated the area (Uchupi & Oldale, 1994). At that time, sea level was hundred's of feet lower than it is today. As a result of the sapping process, the pond is characterized by narrow, elongate coves (Wades and Gilbert's) that extend into the outwash plain. These coves terminate in dry valleys that extend further into the outwash plain and create unique habitat by virtue of their dry, sandy soils, exposure to salt spray and tendency toward frequent frosts. Squibnocket and Menemsha are probably pre-glacial low areas that were not filled with glacial sediment (Kaye, 1964). All three ponds were filled by rising sea level following the end of the Wisconsin glaciation that reached the current level approximately 1000 years ago (Uchupi et al, 1996).

The Ponds studied range in size from Chilmark Pond at 241 acres at high pond before an inlet is cut (178 acres at low pond), to Squibnocket Pond at 603 acres and Menemsha Pond at 790 acres. The nature of exchange with either Vineyard Sound or the Atlantic differs widely from the vigorous, daily tidal flushing of Menemsha to the periodic breaching of Chilmark Pond with short term tidal exchange in the lower (eastern) pond. Squibnocket Pond's tidal exchange with Menemsha Pond has yet to be fully characterized. Herring Creek is a long (1700 feet) shallow creek that joins Menemsha and Squibnocket Ponds. It appears that Squibnocket sometimes has a diurnal tidal flux while, at other times, there may be more limited flow which produces a gradual, small rise and fall of the pond level over a period of up to 10 to 14 days.

The watershed area of the ponds varies from approximately 3173 acres for Chilmark Pond, to 1856 acres for Menemsha and 1303 acres for Squibnocket. Large ponds with small watersheds (Squibnocket and Menemsha) often have their nitrogen loading dominated by acid rain.

A portion of each watershed is held in conservation by the Towns of Chilmark and Aquinnah, the Sheriff's Meadow Foundation, the Land Bank and several subdivision associations. The total land in conservation ranges from 161 acres in the Squibnocket watershed, to 211 acres in the Menemsha watershed and 285 acres in the Chilmark Pond watershed.

Land uses in the recharge area which release water soluble nutrients or other chemicals into the ground water will eventually have some effect on the pond when the ground-water discharges into the pond. At a groundwater travel time of around one foot per day, the majority of the recharge areas are within less than 20 years of discharge to the ponds. However, the relationship between groundwater and stream flow as well as the geology of the watersheds confounds the potential to be accurate with this estimate. Groundwater reaching a stream may complete its journey to one of these ponds in a matter of days or weeks whereas, groundwater pockets that are not part of a single aquifer moving toward discharge at the shore may be decades in transit.

Groundwater and stream input is a significant contributor to the total water in both Chilmark and Squibnocket Ponds. Chilmark Pond receives about 1 million cubic feet of groundwater and stream discharge every day on average. Squibnocket receives about 0.5 million cubic feet per day. Because circulation of these ponds with the sea is sluggish, they are brackish and fresh water inputs are very important to their water and nutrient budgets. Menemsha Pond which has vigorous tidal circulation, receives about 0.65 million cubic feet of fresh water input each day but the tidal exchange is an overwhelming 166 million cubic feet per day.

Present Day Management: Chilmark Pond is breached to the Atlantic Ocean by excavating a trench through the barrier beach at intervals of about 4 months. Typically the pond will reach heights of over one meter above mean sea level before it is breached. The breaching is done to maintain salinity in the pond as well as to limit flooding of septic systems and basements in houses bordering the pond. The opening discharged around 18 million cubic feet of water during the June 1999 opening. Prior to the opening the pond had freshened up so that salinity ranged from 12 to 14 parts per thousand (PPT). Following the opening, salinity ranged from around 20 to 22 PPT. The salinity of seawater is about 35 PPT while that of fresh water approaches 0 PPT. The regular, man made breaching of the system leads to a somewhat variable but always brackish Lower Chilmark Pond and a fresh Upper Pond. If the system were not periodically opened to the ocean, the system would have much wider swings in salinity perhaps from nearly fresh to nearly ocean salinity (after a storm produced a breach through the barrier beach) which would probably cause catastrophic loss of fauna.

Menemsha and Squibnocket receive far less manipulation on an annual basis. The channel into Menemsha Pond is periodically dredged to allow safe access to recreational and commercial boating. This also undoubtedly improves the circulation and flushing to Vineyard Sound.

In addition to physical management by way of breaching the pond, the Shellfish Departments transfer scallops and quahogs into Menemsha Pond for spawning and harvest to support the shellfish industry. The Wampanoag Tribe has just started a shellfish hatchery which will be used to stock Menemsha Pond. Squibnocket is now being studied by the Tribe as a potential commercial source of oysters. Chilmark Pond has no commercial shell fishery. The Chilmark Pond spring openings (April to May) are optimal to allow a herring run but the size or even the presence of the run is not known. Osprey appeared to catch herring during the July 2000 sampling round.

The duration of the opening to Chilmark Pond is crucial to the exchange of water in the pond with that in the ocean. We estimate that an opening of 15 days duration is necessary to exchange 95 percent of the water in the pond for water from the ocean. The June 1999, opening only persisted for about 5 days. As with Edgartown Great Pond, the lowered pond increases the discharge rate from the ground water bringing additional nitrogen into the system and actually initially lowering the salinity in the coves (Gaines, 1993). Once the pond level has been lowered, it is important for the opening to persist long enough to remove enough nitrogen to the ocean so that pond impacts are minimized.

Projected Nitrogen Loading:

Projections are a means to determine the relative risk of undesirable eutrophic conditions. Nitrogen is the key nutrient to evaluate for these ponds. Nitrogen is released from septic systems, lawn fertilization, farm fertilization, acid rain, the sewage treatment plant and the Chilmark and Aquinnah landfills. Today there is an estimated discharge to the ponds as follows:

Chilmark Pond	3400 to 3800 kilograms/year*
Squibnocket Pond	1500 to 2700 kilograms/year
Menemsha Pond	3400 to 4900 kilograms/year

- The Range is based on the high and low acid rain source which is a large part of present day loading.

Projected nitrogen loading from future development in each watershed:

• **Chilmark Pond**	**4946**	**to**	**6551**	**kilograms**	**(13.6 to 17.9/day)**
• **Squibnocket**	**2295**	**to**	**4059**	**“”**	**(6.3 to 11.1/day)**
• **Menemsha Pond**	**4409**	**to**	**6531**	**“”**	**(12.1 to 17.9/day)**

Menemsha Pond also receives the loading from Squibnocket Pond. The net to Menemsha Pond ranges from 6704 to 10590 kilograms per year. Each of these projections has been devised to provide a realistic possible range of outcomes.

Nitrogen Loading Limit:

The data collected indicate that nitrogen is the limiting nutrient in each pond system either continuously (Menemsha) or at times, usually during the growing season in Squibnocket and Chilmark Ponds (Tables 2 and 5). A growing season nitrogen deficiency was found in Great Ponds similar to Chilmark Pond and in Squibnocket Pond from early May through September depending on the weather (Wilcox, 1999). This data set is extensive for both Squibnocket and Menemsha Ponds but is limited for Chilmark Pond (Wilcox, 1999 and Tables 2 and 5 this document). Based on data from other Great Ponds and the limited amount of data collected from Chilmark Pond over two growing seasons, it is highly likely that in Chilmark Pond during the winter or at high pond in spring, phosphorus becomes the nutrient that limits pond productivity (Wilcox, 1999). The difficulty is to draw the line between acceptable annual nitrogen loading and loading which is likely to stimulate more of the eutrophic indicators that are discussed above.

The focus should be on what happens during the summer when poor water quality can damage the ecosystem. At this time, nitrogen is the limiting nutrient.

The loading limit that makes sense for **Menemsha Pond** is 31618 kilograms per year which clearly exceeds the highest projected loading. The indications are that, if the watershed builds out under current zoning, water quality in the system should continue to be excellent.

Chilmark Pond already shows some symptoms of excess phytoplankton in the system at the present day loading. The formula for estimating loading limits is not as well suited to Chilmark Pond with its wide ranging salinity levels resulting from the closed and open pond cycles. The loading limit that seems most appropriate for this system is that identified for Lower Quality rated waters with a 25 day flushing time. This limit is 3802 kilograms per year. This limit cannot be easily reached under the projected loading at buildout.

Squibnocket Pond is somewhat less confusing than Chilmark Pond. While brackish, it does receive some water exchange on a daily basis. The suggested target for nitrogen loading from the watershed for this pond is that associated with Lower Quality waters with a 354 day flushing period or 3037 kilograms per year. This estimate falls midway between the upper (4366 kilograms) and lower (2686 kilograms) projections. This should be an attainable goal.

Phosphorus Loading: Phosphorus is also an important nutrient for the growth of phytoplankton and aquatic plants. Addition of phosphorus to a water resource, particularly fresh water, can stimulate excess plant growth. In coastal ponds, it is usually not the limiting nutrient. In addition, the methodology for determining appropriate phosphorus loading limits has not been developed for marine waters. For these reasons, phosphorus loading calculations are not emphasized here but are limited to Appendix B.

Task 2: Assess Water Quality: Chilmark Pond

This Task was proposed to gather some baseline data on the water chemistry, chlorophyll *a* and water column oceanographic parameters such as salinity, conductivity, turbidity, pH and dissolved oxygen. As there is existing data for Menemsha and Squibnocket (Wilcox, 1999), these ponds were not included. A total of 5 sampling rounds at 10 stations in the Upper and Lower Chilmark Ponds was planned. Water samples were collected, handled and processed in an appropriate manner to assure high quality data as described in Task 1, Quality Assurance and Quality Control.

Comparison of the Ponds Under Study with Other Local Ponds:

Chilmark Pond is similar in form to the other south shore coastal ponds including Tisbury Great, Oyster and Edgartown Great Ponds. All of these ponds have elongate coves extending in a northerly direction. The topographic depressions in which the ponds are found, probably formed by headward erosion as a result of groundwater seepage fed from a large glacial melt water lake situated in Nantucket Sound immediately after the Wisconsin ice had vacated the area (Uchupi & Oldale, 1994).

In terms of their general physiographic features, the ponds in the present study are compared with ponds surveyed in a previous study (Wilcox, 1999) in Table 1. In evaluating coastal ponds for their ability to tolerate nitrogen, the Buzzard's Bay program used a mean depth of 2 meters as the break point between deep and shallow ponds.

Table 1 Physical Characteristics of Ponds Studied

POND	SIZE (acres)	Avg. Depth (meters)	Circulation	Recharge Area (km^2)	Flushing Time
Edgartown Great [1]	890 (high stage)	0.9 (low stage)	wind/breached	20.84 (5150 ac.)	14 days to 3 months
Oyster[2]	207	2 to 3	wind/breached	~4 (1000 ac.)	2 wks. to 4 months
Tisbury Great [3]	718 (high stage)	1.7 (low stage)	wind/breached	43.87 (10840 ac.)	2.6 to 95 days
Chilmark Pond [4]	241 (high stage)	0.5 (low stage)	wind/breached	12.85 (3173 ac.)	15 days to 25 days
Long Cove [5]	83	~1.5	wind	2.02 (500 ac.)	fresh/ unknown
Sengekontacket Pond [6]	620	0.92 MSL	tidal	19.8 (4900 ac.)	1 day
Lagoon Pond [7]	538	2.8 MSL	tidal	15.66 (3868 ac.)	13.6 days
Squibnocket Pond [8]	603	1.5	wind/tidal	5.28 (1303 ac.)	43 to 354 days
Menemsha Pond [9]	790	1.5 MSL	tidal	7.51 (1856 ac.)	3 days

Sources: **1** Gaines (1993) **2** Wilcox (1999) **3** MVC/Taylor in preparation **4** MVC/Wilcox in preparation **5** Wilcox (1999) **6** Gaines (1995) **7** MVC/Taylor in preparation **8** MVC/Wilcox in prep. **9** MVC/Wilcox in prep.

Chilmark Pond Water Quality Survey:

The sampling program conducted under the present study represents only the beginning steps in sorting out the nutrient cycling and condition in Chilmark Pond. The coastal great ponds are complex and will only be understood fully from longer term data collection. Water samples were collected from a total of 10 sampling stations in the two ponds (Figure 2). Sample rounds were completed on May 25, June 21 and August 9, 1999 and July 17 and August 14, 2000.

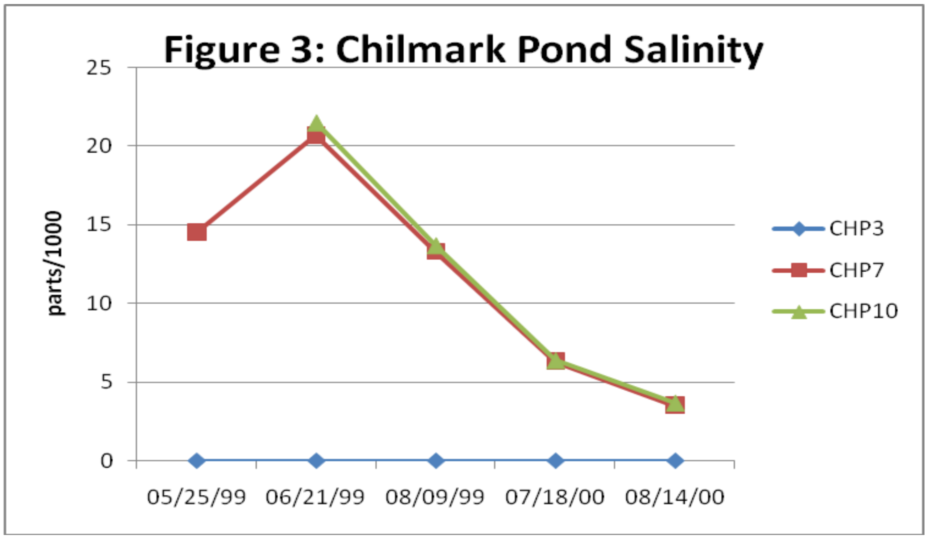
Samples were collected from a depth of 8 to 12 inches below the surface. Dissolved nutrient samples were immediately filtered through a 0.22 micron filter to remove particulates. All samples were stored on ice in a cooler until delivered to the lab. The quality assurance procedures followed are spelled out in Task 1. The data from the lab is shown in Table 2. The water quality criteria cited in the following discussion apply to the growing season- April through October.

Along with water sample collection, a multi-parameter meter was used to profile the water column for temperature, conductivity, pH, dissolved oxygen and turbidity (see Table 3). A Secchi disk is used to determine the transparency of the water column. By profiling the water column from top to bottom, it is possible to identify stratification which can lead to water quality problems by isolating the deep water from contact with the air, the source of oxygen overnight. No stratification was observed in the Lower Pond during the study period and may reflect the shallow pond and wind exposure. At station 3 in the Upper Pond temperature stratification was found in June 1999. Stratification in the area south of station 4 toward station 5 was found regularly and probably occurs due to continuous input of cold water from the Fulling Mill Brook.

The discussion which follows focuses on the Lower Chilmark Pond as it is a coastal salt pond which is the type of system for which nutrient loading limits have been most completely developed. Sample stations in the Upper Pond (station 1 through 5) are in fresh water and are not described here. Those data are discussed in the Summary section. Fresh water resources have another set of standards which are different from brackish and salt waters.

Conductivity:
The conductivity of sea water is around 45 to 48 ms/cm (milli-Seimens per centimeter). The Lower Pond varies from about 20 percent sea water before an inlet is cut through the barrier beach to about 60 percent sea water after the inlet is in place. The Upper Pond is a fresh water system that will only receive sea water during storms as wave overwash of the barrier beach, as salt spray and, under extreme tidal conditions, as flow up Doctor's Creek from the Lower Pond.

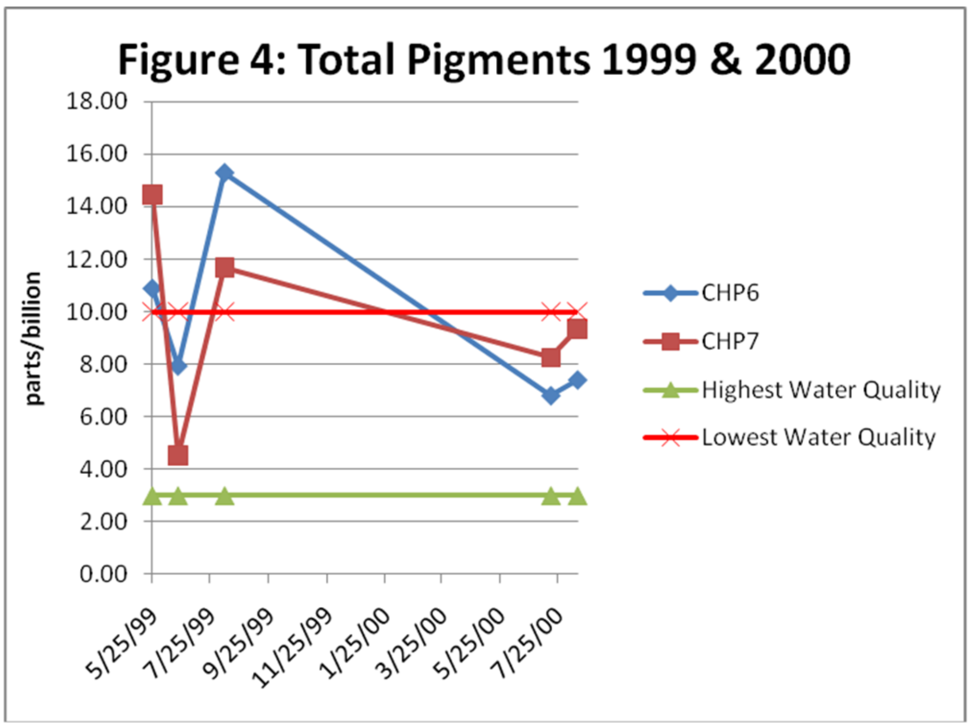
Figure 3 clearly demonstrates the differing salinity of the two systems and illustrates a fundamental difference between the two ponds. In the Lower Pond, the conductivity varies between "closed pond" lower values and "open pond" higher values. The Upper Pond is continuously fresh with conductivity near 0. Most of the Lower Pond conductivity values range between 10 and 35 milli-Seimens per centimeter while the Upper Pond values mostly fall below 0.3 mS/cm.



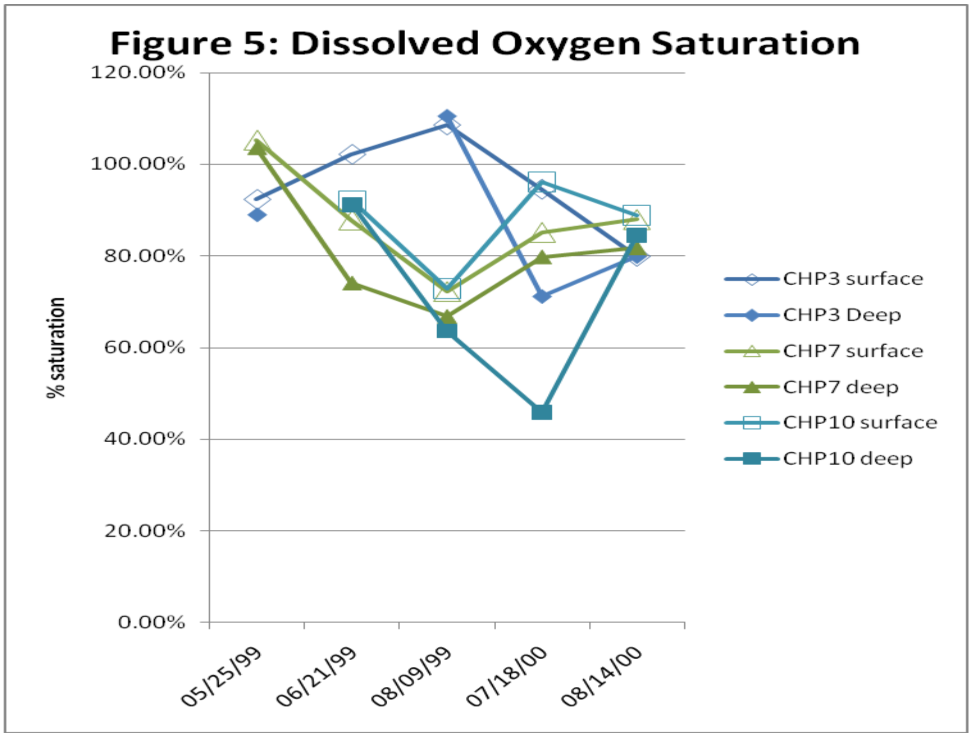
Chlorophyll *a*:
This is an indirect measure of the total amount of phytoplankton in the water column. Chlorophyll bearing phytoplankton are at the base of the food chain. However, as their numbers increase, the light penetration to the bottom declines and can make it difficult for the bottom plant community including eelgrass to get adequate light. No eelgrass was found throughout the Lower Pond where it should have some chance of surviving considering that it is found in Edgartown Great that has similar conditions. One symptom of nutrient loading to coastal salt ponds is the overall increase in phytoplankton and the frequency of excessive blooms. Excess phytoplankton in the water column may cause oxygen problems overnight when they respire, removing oxygen and releasing carbon dioxide. This can lead to hypoxia (low oxygen levels below 3 milligrams per liter) which can stress marine animals such as fin fish and shellfish.

Oxygen in the water column is a fundamental characteristic of natural waters. Oxygen content is in a dynamic state of equilibrium with consumptive uses like respiration and organic matter decay reducing the content and being balanced by diffusion into the pond from the air and release by green plants raising the content. Short term oxygen deficit (e. g. overnight consumption during an algae bloom) may lead to transient population changes in a water body. However persistent low levels of dissolved oxygen (e.g. brought on by excess organic matter in decay at the bottom) are a symptom of a functional change in an estuary. Where there are dense stands of macrophytes, decay of the plant material at the end of the season may be accompanied by prolonged periods of low oxygen that can lead to die off of fish and other animals. This has been documented in Waquoit Bay and related to nitrogen loading from septic systems in the watershed (Valiela et al, 1992). An excessive algae bloom in Edgartown Great Pond during the late summer of 1993, probably lead to a massive oyster die off when the algae died, settled to the bottom and began to decay robbing the lower water column of oxygen.

As an indicator, the quantity of chlorophyll *a* in the water column has been used as a means of characterizing the water quality in coastal salt ponds by both NOAA (1996) and the Buzzard's Bay Program (Costa & Howes, 1996). According to the Buzzard's Bay system, concentrations of 3 or less micrograms per liter (ug/l) are indicative of the highest quality. Concentrations of 10 or more are typical in the lowest quality waters. NOAA uses 0 to 5 ug/l as the best, 5 to 20 ug/l as moderate quality and over 20 ug/l as the worst quality. Chlorophyll *a* is plotted in Figures 4.

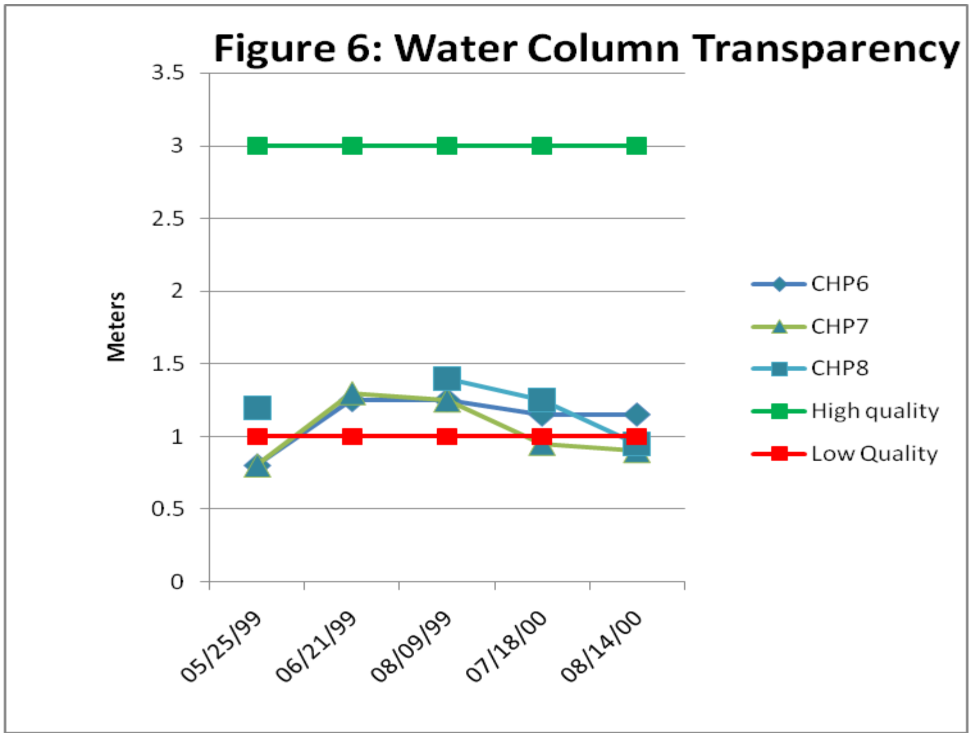


The biological activity in the system affects the amount of oxygen in the water column. The water column can only hold so much oxygen in solution at a given temperature. This amount is 100 per cent saturation. During the day the saturation may exceed 100 percent as aquatic plants release it in such volumes that it may actually bubble out of the water as a gas. Overnight, when plants take up oxygen instead of releasing it, oxygen concentrations can drop and reach a point where bottom dwelling animals may be stressed or even killed by the lack of oxygen. The dissolved oxygen readings converted to percent saturation are plotted in Figure 5 for three stations over the five sampling periods. The stations in the Lower Pond (6 through 10) were more likely to have lower oxygen saturation compared to those stations in the Upper Pond (1 through 5). The deep measurements (open symbols) typically contain less oxygen than the upper levels. While no results from this survey indicate the pond reached hypoxia, station 10 did reach less than 50 percent saturation in July 2000. Additional, overnight data would be valuable.



Secchi Depth:

The depth to which a 1 foot diameter white disk can be seen in the water column is directly related to the amount of suspended material in the water column. The suspended matter can be either phytoplankton or silt. The depth to which the disk can be seen has been correlated to the depth to which light penetration is sufficient for the growth of phytoplankton and, by inference, the depth to which rooted plants such as eelgrass can thrive. This correlation is 2.5 times the depth to which the disk is seen. Generally, when the depth is 1 meter or less, the water column has an over abundance of phytoplankton and the water quality is considered to be poor and if the depth is over 3 meters the water quality is highest. See Figure 6.



Total Dissolved Nitrogen (TDN):

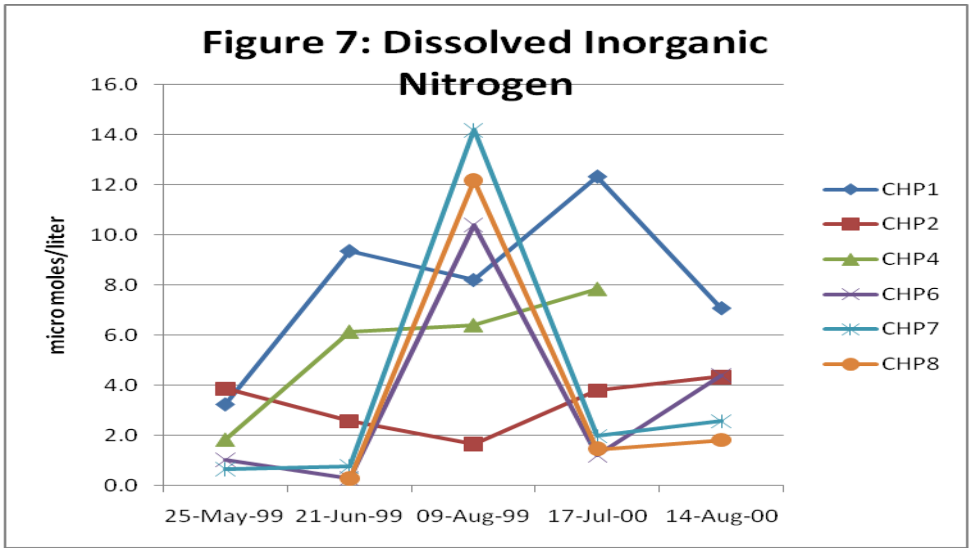
This is the sum of the dissolved inorganic nitrogen (DIN) and dissolved organic nitrogen (DON). The inorganic forms include nitrate, nitrite and ammonium. They enter the system from acid rain, fertilizers, wastewater or are cycled out of bottom sediments. These nutrients are generally so thoroughly scavenged by phytoplankton that they are only found in minute amounts, typically below 10 micromoles per liter (um/l) which is about 0.14 parts per million or less. Dissolved organic nitrogen includes waste products from organisms in the water column as well as decay products from formerly living phytoplankton, macrophytes, fin and shellfish. In 1995 (Wilcox, 1999) the offshore sampling site located in Vineyard Sound averaged 22 um/l of TDN. This average, Vineyard Sound concentration can be thought of as a base level to which groundwater, streamflow, rainfall and runoff are added in the coastal ponds.

NOAA (1996) has set quality ratings for TDN as follows:

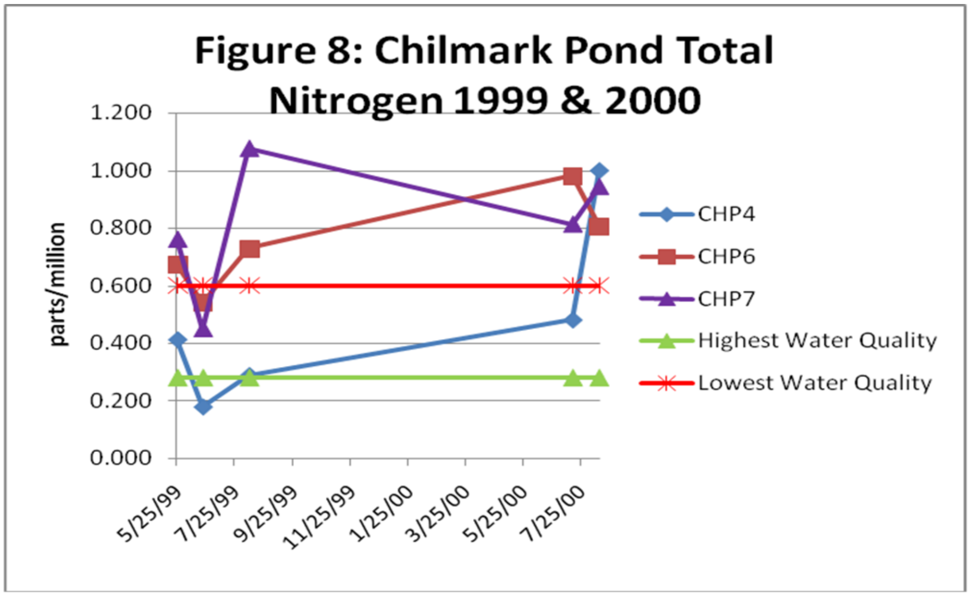
Best Quality	0 to 7.14 um/l
Moderate quality	7.14 to 71.4 um/l
Worst Quality	Over 71.4 um/l

The Buzzard's Bay Program set standards for dissolved inorganic nitrogen (DIN), a component of TDN, that range from 1 um/l at the best quality end to 10 or more at the lowest quality rating. DIN is a rare commodity in marine waters and is in great demand as nitrogen is an essential nutrient for the growth and reproduction of phytoplankton. It is taken into the biomass in the pond so quickly that even very low concentrations indicate a large source of nitrate or ammonium. DIN is more common in the freshwater system particularly groundwater where it is commonly 100 um/l or more. DIN is plotted in Figure 7 for Stations in both Upper and Lower Ponds. The input of DIN from the streams

(Stations 1 and 4) picked up in June, 1999 to between 5 and 10 uMoles per liter and continued through August. The Lower Pond DIN concentrations exceeded 10 uMoles per liter throughout the pond by August, 1999. The 2000 season had poor openings to the sea which did not persist. DIN levels are much lower at the Lower Pond stations during July and August in 2000 compared to 1999.



Total water column nitrogen is plotted in Figure 8 for Stations 4, 6 and 7 in the Pond. Station 4 is at the mouth of Fulling Mill Brook while station 7 is in the middle of the Lower Pond. At Station 7 in August 1999, TDN approaches 60 uMoles per liter (0.9 parts per million) exceeding the threshold to the lowest quality rating. The spike in nitrogen content found in August probably resulted in part from the June opening to the ocean. In addition, although June and July were drier than normal, a heavy rainfall occurred on August 8 that resulted in 1.5 inches of precipitation falling in 15 minutes. This rate of rainfall would generate a large volume of runoff into the ponds. In 2000, this is repeated but the portion that is DIN is much lower.



Other Data from the Water Quality Survey of Chilmark Pond:
Silicate concentrations found in the two ponds were similar to those found in the other great ponds surveyed in 1995 and 1996 (Edgartown Great, Oyster and Tisbury Great Ponds). The concentrations, ranging from 40 to over 100 um/l in the Chilmark Ponds, are quite high when compared with better circulated salt ponds such as Menemsha, where silicate averaged under 10 um/l during the 1995-96 survey. This is a result of the strong influence of ground water and stream inputs to the system. Somewhat surprisingly, the highest concentrations were found in the Lower Pond which has the smaller watershed and lacks substantial stream inputs. There may be a mechanism trapping silicate in the Lower Pond as it fills with water from the Upper Pond.

The ratio of DIN to orthophosphate has some implications to the growth of phytoplankton. Redfield (1963) found that the ratio averages around 16 to 1 for phytoplankton. This implies that when the ratio is substantially less than 16, nitrogen is deficient and is limiting the growth of phytoplankton. Conversely when the ratio is over 16, phosphorus is deficient and limits growth. Throughout the sampling period, the ratios averaged less than 16 in the Upper (western) Pond implying that nitrogen limits further growth of fresh water phytoplankton (see Table 2). This is not usually the case for fresh water systems.

In the Lower Pond the situation is more complex. During the May and June 1999, sampling rounds, the ratio was generally below 16:1 throughout both ponds. However, the August round saw the ratio explode to values ranging from 82 to 354. On June 6, the Lower Pond was opened to the ocean, removing some 18 million cubic feet from both ponds and lowering the water level in the Lower Pond by about 3.5 feet. From the May 25 sampling round before the inlet to the June 21 round two weeks after the opening, little change in DIN was seen despite the major removal of water from the system. However, by early August, ammonium levels in the Lower Pond had dramatically increased to 6.8 to 9.6 um/l. This was accompanied by a substantial freshening of the system from 16 to 18 parts per thousand (PPT) on June 21 to 7.8 to 12.4 PPT in early August. The conclusion is that the Lower Pond varies from being nitrogen limited to being phosphorus limited while the Upper Pond is always nitrogen limited.

One possible explanation that requires more investigation revolves around substantial input of DIN primarily in the form of nitrate at the Mill Brook (station 1) and Fulling Mill Brook (station 4) sampling sites during the June and early August sampling time periods. Particularly following the rainfall event on August 8. By August, the phytoplankton concentrations in the Upper Pond were very high with chlorophyll *a* reaching 117 ug/l at Station 5 on August 9. This number is so high it would be considered as a possible error if it weren't supported by the dramatic increase in the particulate organic carbon (POC) concentration found on the same date. POC is a measure of the suspended particulate matter in the water column as is chlorophyll *a*. All of this suspended living biomass was exported from a fresh water pond with salinity values of around 0.1 PPT into a brackish system with salinity ranging from 8 to 12 PPT. The osmotic change may have killed these cells and begun the conversion of their nitrogen into soluble products causing dissolved organic nitrogen (DON) and ammonium levels (NH4) to rise dramatically.

During the summer of 2000, orthophosphate levels were much higher in both ponds than the concentrations found in 1999. While the reason is not clear, different weather patterns and the limited lifetime of the openings during 2000 may play a role. In the period from June through just before the August sampling round, 1999 saw 2.3 inches of rain while 2000 had nearly 12.5 inches. Increased runoff and streamflow probably played a role in the high phosphate concentrations. It is possible that in 2000, some other micro-nutrient not tested became a limiting factor leaving excess phosphorus in the water column perhaps due to the lack of flushing.

Menemsha and Squibnocket Ponds:
These ponds were surveyed during 1995 and 1996 in cooperation with the Wampanoag Tribe of Gay Head (Aquinnah). Chlorophyll *a* concentrations in Squibnocket during the growing season ranged between 2 and 10 ug/l, generally in the moderate rating for this parameter. Menemsha Pond had chlorophyll *a* in the 2 to 4 ug/l range in the highest quality rating. Squibnocket Pond has a large population of rooted macrophytes in the southeastern cove which leads to sluggish circulation in the shallow waters (less than 1 meter).

The data from that survey (Wilcox, 1999) show that Squibnocket Pond averaged 35 to 45 um/l of Total Dissolved Nitrogen in the Moderate rating for TDN but ranged up to near the lowest quality rating. Menemsha averaged between 20 and 25 um/l well into the moderate quality rating.

In Squibnocket Pond, DIN ranged widely from less than 1 to over 8 um/l. The averages for all stations were less than 4 um/l. Menemsha averaged less than 2 um/l and ranged from a maximum of 4 to a fraction of a um/l during the course of the study. The higher values in Squibnocket are a reflection of the larger volume of fresh water in the system.

Secchi disk depth readings in Squibnocket were near 1 meter from June 1995, through early August indicating a substantial amount of phytoplankton or other suspended material in the water column. Menemsha Pond averaged in excess of 2 meters at the station in mid-pond through the period from June through August.
Data from two rounds of water sampling funded by the Wampanoag Tribe in August and September 1999, are attached as Table 5.

<u>Summary & Discussion:</u>

The Upper or western Chilmark Pond: The Upper Pond (western) is a fresh water pond that receives all stream input to the entire system from Mill Brook, Fulling Mill Brook and an unnamed ephemeral stream through the Allen Farm. The watershed of the Upper Pond is much larger than the Lower Pond. The Upper Pond is nearly bisected by a large sand washover from the barrier beach. During much of the study period, the two halves of the Upper Pond were connected by a shallow channel with observed flow continuously to the east. If compared with data from other fresh waters (ENSR, 2000), Station 3 in the Upper Pond falls in the middle of the group for Total Nitrogen (around 500 micrograms per liter) but jumps up to a concentration found in less than 10% of the database in August 2000 (1000 ug/l). The same is true for chlorophyll *a*. Secchi disk depth declined to only 0.6 meters at Station 3 in August 2000, where fewer than 7% of the database values occur. In 1999, visibility exceeded 1.3 meters, where the database indicates over 30% of the measurements are reported.

During July and August 1999, the Upper Pond at the western end the presence of large numbers of colonial bryozoans (*Pectinitella magnifica)* was notable. These organisms form spherical clusters ranging in size from a softball to a large beach ball. They are common in warm, eutrophic fresh waters (Scott Jackson, personal communication 1999). The Upper Pond also has a substantial stand of the rooted aquatic plant Potamegeton (broad leaf variety) found primarily in the western half. In the eastern half of the Upper Pond, the narrow leaf variety of Potamegeton is more common but not as dense as the population in the western end. Both varieties are found in the eastern end of the Upper Pond.

The eastern half of the Upper Pond displayed a much more substantial phytoplankton population than the western portion. Turbidity values recorded near Station 5 at the Doctor's Creek outlet in August 1999 ranged between 20 and 40 NTUs and the Secchi depth was 0.6 meters compared with the western portion of the pond where the Secchi depth was over 1.1 meters (disk on bottom). This theme was picked up by the particulate carbon (POC) and chlorophyll *a* values which were 290 umoles per liter and 117 micrograms per liter respectively at Station 5 in the eastern end of the Upper Pond in August 1999. In the western end of the Upper Pond (1, 2 and 3) high POC values (from 57 to 206 um/l) were found but the chlorophyll ranged from 3 to 11 micrograms per liter.

That the streams are sources of inorganic nitrogen is indicated by an average Dissolved Inorganic Nitrogen (DIN) value of 8 umoles/liter at the mouth of Mill Brook and 5.5 at the mouth of Fulling Mill Brook. In the mid pond area at Station 3, the average was 2.9 um/l. Throughout the course of the study, there was continuous flow from the Upper to the Lower Pond. At station 5, although the average inorganic nitrogen content is low at 2.04 umoles per liter, it ranges up to 6.5 during the August 2000 sampling round. At a ballpark outflow of 400,000 cubic feet of water per day going from Upper to Lower Pond, the daily nitrogen introduction to the Lower Pond as indicated by station 5 is over 300 grams.

Rainfall events played a role in the water quality data collected in August 1999 (as discussed above) and in August 2000 when over 6 inches of rainfall occurred in the first two weeks of the month.

The Lower (eastern Chilmark Pond): The Lower Pond is the site of the cut through the barrier beach which drains the system and provides an influx of saline water. For this reason, it experiences wide swings in salinity. It has a barren bottom with very few aquatic plants. Those familiar with the pond do not remember eelgrass in it for at least the last 60 years.

The water quality data assembled at stations 6 through 10 in the Lower Pond to date is summarized as follows:

Table 4: Lower Chilmark Pond 1999-2000 Quality Determinants

Parameter	Range of Values Measured	Quality Rating
Chlorophyll *a*	4.4 to 28.1 ug/l	Moderate to Poor
Total Dissolved Nitrogen	23 to 57 um/l	Moderate
Dissolved Inorganic Nitrogen	< 1 to 14 um/l	Moderate to Poor
Secchi Disk Depth	0.8 to 1.4 meters	Moderate to Poor

The water quality survey results reported in the discussion above indicate that the Lower Pond is impacted by input of nutrients, much of which enter the system in the Upper Pond and which then flow through Doctor's Creek to the Lower Pond. This pathway is implied by the Inorganic Nitrogen data in Figure 7. In Figure 7, the inorganic nitrogen concentration in May and June 1999 at stations 1, 2 and 4 are much greater than in the Lower Pond (6, 7 and 8). This nitrogen is cycled into phytoplankton as indicated by the larger values of dissolved organic and particulate nitrogen at station 7 in the Lower Pond in Figure 8. With the failed cuts through the barrier beach in 2000, the pattern of greater inorganic nitrogen at the Upper Pond stations remained in place.

Inadequate flushing failed to remove the nutrient load when the Pond was opened to the sea during the study period. Despite the removal of some 18 million cubic feet of water during the June 1999, opening (see Task 4), the Upper Pond only dropped 0.5 feet during this time because the opening closed within 4 to 5 days. The lower level of the Lower Pond which had dropped over 3 feet from its high stand encouraged the discharge of nutrient and organic matter rich water from the Upper Pond. The influx of groundwater and surface water from the Upper Pond into the Lower Pond sets the stage for the low quality seen in August 1999. A successful August opening is a prerequisite for improved water quality. As the watershed is still only partly built out, a good deal of the lower water quality may well be the result of natural eutrophication.

The duration of an opening to the Atlantic Ocean needs to persist for 14 to 15 days for 95 percent of the water in the Lower Pond to be exchanged for new ocean water (Task 4). Over the two seasons of observations, cuts through the barrier beach closed in less than a week. In 2000, the opening closed in a matter of days. Short duration openings do not flush the system and may well carry large amounts of nitrogen into the Lower Pond from the Upper Pond and from the increased groundwater discharge along the shore.

The factors which will determine the future water quality in the system are discussed in the Tasks which follow dealing with flushing, fresh water input, projected build out and nutrient loading. While it is clear that there are problems in water quality now, we have really only started to accumulate the data necessary for a full understanding of the system.

COLIFORM BACTERIA SURVEY: CHILMARK POND

This survey was planned to examine the levels of fecal coliform bacteria in the system before and after a rainfall. Fecal coliform bacteria are an indicator of the possible presence of pathogens that may be present from fecal matter deposited by warm blooded animals. The fecal coliform test is an easy analysis to perform when compared to tests for human disease causing organisms. Sources of fecal coliform include migratory and resident waterfowl, other wildlife such as otters and muskrat, domestic livestock and human sewage. The results of these surveys need to be examined with the immediate potential sources in the vicinity in mind.

The primary pathways for fecal coliform to reach a water body include surface runoff from roadways or pastures, stream inputs, direct deposition in the waterbody itself and possibly by groundwater. The groundwater pathway is not likely where septic systems are properly installed with appropriate separation from the water table. It is also a remote likelihood where the subsurface soils are sands and gravel along the path of flow from septic system to waterbody. Where subsurface soils are impervious and present an opportunity for effluent to flow along a direct pathway on the clay material or through a crack or fissure where filtration does not occur, the opportunity for fecal coliform to reach a pond by the subsurface route increases. It is not expected to be a major pathway for Chilmark Pond.

Weiskel et al (1996) found that fecal coliform survived much longer in the wrack line of algae and seaweed washed up near the shore along Buttermilk Bay. Their conclusion was that fecal coliform could survive from one spring tide to the next allowing the increasingly higher tides to wash out bacteria that were deposited in the wrack line two weeks prior. This may also be a source in Chilmark Pond however, during the 1999 survey period, a well developed wrack line was not seen.

Fecal Coliform bacterial counts are used to decide whether it is safe to use the water body for direct contact uses or for shellfish harvest. The shellfish harvest limit is 14 colonies per 100 ml of the geometric mean of the last 15 samples. The standard for swimming is 200 or fewer colonies per 100 ml (with up to 10% of the samples over 400 colonies per 100 ml).

Historical Data:

During late 1988 and 1989, SP Engineering collected regular fecal coliform and fecal streptococcus samples at 11 sampling stations. The data is summarized for that survey in Table 6. Where these stations are close to sample stations used during the 2000 survey, the current numbers are used (see Figure 9). The letter station identifiers are for SP stations that do not coincide with the current study.

Table 6 SP Engineering Fecal Coliform Sample Results Colonies/100 ml

Station #	9/2/88	6/5/89	7/11/89	8/8/89	9/28/89
4	<2		22	<2	264
5	<2		148	6	86
6	<2	108	<2	16	78
7	2		4	<2	12
8	4		6	24	20
9	<2		4	2	12
10	4		<2	4	14
C			<2	2	16
G	8	76	118	12	68
J	<2		20	6	>400
K			120	32	>200
M	14			4	8

Stations where elevated fecal coliform levels (over 14) were found more than one time include:

Cove where Fulling Mill empties #4
Doctor’s Creek #5
Off MV Land Bank #6
Near site of opening #8
at the outlet to Doctor’s Creek #G
at channel between east and west Upper Ponds #J
at the outlet to the westernmost Upper Pond #K

The Commonwealth Division of Marine Fisheries has also sampled the pond (identification number V32). Data from 1997 and 1998 is tabulated in Table 7 below. Station numbers used in the current survey are substituted for the DMF's station numbers where the station locations coincide.

Table 7 Division of Marine Fisheries Fecal Coliform Data -- 1997 and 1998

#	8/20/97	9/15/97	11/4/97	1/27/98	2/3/98	2/12/98	3/4/98	3/24/98	4/13/98	5/14/98	8/11/98	10/6/98	11/16/98	Mean
1	55	71	>246	<11	<11	<11	51	<2	4	50	137	23	<11	53
6	90	18	55	<11	<11	<11	<11	<2	<2	>50	88	11	<11	29
8	55	41	18	<11	<11	<11	<11	<2	<2	14	23	<11	<11	17
10	<9	<9	9	<11	<11	<11	<11	<2	<2	36	>311	11	<11	34
11	9	9	>246	51	<11	<11	<11	<2	18	50	51	11	<11	39
23	29	9	90	<11	<11	<11	<11	<2	14	50	51	23	36	27
DMF3	<9	9	18	<11	<11	<11	<11	<2	<2	22	11	<11	<11	11
DMF7	71	29	29	<11	<11	<11	<11	<2	2	8	>311	<11	<11	40

All stations except off Allen Point show fecal coliform over 14 more than one time and all average over 14 except DMF3 off Allen Point. In this data set, those occurrences are mainly during the time of warmer water temperatures, May through November. The average during the December through April period is less than 14 for all stations. The locations with the highest averages appear to be those influenced by one or more high results. These are at the Mill Brook outlet to the Upper Pond (#1), in Gilbert's Cove (DMF7), in the lower part of the Upper Pond cove where Fulling Mill enters the system (#11) and at the lower end of Wade's Cove (#10).

It also seems that during the late spring and summer months any of the stations can have high counts (5/14 and 8/11/1998). Gilbert's Cove has no houses near the shore and the contamination probably results from the waterfowl that roost and feed in the area. The tip of Wade's Cove receives drainage from a wetland area to the north of the Wade's Field Road.

The Chilmark Board of Health sampled 5 stations regularly during the summer months of 1993 and 1994. The results are tabulated in Table 8 below. The analyses were done by the Dukes County Water Testing Lab.

Table 8 Chilmark Board of Health Fecal Coliform Data – Colonies/100 ml

Dates	Station ~2	Station 6	Station 8	Station 9	Station SP J
7/8/93		20	0	4	8
7//21/93		tntc*	8	36	
8/3/93		tntc	2	18	tntc
8/9/93		84	0	2	46
8/23/93		82	24	38	62
9/10/93			135	36	14
6/1/94		82	4	32	32
6/28/94		34	0	4	2
7/22/94	50				8
7/25/94		0	0	4	120
8/31/94	38	18	4	12	44
9/20/94	240	64	2	8	30
Mean	109	>48	16	18	>37

***TNTC== Too Numerous to Count**

The highest individual counts and the highest means were found off the Land Bank property (#6), at the channel connecting the east and west Upper Pond segments (Station SP J) and off the Allen Farm (#2).

Current Investigation:
From the data described above, it is obvious that there are wide variations in the fecal coliform counts at a given site over the course of a season and even within a given month. The two rounds of samples proposed in this study are unique in that samples were also collected at road crossings on the contributing streams. A total of 14 stations were sampled on July 17 and another 5 on July 18, 2000 and again on August 14 and 15. The stations are shown in Figure 9. Station numbers coincide with the water chemistry stations sampled at the same locations. New numbers reflect new stations within the pond or stream stations. The samples were collected, immediately put on ice, refrigerated over night and mailed by overnight delivery with the remainder collected on the next day. The samples were analyzed by SP Engineering, Inc. for the July round and by the State Laboratory (Division of Marine Fisheries) for the August round. The data are presented in Table 9.

Table 9 Fecal Coliform Survey—Chilmark Pond Colonies per 100 ml

Station #	Locus	7/17/00	8/14 /00
1	Upper Pond at Mill Brook outlet	196	1170
2	Upper Pond at Allen Farm Creek outlet	172	tntc*
3	Upper Pond mid pond	10	900
4	Fulling Mill Brook outlet	180	250
5	Doctor’s Creek west end	4	20
6	Off MV Land Bank Lower Pond	0	20
7	West of Long Point Lower Pond	0	<10
8	Off inlet site Lower Pond	2	<10
9	Wades Cove north end Lower Pond	8	--
10	Off Allen Point	12	<10
11	Upper Pond west of entry to Doctor’s Creek	0	50
12	East Branch of Fulling Mill Brook at South Road	14	410
13	West Branch of Fulling Mill Brook at South Road	122	430
14	Mill Brook at Menemsha Crossroad crossing	26	150
15	Mill Brook at South Road crossing	105	410
16	Pond spillway at South Road crossing	500	880
17	Mill Brook at crossing of dirt road to Weyquobsque Cliffs	108	710
18	Allen Farm stream at South Road	164	tntc
19	Duplicate of Sample 11	6	---
23	At north end of Wades in marsh	848	40

Duplicate collected at same site with second sample bottle
***tntc Too numerous to count**

Approximately 0.8 inch of rain fell in West Tisbury ending at 8 a.m. on July 16, prior to the sample round. Rainfall is a likely stimulant to release of fecal coliform residing in droppings on roadways, fields and pastures and in the riparian edges of the pond and streams.

Sample sites 18 and 23 had no visible flow of water at the July sampling. Samples 1, 2 and 4 were sampled in shallow water (less than 1 foot) near the edge of the Pond as close to the outlet of the stream as possible. Station 4 (Fulling Mill) had a strong flow of water while the flow was sluggish at Station 1 but the water temperature was 5 degrees centigrade cooler than the surface water at Station 3 in mid pond indicating the stream outlet. No flow was visible at Station 2 and warm water temperatures imply little input from the intermittent stream. The Mill Brook entry (#1) into the western end of the Upper Pond seems to be diffused through dense wetland vegetation and no defined discharge could be found. At the time of sampling, four horses and a foal were in the Allen Farm field that abuts the Upper Pond. No concentrated area of manure was observed on the sloping ground down to the pond shore. For the August round, 0.9 inches of rain had fallen in West Tisbury overnight and rain continued heavy at times during the 14th.

Conclusions:

The data collected imply input of fecal coliform from the land side and from waterfowl in shallow, nearshore water. The highest counts occur in the stream systems and in the samples collected in shallow water. The post-rain event data indicate that moderate to heavy rainfall sufficient to generate runoff will add fecal coliform to the pond.

The data collected is only adequate to make some suggestions for follow up data collection and for some slight modifications to current pasture management practices. These recommendations include:

1. Continue fecal coliform sampling in stream watersheds and the pond.
2. A follow up sanitary survey should be requested of Division of Marine Fisheries and/or Department of Environmental Protection personnel.
3. Use optical brightener detection pads to determine if there may be direct septic effluent input to the streams. The Retired Senior Volunteer Program, Environmental Corps has started this program in several streams and should be asked to extend the program to the Mill Brook and Fulling Mill Brook waters.
4. Pasture areas should be fenced at the top of the bluff to keep animals from spending much time on the slopes which run to the ponds and streams. This exclusionary fencing can be removed and access allowed periodically to graze off the vegetation.
5. Where possible, cattle crossings and pasture areas which abut the streams or pond shore should be shaped to create berms to divert runoff to heavily vegetated areas and to prevent direct flow to the stream or pond during runoff events.
6. Road crossings of the Fulling Mill, Mill Brook and the Allen Farm Stream should be examined to determine whether runoff can be better diverted into riparian vegetated areas to remove fecal coliform bacteria. The Natural Resource Conservation Service may be helpful.

Tasks: 4—Watershed Determination, Hydrologic Budget and Nitrogen Loading Limit for Chilmark Pond

4.1 Chilmark Great Ponds Watershed

Size of the Watersheds:

The watersheds were determined based on topographic divides from the USGS quad sheets (Squibnocket and Tisbury Great Pond) at a scale of 1:25000. See Figure 10 in a separate file. The watershed contributing to the Upper and Lower Ponds and the channel connecting them was measured with a planimeter using three replications to assure accuracy. The sizes of these water sheds is as follows:

Upper Chilmark Pond:	92.43 X 10^6 square feet	2122 acres
Lower Chilmark Pond:	44.49 X 10^6 square feet	1021 acres
Connecting Channel:	1.3 X 10^6 square feet	30 acres

The total watershed for the entire pond system is 3173 acres or 138.2 million square feet. The Assessor's Office lot size data was then used as a check. The sum of all lots within the watersheds plus an estimate for road area which is not included in the lot sizes leads to a figure of 3209 acres or 139.78 million square feet.

4.2 Pond Area:

The area covered by water varies with the height of the Ponds which depends on the state of the inlet through the barrier beach. The area of the ponds during an open pond was determined from aerial photographs (3/25/98 flight with scale at 1 inch is 1042 feet) using planimeter. The Upper Pond measured 33.07 acres (1.44 million square feet) and the Lower Pond was 145.54 acres (6.34 million square feet) at low water. When the Lower Pond is at its highest (about 5 feet NGVD), a large area of wetlands is flooded. The wetlands area was measured by planimeter from aerial photos (1998) at 79.8 acres which brings the Lower Pond (including the connecting channel to the Upper Pond) to a total surface area of 241 acres when it is at its highest stage. The Upper Pond at that stage approaches 35 to 40 acres.

These areas were then checked against the area as defined by the bathymetric map of the Pond. During the June opening the pond reached an elevation of about 1.5 feet NGVD at low tide and nearly 1.75 feet at mid tide. The area at and below the 2 foot contour as measured by planimeter is 107 acres for the Lower Pond and 26.5 acres (below approximately 3.5 feet NGVD) in the Upper Pond. During a late July survey when the Lower Pond stood at 4.1 feet NGVD, its area was 161 acres (7.03 million square feet). The Upper Pond at a somewhat higher elevation encompassed 31 acres (1.36 million square feet). Bathymetry and pond volume are discussed in section 4.4.

4.3 CHILMARK PONDS HYDROLOGICAL BUDGET: APRIL 1999

The hydrological system refills the pond system through discharge of groundwater into the Lower Pond and by both stream flow and groundwater discharge into the Upper Pond. The Upper Pond discharges through Doctor's Creek into the Lower Pond. The model used is based on three sources bringing water into the Ponds. These are: groundwater discharge, stream flow and direct rainfall landing on the surface of the Pond. The processes operating to offset these sources are: evaporation from the water surface and seepage through the barrier beach to the ocean. The difference between the inputs and outflows is the rate of refilling. The refill rate is the number for which we have the best supporting data.

SOURCES OF POND WATER INPUT

Estimated Recharge from the Watersheds:

The USGS (1980) estimated the annual recharge for the Vineyard at 22.2 inches on average. Over the watershed for the entire system an annual recharge of 255.7 million cubic feet or 1913 million gallons occurs on average based on this figure. The recharge figures found on the Cape range from 23 to 18 inches per year. A recharge of 18 inches over the watershed would amount to 207.3 million cubic feet or 1551 million gallons. Gaines (1995) estimated that about 9% of the annual groundwater discharge into Sengekontacket Pond occurred during April. For the Chilmark Great Pond watershed, this amounts to 19 to 23 million cubic feet during the month.

In addition to groundwater recharge, some portion of the annual rainfall flows overland to the streams and contributes to their daily discharge. The stream flow is unknown but an estimate of the additional contribution from runoff above base flow supported by groundwater is 10 to 15 percent of annual rainfall. The coefficient of runoff for wooded areas is commonly assumed to range from 0.1 to 0.2. The Natural Resource Conservation Service estimates runoff coefficients in small watersheds with under 10 percent impervious surfaces as being less than 0.15. The Engineering Field Manual includes a method (ES 1014) for estimating annual discharge from watersheds under 2000 acres in size. This method predicts a 90 percent chance of 7 inches of runoff out of the annual 46.9 inches or 15.0 percent. Over the 2122 acre watersheds of the main streams 18 to 54 million cubic feet per year or, on average 0.06 to 0.15 million cubic feet per day are added from overland flow.

The April time period influx from streams is calculated below based on several assumptions. I assume that 2/3 of the annual stream flow generated by overland runoff occurs during the 5 month period from January through May. At this time of year, factors such as frozen ground, lack of leaf cover and minimal evapotranspiration will encourage more runoff. The range of runoff figures used is from 4.6 inches (10% of rainfall) to 7 inches (15%). The calculations are:

$$\frac{7''}{12} \text{ X } \frac{2}{3} \text{ X } 2152 \text{ acres X } \frac{43560 \text{ sq. ft.}}{\text{acre}} \; \frac{1}{151\text{days}} === \quad \mathbf{0.2414 \text{ X } 10^6 \text{ cubic feet/day}}$$

$$\frac{4.6''}{12} \text{ X } \frac{2}{3} \text{ X } 2152 \text{ acres X } 43560 \; \frac{\text{sq. ft.}}{\text{acre}} \; \frac{1}{151 \text{ days}} === \quad \mathbf{0.1586 \text{ X } 10^6 \text{ cubic feet/day}}$$

In addition to the overland input there is steady input of groundwater to keep the larger streams (Fulling Mill and Mill Brook) flowing through the summer months. The small stream coming out through the Allen Farm pasture had no flow during this past summer.

An investigation of the volume of stream discharge into Tisbury Great Pond (Healy, 1995) found a combined daily discharge that averaged 0.68 million cubic feet per day from the two watersheds (6036 acres, Taylor, MVC, 2000). Proportionally, the watersheds of Tisbury Great Pond are about 2.8 times the size of the Chilmark Ponds watersheds. The geology of the two great pond watersheds is similar. If this proportional watershed area factor is applied to the Tisbury Great Pond streamflow to estimate the Chilmark Pond streamflow, a flow of 0.24 million cubic feet is predicted. Although this agrees with the estimate developed in section 4.3 for April 1999, it is not clear that this is a reliable method to estimate flow. A factor that confounds a direct comparison of the stream flows is the fact that the Mill Brook flows to Tisbury Great Pond through a large area of outwash deposits before the stream gauging station which raises the question of how much water may have been lost in transit. The streams flowing into Upper Chilmark Pond discharge into the pond from glacial moraine deposits that are more impermeable in general. The combined discharge averaged from the two streams into Tisbury Great Pond is just over 1 million cubic feet per day during the January through May period declining to an average of about 0.5 million for the remaining 7 months. About 60% of the annual stream discharge occurs during the 5 late winter/spring months in this system.

Direct Rainfall

On an annual basis Edgartown gets about 46.9 inches as measured at the National Weather Bureau weather station there. The actual figure varies from one end of the Island to the other. This much rainfall intercepted by the Pond area at elevation 4.1 feet totals 26.8 million cubic feet on the Lower Pond and another 5.2 million on the Upper Pond. A daily average derived from these inputs is 0.088 million cubic feet per day.

During April 1999, the official gauge recorded 2.11 inches in Edgartown which is well below the mean April rain of 4.28 inches. In my backyard gauge in West Tisbury, I recorded 2.56 inches. If we assume that 2.5 inches fell on Chilmark Pond during the time period when it was refilling, a total of 0.048 million cubic feet per day was added to the system. This is about 58% of the amount that would result from the average April rain.

POND WATER LOSS TERMS

Evaporation

Evaporation from the surface of small lakes and reservoirs in the area during April is 2.5 inches (Visher, 1966). This offsets the estimated addition to the system from direct rain although, normally, it would not as average April rain exceeds 4 inches.

Seepage through the Barrier Beach to the Atlantic Ocean

The time period over which we determine the rate of refilling of the pond system is from April 8 through May 4 (see Figure 11 & 12). Over this time period the Lower Pond rose by 2 feet from 2.5 feet to 4.5 feet NGVD. The relationship between Mean Sea Level and the NGV Datum is not known for the south shore, however, on the north shore MSL is 0.5 to 1 foot above NGVD. It is likely that, throughout the refilling period under consideration, the Lower Pond stood at an elevation above MSL and seepage through the barrier beach to the ocean could be expected to occur. The rate of seepage would vary with the stage of the tide on the south shore, being faster at low tide and quite slow at high tide as well as the head difference between pond and ocean.

The amount of seepage is dependent on the nature of the soil materials (their permeability), the head difference between Pond and ocean and the area through which seepage occurs. The formula is Q == kiA where Q is the quantity of water discharged, I is head drop over the length of the flow path (i.e. pond to ocean), A is the area through which the discharge passes and k is the hydraulic conductivity of the beach material.

The value of k for clean sand ranges from less than 10 to over 2000 feet per day. To narrow the range, sieve data from the south shore barrier beach (Wilcox, unpublished) was used in the formula $k == A\ {}_{10}d^2$ where A is 1 for units of d in millimeters and k in centimeters per second. The term ${}_{10}d$ is the particle diameter for the population such that 10 percent of the sample is finer than this diameter. Data from three cores (2 to 3 feet deep) on the beach face was examined and the range of ${}_{10}d$ was from 1.25Φ to 1.75Φ. The average was used yielding a particle diameter of 0.375 millimeters in the medium sand range. When carried through the formula, k is 0.141 cm/sec or 399.7 feet per day. The graphic mean of the particle sizes was also examined as a parameter more representative of particle size distribution. The graphic mean takes into account the extremes represented by the particle size where 16 percent is finer and the size where 84% is finer. A value of 562 feet per day was derived for k. Given the location of these cores on the beach face which is one of the coarser particle zones on a barrier beach, the lower value of 400 feet per day was used with 500 feet per day as an upper range.

The length of beach through which this seepage occurs is 1500 feet in the Upper Pond and 6900 feet in the Lower Pond. No seepage is assumed to occur through the western most portion of the south shore of the Upper Pond as this is heavy clay. The width of the barrier beach varies but averages about 300 feet. The head drop is from Pond level to the ocean. This varies depending on the tide but gradually rises over the 26 days in April from 2 feet when the Pond stands at elevation 2.5 NGVD to 4 feet when the Pond stands at 4.5 NGVD. In the Upper Pond, the discharge is through 1500 feet of sandy barrier beach, with a pond elevation that would remain above the Lower Pond level. We have no data during the March-April opening for the Upper Pond but, during the June opening, it remained at about 4.5 feet NGVD or 4 feet above MSL throughout the drawdown phase when the Lower Pond dropped to 1.5 feet NGVD. For the calculation, we assume that there is 4 feet of head from the Upper Pond throughout the April refilling phase. The average daily seepage loss through the Lower barrier beach is 0.2109 million cubic feet and 0.0456 through the Upper barrier beach. For the higher seepage loss term, a “k” of 500 feet per day was used which indicates just over 0.32 million cubic feet out per day.

Pond Refill Volume
The Lower Pond rose from elevation 2.5 feet NGVD on April 8 to 4.5 feet NGVD on May 4. Volumes at each elevation were estimated by interpolation from the bathymetric map. The increase in volume totaled 13.48 million cubic feet over **26 days** or 0.5184 million cubic feet per day. During this time, the Upper Pond rose an estimated 2 to 2.5 feet over the same time period which brings the total volume increase to 0.5757 million cubic feet per day. Table 10, summarizes the figures discussed in the preceding paragraphs.

TABLE 10-- SUMMARY OF HYDROLOGICAL BUDGET OF CHILMARK POND SYSTEM

Ground-water	**Recharge**	**Area**	**Volume/ Year**	**April @ 9%**	**HIGH Estimate**	**LOW Estimate**
	Feet	Square Feet 10^6	Cubic Feet 10^6	Cubic Feet 10^6	Cubic Feet 10^6/day	Cubic Feet 10^6/day
	22.2/12	138.216	255.699	23.013	0.7671	
	18/12	138.216	207.324	18.659		0.622
Stream Flow	**Runoff/ Year**	**Area**	**Volume/ Spring**			
	2/3 X 7/12	93.741	36.455		0.2414	
	2/3 X 4.6/12	93.741	23.956			0.1586
Direct Rain	**Feet**	**Pond Area**				
	2.5/12	6.023			0.0418	0.0418
			INPUT	**TOTALS**	**1.0503**	**0.8224**
Evap.					0.0483	0.0483
Seepage					0.3206	0.2565
REFILL					0.5757	0.5757
			LOSS	**TOTALS**	**0.9446**	**0.8805**

The implication from this table is that the largest input term (groundwater recharge/discharge) may be too large in the high estimate. Alternatively, the estimated seepage term (the largest of the water loss terms) may be on the low side.

A check of these estimates can be derived from the early refill data collected by the tide gauges immediately after the inlet to the pond has closed (Figure 12). At this time, the Lower Pond is steadily rising but the seepage loss is at its lowest because the head between the Pond and ocean is smallest. In April, the gauge was put in after the inlet had closed, so the Pond elevation ranged between 2.50 and 2.92 feet NGVD over the 2 day period examined. During this time, the average daily rise of pond water level was 0.18 feet per day. In June, the gauge was in place during the opening, so the earliest pond level rise is recorded. Over the 3 day period examined the average daily rise in pond level was 0.156 feet. With a low pond acreage of 145.5 acres, this implies an average daily input of 0.989 million cubic feet during June. The April influx is greater, averaging 1.14 million cubic feet per day which may be somewhat low as the pond had already risen by about 1 to 1.5 feet when the gauge was placed increasing the seepage loss factor.

These figures are net rise in pond level including all the additive factors such as direct rainfall as well as negative factors such as seepage and evaporation. There was no measurable rain in Edgartown during the June period and 2.11 inches in the April period. These input figures agree reasonably with the estimates developed in Table 10.

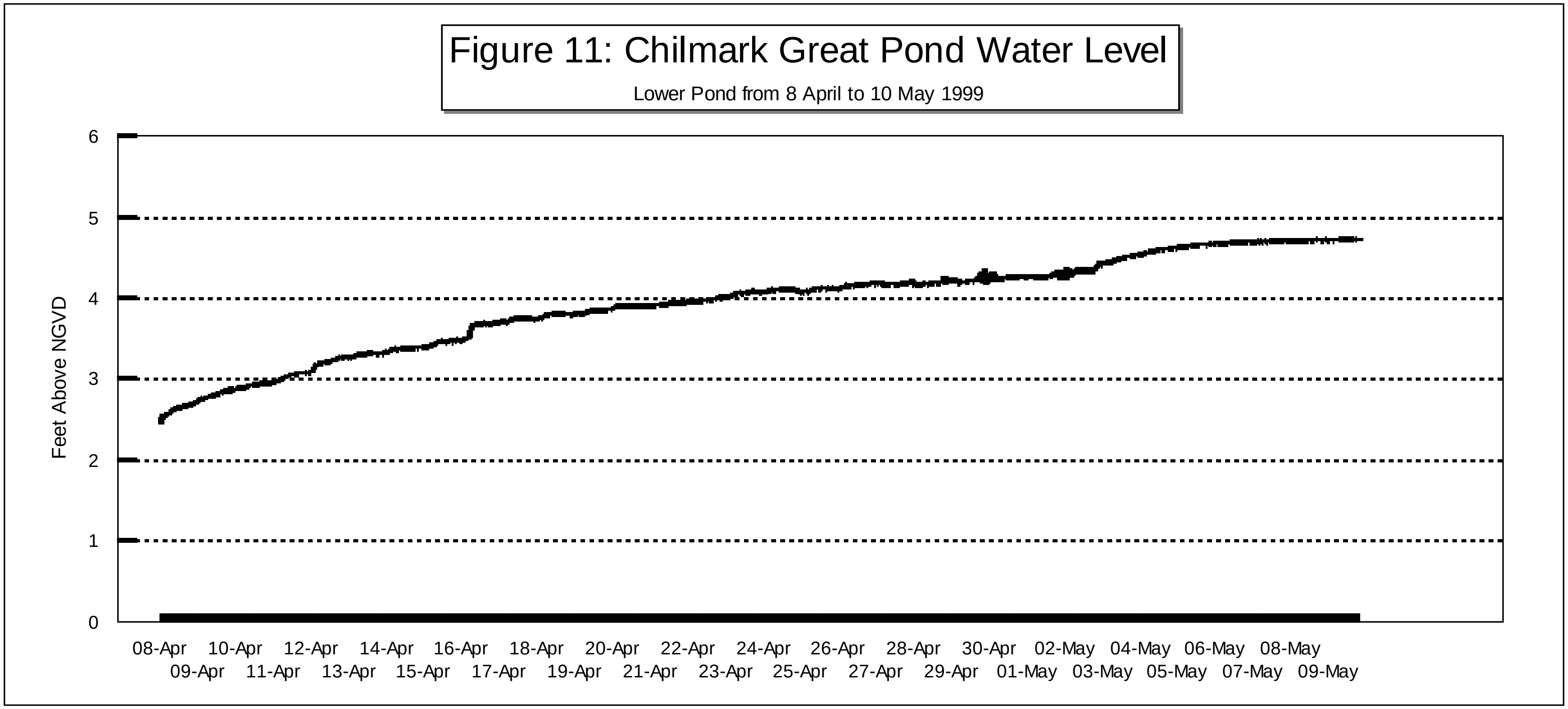


Figure 11: Chilmark Great Pond Water Level
Lower Pond from 8 April to 10 May 1999
Feet Above NGVD
0
1
2
3
4
5
6
08-Apr
09-Apr
10-Apr
11-Apr
12-Apr
13-Apr
14-Apr
15-Apr
16-Apr
17-Apr
18-Apr
19-Apr
20-Apr
21-Apr
22-Apr
23-Apr
24-Apr
25-Apr
26-Apr
27-Apr
28-Apr
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01-May
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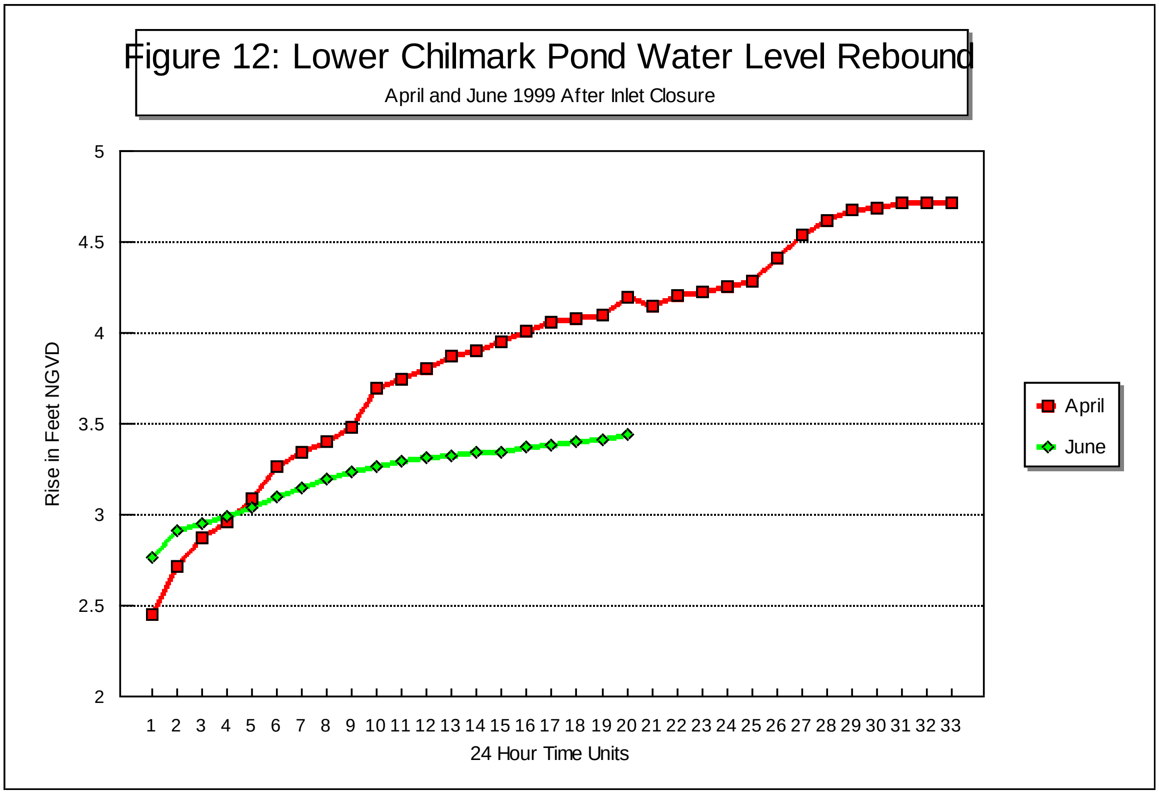
07-May
08-May
09-May



4.4 CHILMARK POND DEPTH MEASUREMENTS:

These measurements were taken from the shoreline and bathymetric map created during late July and early August 1999 (see Figure 13 in a separate file). The shoreline and the location of depth readings were recorded by Global Positioning System to within less than 10 feet. The elevation of the Pond at this time was determined from a bench mark placed by Kent Healy on the north shore of the Lower Pond. Unfortunately, no benchmark was available for the Upper Pond survey site and its elevation is an estimate. The area measurements taken from the bathymetric map (500 feet to the inch) are as follows:

Lower Pond:	**Area X 10^6 square feet Lower**
4.1 feet NGVD shoreline	7.0275
2.0	4.66
0	3.095
-1.0	0.64
-2.0	0.535
Upper Pond	
4.4 feet NGVD shoreline	1.363
2.0	0.708
1.0	0.193
0	0.06

CHILMARK POND VOLUME CALCULATIONS:

The volume was calculated by two simple methods. In the first, the area within a given contour interval was multiplied by the average depth within that interval and the volumes summed. The second method is after Reid (1961) which uses the following formula:

$$\mathbf{1/3(\ A_1 + A_2 + SQRT\ (A_1{*}A_2)H}$$

In the formula, A_1 and A_2 are the areas of two adjacent contours and H is the depth interval of those two contours. The formula is applied to each pair of contours and the results summed. During the time of the late July survey when the Lower Pond stood at elevation 4.1 NGVD, the volume in the Lower Pond is estimated at 24.3 million cubic feet while the volume in the Upper Pond is 3.1 million cubic feet. In addition, the channel connecting the two ponds holds about 0.06 million cubic feet. Total system volume was about 27 million cubic feet.

At high stage, the Lower Pond will stand at about elevation 5.1. The Lower Pond holds an additional 7.97 million cubic feet at this time for a total of 32.27 million cubic feet. This is an increase of about 1/3 over the volume at the time of the survey. This estimate includes all flooded wetlands (assumed average depth is 0.5 feet) as well as the channel connecting the two ponds.

As some flow was found from the Upper Pond into the Lower throughout the study period, it appears that the Upper Pond stands at a somewhat higher elevation than the Lower Pond at all times, however the elevation does not appear to vary during the drain down by such a large factor. I estimate that, at high pond, it holds an additional 0.57 million cubic feet for a total of 3.67 million. Total system volume at high stand is 35.94 million cubic feet.

At low pond in June (see Figure 14), the Lower Pond reached an elevation of 1.5 feet NGVD at low tide. With the limited tidal data available, the tide range is estimated at 0.45 feet with mid-tide at about 1.7 feet. The volume below the 1.5 foot depth contour is estimated at 18.1 million cubic feet using the same methodology as discussed above. At that time, the Upper Pond had only dropped 0.5 feet, which indicates a volume of 3 million cubic feet still in the system.

By subtracting low pond system from the high pond system volume, the combined Pond system discharged about 18 million cubic feet during the initial drain down phase for the June 1999 opening. This is about 55 percent of the Lower Pond volume. The Upper Pond during the same opening dropped about 0.48 feet which represents less than 10 percent of its volume. As a result of this differential drop, the gradient between the two ponds increases and flow through the channel to the Lower Pond increases. With a persistent inlet, the Upper Pond would eventually discharge enough water to approach the elevation of the Lower Pond. For comparison, Gaines (1993) estimated 60 percent of the water in Edgartown Great Pond was emptied during the November 1993, opening.

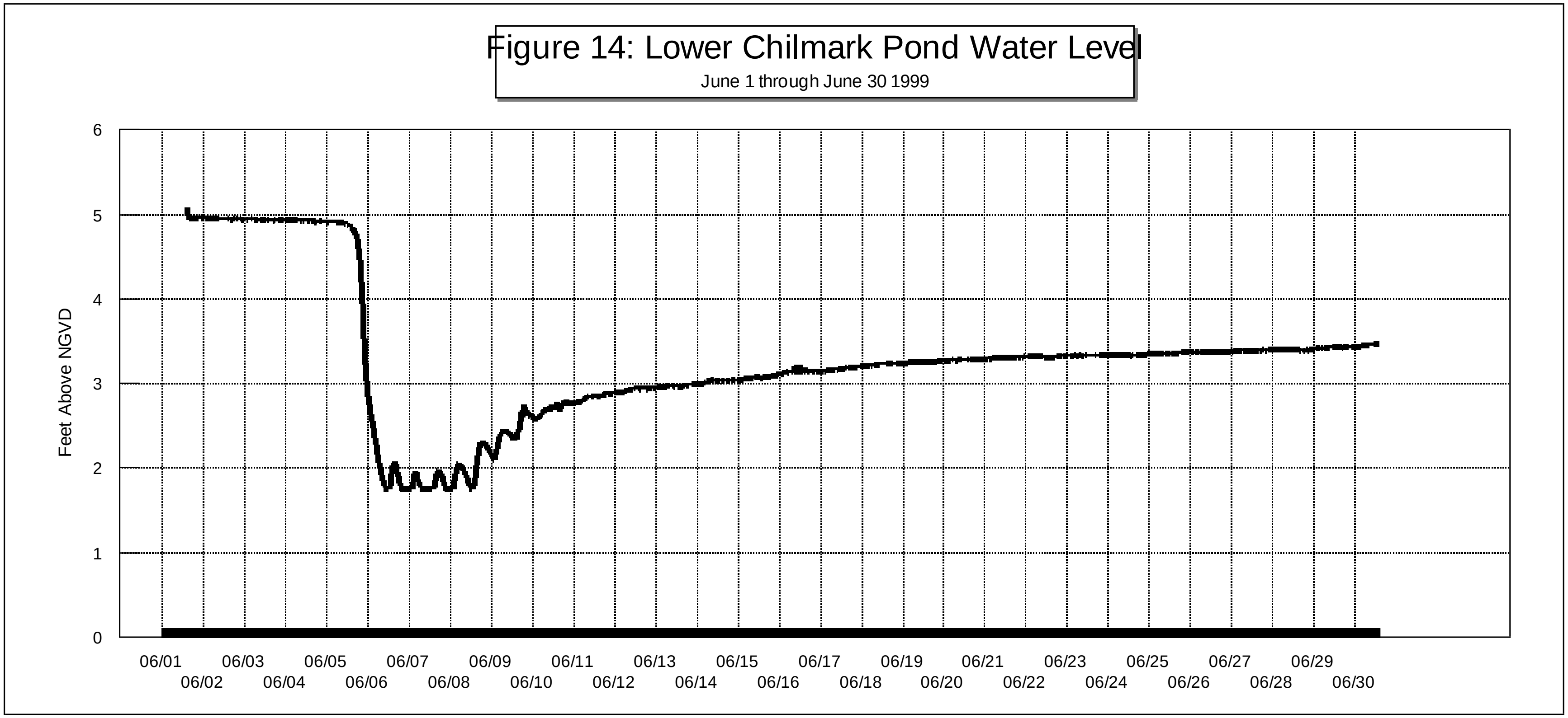


Figure 14: Lower Chilmark Pond Water Level
June 1 through June 30 1999
Feet Above NGVD
0
1
2
3
4
5
6
06/01
06/02
06/03
06/04
06/05
06/06
06/07
06/08
06/09
06/10
06/11
06/12
06/13
06/14
06/15
06/16
06/17
06/18
06/19
06/20
06/21
06/22
06/23
06/24
06/25
06/26
06/27
06/28
06/29
06/30

4.5 Chilmark Pond Tidal Flushing:

The tidal prism as measured during the June 1999, inlet was on the order of 0.45 feet. The inlet was tidal for approximately 4 days (June 6 through June 10). See figure 14 for the change in Lower Pond level and Figure 15 for the changes in the Upper Pond level during this time. The opening persisted during the lunar third quarter. The tide range obtained from the recording tide gauge during this time is probably somewhat on the low side of average. We can estimate the flushing time for the Lower Pond by dividing the volume of the tidal prism into the volume of the Lower Pond at low stage. It is appropriate to use the low pond volume for the flushing time calculation as, at mid pond volume, the tidal action would be greatly suppressed due to the relative height of the pond compared to the ocean. The tidal prism is the product of the tide range multiplied by the area of the Lower Pond at low water. This volume is calculated as:

0.45’ X 4.269 X 10^6 square feet == 1.92 x 10^6 cubic feet per tide

In order to calculate the flushing time, we divide the pond volume by the prism but must also multiply by a conversion factor that takes into account that there are less than two tidal cycles per day. For Chilmark Pond the time to complete one cycle is 12 hours and 43 minutes on average. There are 1.89 tide cycles per day. This is 0.53 days per tidal cycle. Residence time is:

$$\frac{18.1 \text{ X } 10^6 \text{ cubic feet}}{1.92 \text{ X } 10^6 \text{ cubic feet}} \text{ X } 0.529 \text{ days} == \mathbf{4.98 \text{ days flushing time}}$$

During much of the time the inlet was tidal, the tide curve was ebb dominated reflecting the steady input of fresh water from the Upper Pond into the Lower Pond and exiting the system. Ebb tides lasted 6 hours and 38 minutes on average while flood tides were only 6 hours and 5 minutes long.

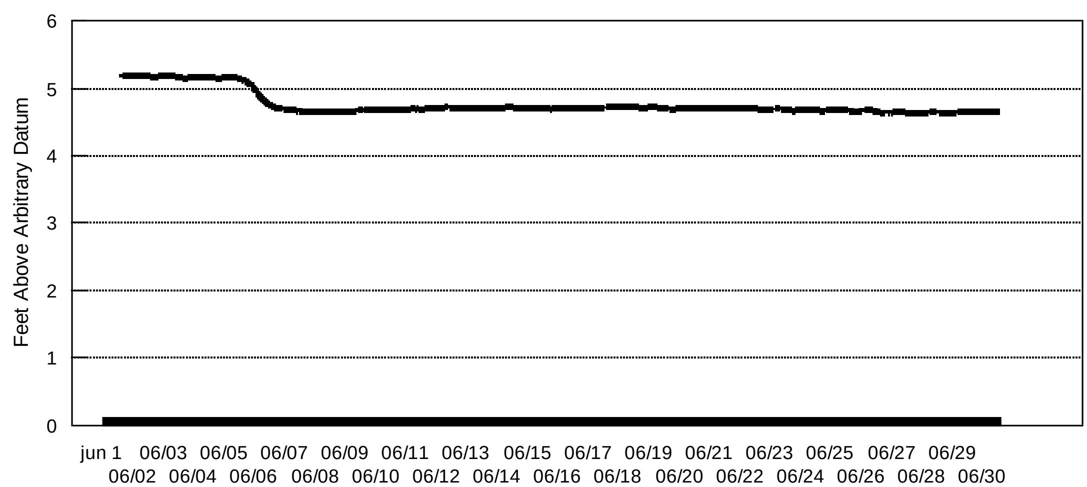
The actual residence time of the system will require approximately three cycles equal to the flushing time for 95 percent exchange of Lower Pond water for Atlantic Ocean water. This happens because water beginning at the head of Wades Cove or at the western end near the MV Land Bank property does not make it all the way out of the inlet before the ebb tide has turned to flood. Some of the old water is pushed back into the recesses of the pond with each flood tide and the 0.45 foot tide range does not consist entirely of new Atlantic Ocean water. Formulas which follow a diminishing return curve best describe the exchange process found in coastal ponds with restricted inlets.

The estimated time for 95 percent flushing of Chilmark Lower Pond is 14.9 days. Inlets of this duration should be the target for pond sewers managing the system. For comparison, the time required to flush Edgartown Great Pond to the 95 percent exchange level is 15 days (Gaines, 1993). It is important to note that, during the two year study, the lifetime of the openings was much less than the 95 percent residence time. Both cuts during 2000, failed to last more than a couple of days and probably brought very little if any new water into the system.

The steady input of fresh groundwater and stream discharge into the system also offers a source of flushing as the pond water seeps through the barrier beach to discharge into the Atlantic. If we average the annual fresh water inputs and divide into the volume of the Lower Pond when it is at 4.1 feet, the flushing time is indicated at 23 to 29 days under average conditions. Using the seepage loss term as a flushing factor, about 100 days are required for a volume of water equal to the Lower Pond volume (at high pond) to exit through the barrier beach. Given that the time interval between cutting inlets to the sea is 3 to 4 months, the maximum flushing time is about 90 to 120 days.

Figure 15: Upper Chilmark Pond Water Level

June 1 thru 30, 1999



Note: Water Level in this Pond is estimated to be ~0.25 feet higher than the highest level in the Lower Pond
This Datum is Used to Establish the Pond Level here but it is Approximate

4.6 Nitrogen Loading Limit:

Lower Chilmark Pond is a coastal salt pond that receives periodic influx of salt water from inlets cut through the barrier beach. After these breaches are healed by longshore drift of sand, the Lower Pond salinity is diluted by groundwater input and discharge of fresh water from the Upper Pond. The Upper Pond appears to remain fresh under normal conditions.

Phytoplankton growth in salt water bodies is typically limited by the availability of nitrogen in the form of nitrate, nitrite or ammonium. This is called the nitrogen limit. The other major nutrients required for growth are carbon, hydrogen, silica and phosphorus. The first two are abundant and do not limit growth. The nitrogen limit is partly the result of the ratio of nitrogen to phosphorus required in the tissue of phytoplankton which is normally about 16 to 1. In other words, in average tissue, 16 atoms of nitrogen are required for every phosphorus atom. If provided in excess, growth will continue to increase until some other nutrient or environmental factor limits its increase. At some point, such minor nutrients as iron or manganese may become a growth limiting factor if all major nutrients are widely available.

The following discussion is partially drawn from Gaines (1998) who devised nitrogen loading limits for Edgartown Great Pond which, in many ways, is similar to the Lower Chilmark Pond. The Upper Pond, being fresh, is probably not limited by nitrogen, however, it is a source of nitrogen discharge into the Lower Pond which probably is limited by nitrogen at least during the growing season (May through September, see discussion in Task 2). The Buzzard's Bay Project (Costa, 1999) proposed a process for estimating the amount of nitrogen that a coastal pond system can tolerate before undesirable deterioration of such factors as dissolved oxygen, turbidity, loss of eelgrass beds and excessive growth of wrack algae developed. The relationship between nitrogen loading and pond water quality is a difficult one to establish with absolute certainty. The relationship was drawn by using flushing estimates (Vollenweider, 1976), the volume of the pond system and the desired water quality goal for the pond. The nitrogen loading capacity (or tolerance) was linked directly to the rate of flushing of the water body. The flushing rate can be approximated by the pond volume and the size of the tidal prism. The formula that was developed by the Buzzard's Bay program (Costa, 1999) is:

$$Qn \sim \frac{Qc * Va * Vr}{r}$$

Where: **Qn** is the critical nitrogen limit
Qc is the nitrogen loading rate limit
Va is the average volume of the pond
Vr is the Vollenweider flushing period
r is the residence time for the system

The appropriate values for Qc were derived by the Buzzard's Bay Program using the Commonwealth's water classes in 314CMR4.00 as a framework. There are presently no nitrogen loading limits in the surface water classification system in 314CMR4.00, although that is now under study. In Table 11 as well as Tables 12, 14 and 15 descriptive quality categories are substituted for the surface water classifications.

Table 11-- Recommended Nitrogen Loading Rate Limits for Coastal Embayments
Modified from: Costa, 1999, Buzzard's Bay Program

Embayment	Reduced Quality Waters	Good Quality Waters	Highest Quality Waters
Shallow	300 mg/M^3/Vr	150 mg/M^3/Vr	50 mg/M^3/Vr
Deep	400 mg/M^3/Vr	200 mg/M^3/Vr	75 mg/M^3/Vr
mg = milligrams	g = grams	M^3 = meters cubed	

Shallow is defined as having 40% or more of the area less than 2 meters deep or having an average MLW depth of 2 meters or less.

For purposes of conveying a clear picture of the implications of each nitrogen loading rate level, the following manifestations of each level are proposed as guidance. These symptoms should be thought of as occurring on a continuum of nitrogen loading rather than being confined to the loading figure used. There is no strict relationship yet established between the loading rate, the classification and the manifestation of nutrient loading impacts. Currently Chilmark Pond, Menemsha and Squibnocket Ponds are rated as SA waters due to their being "…subject to the rise and fall of the tide…" (314CMR4.00).

Highest Quality Waters:
In terms of water quality indicators, at this level of nitrogen loading and flushing coastal ponds should show little degradation from the pristine, natural state. They should be useable for fishing, shellfishing, swimming and be aesthetically pleasing. There may be some accumulation of macroalgae such as *Ulva* (sea lettuce) or *Enteromorpha* and localized eelgrass bed decline but these occur primarily where the nitrogen inputs enter the system. This classification is comparable to the Buzzard's Bay Program's (BBP) Stage 1 condition.

Good Quality Waters:
These waters are useable for fishing, shellfishing in designated areas, primary contact (swimming) and should be aesthetically pleasing. They are excellent habitat for fish and aquatic life. In waters characterized by this level of nitrogen loading and tidal flushing, there may be periodic elevated chlorophyll in the water column, some eelgrass bed decline and seasonal reduction in transparency below 3 meters. Corresponds to Stage 2 of the BBP system.

Reduced Quality Waters:
These waters may not be suited to shellfishing without depuration but are useable for fishing, primary contact (swimming) and are aesthetically pleasing. In waters with this combination of nitrogen loading and flushing, the onset of eelgrass bed decline is obvious and eelgrass may be absent, seasonally the chlorophyll levels are moderate to high and macroalgae may be excessive in areas. Hypoxia (low dissolved oxygen levels) seasonally in summer when the system becomes stratified or during periods of limited mixing of the water column. Corresponds to Stage 3 of the BBP system.

Lowest Quality Waters:
These waters are not suited for shellfishing or swimming, but secondary contact uses such as fishing, boating and hiking are acceptable. Eelgrass is absent, masses of macroalgae are common through the growing season and hypoxia and anoxia are found in the deep and even shallower portions of the system. If the pond does not develop macroalgae, the phytoplankton levels are periodically high making water column visibility very low. Dissolved inorganic nitrogen levels are 10 um/liter or more during the growing season indicating nitrogen is no longer the limiting nutrient.

A number of studies have attributed declining water resource quality to increasing nutrient loading (Valiela, 1995). The following breakdown of the manifestations of increasing nitrogen loading is drawn from Costa et al (1996) and NOAA (1996).

Parameter	High Quality	Moderate Quality	Lower Quality
Dissolved oxygen	>90% saturation	75 to 90%	60 to 75%
Total Dissolved nitrogen	<7 um/l	7 to 40 um/l	40 to 70 um/l
Dissolved Inorganic nitrogen	<2 um/l	2 to 7 um/l	7 to 10 um/l
Chlorophyll *a*	0 to 5 ug/l	5 to 10 ug/l	10 to 20 ug/l
Secchi depth	3 meters or more	3 to 1 meters	1 to 0.6 meters
Macrophytes	limited quantities	moderate	moderate to severe

NOTE: These symptoms are provided to give the reader some sense of the implications of different levels of nitrogen loading.

The Lower Chilmark Pond is unlike the ponds for which this Buzzard's Bay Program's system was crafted in several important ways. First, it is only opened to the Atlantic Ocean for limited periods of time. Most of the time it is not subject to tidal flushing at all. The flushing time necessary when the Pond is open to the ocean for 95 percent exchange is about 14.9 days, however, when it is closed for 2 or 3 months it flushes at a different rate depending on seepage through the barrier beach. However, given the fragility of these coastal resources it is worth applying the formula as a tool for determining the level of concern that should be given to the management of nitrogen loading. There are some symptoms of nitrogen loading that are already showing at the current loading level as discussed in the water quality section of this report.

The hypsographic curve derived from the bathymetric survey (Figure 16) indicates that the mean depth of the Lower Pond is less than 4 feet putting it into the "shallow" category. Its flushing time is 14.9 days at best. The longest non-tidal flushing period is about 25 to 30 days which is the time required for the groundwater and stream inputs to equal the volume of the pond at 4.1 feet elevation. The flushing time period between cutting inlets of 90 days is also used to derive a range of possible nitrogen loading limits for the system. The system volume used in these calculations is the low pond stage volume for the 14.9 day residence time when the inlet is open and the volume at pond elevation 4.1 feet for the longer flushing time intervals.

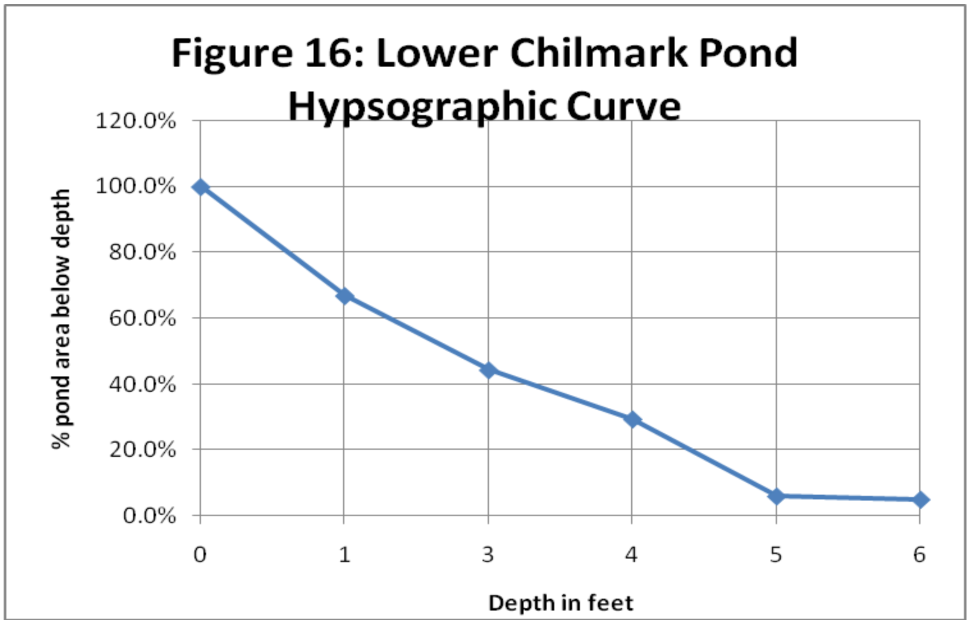


Table 12 Nitrogen Loading Limits for Chilmark Lower Pond
Based on the Buzzard's Bay Program Formula NOT part of 314CMR4
In Kilograms/Year

Embayment	Reduced Quality Waters	Good Quality Waters	Highest Quality Waters
Shallow R = 14.9	4522	2261	753
Shallow R = 25	3802	1901	633
Shallow R= 90	1252	626	209

The suggested loading limit for the Lower Pond system is the target for the Good Quality rating or 1901 kilograms per year. This loading limit will be very difficult to meet therefore the limit for Reduced Quality loading of 3802 will also be examined. The Upper Pond, being a fresh water system does not fit into the nitrogen loading model.

Task 5 Squibnocket Pond Watershed:

5.1 Geologic Setting:

The surrounding uplands are mapped as Qgh, the Gay Head Moraine. The moraine includes not only glacial till applied as a veneer over the underlying materials but the underpinnings are composed of imbricated (stacked) thrust sheets of pre-glacial coastal plain sediments including all of the various beds exposed in the Gay Head Cliffs at the west tip of Aquinnah. As many of the coastal plain materials are impervious clay, the groundwater flow to Squibnocket is quite complex.

These relatively impervious materials support large areas of wetlands developed in perched water tables and several streams flowing into Squibnocket Pond (see Table 13 below). The streams include Black Brook, an unnamed drainage out of Black Pond to the east and another to the west.

Watershed and Pond Area:

Gaines (1990) described the nature of the Squibnocket and Menemsha Pond watersheds as in Table 13.

Table 13: Squibnocket and Menemsha Ponds Watersheds (After Gaines, 1990)

FEATURE	Area in Square Kilometers	Area in Acres
SQUIBNOCKET		
Total Area	**7.930**	**1960**
Terrestrial	**5.410**	**1340**
Wetland	**1.24**	**310**
Non-wetland	**4.17**	**1030**
Aquatic	**2.52**	**620**
Squibnocket	**2.51**	**620**
Black Pond		
Lily Pond		
MENEMSHA		
Total Area	**11.85**	**2930**
Terrestrial	**8.68**	**2140**
Aquatic	**3.2**	**790**
Menemsha	**2.71**	**670**
Nashaquitsa	**0.36**	**90**
Stonewall	**0.13**	**30**
Wetland areas are those	*mapped as such on USGS*	*Maps (1972)*

The present study estimated watershed area by planimeter from a USGS topographic sheet (Squibnocket Quadrangle) and this was checked by summing the acreage from the Assessor's data for all lots in the watershed plus an additional acreage for roads not included in the lot acreage. The acreage for the Squibnocket Pond watershed from the Assessor's data is 1303 acres and from the USGS map 1239 acres (see Figure 17). For the Menemsha Pond watershed, the area is 1793 acres by the Assessor's data and 1856 acres from the USGS map (Figure 18).

Gaines (1990) describes the formation of Squibnocket Pond as the drowning of a depression in the glacial moraine as sea level rose following the last glaciation. As such, its age is probably less than 7000 years. The southwest shore is a baymouth barrier beach connecting the upland to the northwest and to the southeast. This is a permeable geologic deposit and is probably a pathway for discharge from Squibnocket Pond as seepage through the beach face when the ocean is lower. In addition, the Pond drains through the Herring Creek some 1700 feet into Menemsha Pond. The Creek is also a source of flood waters from Menemsha Pond. The Creek flows through two cement box culverts used in trapping the herring during the spring run. There is also a 6 foot diameter culvert under State Road. At low tide in June 2000, the water depth was 6 inches or less over the bottom of the two box culverts and about 18 inches in the State Road culvert. Each of these structures influences the flow in and out of Squibnocket Pond. In the past the pond was connected to the Atlantic via an inlet through the southwest barrier beach shown on maps from the late 18th century. Later maps indicate an inlet at the southeast corner of the Pond and there are remains of a wooden sluiceway in place into the early 1900's still to be found today (Gaines, 1990).

5.2 Hydrologic Budget and Flushing: Squibnocket

Previous Work: Gaines (1990) found the pond to average 10 parts per thousand salinity indicating it to be about 2/3 fresh water and 1/3 Menemsha Pond water based on measurements in May and August 1989. He found the salinity readings to be relatively constant around the Pond. A survey funded by the Wampanoag Tribe in 1995 (Wilcox, 1999) found the salinity to range between 11 and 12 PPT through the year (10 sampling rounds) at 4 stations throughout the Pond. Gaines estimated a pond volume of 6.3 million cubic meters (222.5 million cubic feet or 1.68 billion gallons) derived from the 2.51 square kilometer area (620 acres) and an average depth of 2.5 meters (8.2 feet). Of this total volume, 2/3 or 4.2 million cubic meters is fresh. With an estimated average daily input from streams and groundwater of 13.9 thousand cubic meters, the flushing time for fresh water was estimated as 302 days for fresh water.

The remaining 2.1 million cubic meters is saline (Menemsha Pond) water. The average daily volume of Menemsha Pond water entering Squibnocket Pond was estimated as 11.6 thousand cubic meters (Gaines 1990). This influx was estimated from tidal current flow data as the pond level itself did not show a tidal curve during the one week period shown in that report. Gaines observed, in regard to typical tidal curve expression, that "… this was not observed in terms of surface elevation changes during our period of measurements." Dividing the daily input into the average total volume of Menemsha Pond sea water in Squibnocket gives a flushing time of 181 days for salt water.

Hydrologic Budget- Present Study:
Fresh water inputs from groundwater, streams and precipitation is an important part of the total water budget for this system, particularly when it is non-tidal. Using an annual average recharge of 22.2 inches over the 1300 acre watershed, the annual groundwater contribution to the system is 0.288 million cubic feet per day. Stream flow from direct runoff, based on the area of the stream watersheds and the assumptions used to estimate stream flow to Chilmark Upper Pond, is on the order of 0.046 million cubic feet per day. This figure is in excess of the portion of the groundwater recharge that enters the streams flowing to the pond. Direct precipitation less evaporation contributes 0.159 million cubic feet per day. The total annual input is 0.493 million cubic feet or 13690 cubic meters per day which is very close to Gaines estimate (1990).

5.3 System Flushing-Present Study:

Over the course of 4 weeks a Global tide gauge was placed in Squibnocket Pond to the east of the Herring Creek channel. The gauge was set to record at 10 minute intervals during the time it was in place. Over the period from October 28 through November 19 the Pond exhibited a cyclic pattern of pond level variation known as a diurnal tide consisting of one high tide and one low tide each day (see Figure 19 in a separate file). Over this 22 day period, 22 tidal cycles were measured with the average tide range of 0.47 feet or slightly less than 6 inches. The tidal pattern in Menemsha Pond is semidiurnal having two high tides and two low tides in each 24 hour period. NOTE: This pattern is now thought to have resulted from a restriction in the air pressure compensating vent. This possibility is supported by the November water level shown in Figure 20 that does not display daily fluctuation.

The tidal curve recorded from the 19th of November through the 10th of December (see Figure 20) is more like the water level response recorded by Gaines (1990). The Pond level oscillates rapidly over a 24 hour period with a range of 0.1 to 0.15 feet during four discrete time periods separated by days with little oscillation. These oscillations are superimposed on an eight day rise of pond level by about 0.1 feet followed by a similar decline during the next eight days. The pond level then rises by about 0.2 feet over the next day (December 6). The rise in water level results from 1.74 inches of rain that fell over a 2-day period (National Weather service Observer, Edgartown). This long term rise and fall is not tidal but may be a manifestation of the spring to neap tidal cycle. The tide gauge was replaced on November 19th accounting for the slight change in depth over the arbitrary datum however, the gauge location and placement in the stilling pipe was the same.

The cycle was checked a second time in April 2000. During the entire 28 day period there are no discernible regular tidal oscillations. The sharp rise in pond level on March 17 is a response to rainfall in excess of 3 inches (Lovewell, Edgartown). See Figure 21.

It is puzzling that the change in pond tidal regimes occurs coincident with the change of recording equipment. A check with Global Water indicates that if the vent for pressure compensation were blocked, there could be diurnal variations in response to this blockage.

The rapid oscillations in both Figures 20 and 21 are thought to be **seiches**, a phenomenon where the water level in a pond sloshes back and forth around a pivot node usually in the center of the pond. The phenomenon is often a response to an outside force such as wind or even an earthquake. An examination of wind data from the Nantucket weather buoy 44008 (latitude 40 degrees 30' 1" N and longitude 69 degrees 25' 54" W) indicates, for the seiche on 5 December, that northwest winds of 10 to 25 mph swung to the southwest and south at 5 to 10 mph by 15:00 followed by south and south-southeast winds increasing to 8 to 15 mph by 1 a.m. on the 6th. The oscillations began about the time the wind shifted almost 120 degrees from northwest to south (Figure 20 in a separate file). They continued as the wind backed to the south and south-southeast.

On March 11 and 12 in Figure 21 (in a separate file), a northeast wind at 10 miles per hour shifted to east at 15 to 26 mph as the oscillations began to build. After 8 hours of east wind and building oscillation height, the wind shifted to southeast at the same speed for 20 hours. This wind continues into the dampening of the seiche oscillations but a wind shift to the south and quickly to the southwest (at the same speeds) ended the seiche phenomenon.

Two seiche events can be seen in the tide curve for the period from April 1 through late on April 4. The wind was from the southwest most of April 1 but shifted to the south and south-southwest at the onset of the oscillations at noon on April 2. The wind also picked up speed from 6 to 8 mph prior to the seiche start up to 10 to 18 during the onset of the seiche. The phenomenon ceased when the wind turned more from the southwest despite the wind speed of 16 to 19 mph. Prior to the second seiche, wind speed was 8 to 10 mph from the south from 14:00 on the 3rd to 02:00 on the 4th. At that point, wind speed increased to 15 to 20 from the south until noon and then rose to 20 to 25 from the south-southwest. The seiche was strongest under the influence of the south wind.

It is possible that the two different types of water level curves may relate to a combination of wind speed and direction and tide stage that causes the pond to be tidal at some times and non-tidal at others. The tidal period in early November extended over both Neap and Spring tides. This phenomenon should be examined in greater detail as the flushing varies widely between the tidal and non-tidal conditions.

Pond Area & Volume:

The area of the Pond was calculated from the USGS Squibnocket Quad map by averaging three repetitions with planimeter. The average area ranged between 25.99 million square feet (601 acres) and 26.29 million square feet (603 acres). The product of the tide range and the area of the pond is the tidal prism. The prism recorded in early November represents the exchange of approximately 12.3 to 12.4 million cubic feet per day or 348000 cubic meters per day. This is significantly greater than that measured by Gaines(1990) however, it is only a portion of the observed tidal flushing as it is followed by a 3 week period with a "tide range" of a little over 0.1 feet over a 12 to16 day period. This is cause for concern. The approximate average daily flow during this period based on water level only is 6168 cubic meters per day which is about 60 percent of Gaines' estimate based on tidal currents.

The volume of the Pond is estimated at 175 million cubic feet (4.98 million cubic meters) which is considerably less than Gaines estimate. This figure is derived as discussed for Chilmark Great Pond. The area between each pair of bathymetric contours was calculated and multiplied by the average depth. The contours are those prepared by the Wampanoag Tribe (Walsh et al, 1979). Gaines (1990) had estimated the volume at 6.3 million cubic meters by the product of the area and the mid depth.

The flushing time during the diurnal tide time period is 14.2 days. If the Pond always exhibited diurnal tide cycles, the time for 95 percent exchange of old Squibnocket Pond water with new Menemsha Pond water would be 42.6 days. This is because each flood tide pushes old water back into the system such that a portion of the new tide prism includes old water. Given the subsequent late November and April lack of a tidal cycle, on average I would suggest that the exchange time be based on the time required for the fresh water inputs to the system to equal the pond volume. This figure is 354 days. Additional tidal data is a priority to determine the average annual conditions.

5.4 Squibnocket Nitrogen Loading Limits:

In addition to flushing, another determinant of the tolerance of the system for nitrogen loading is the depth of the pond. From the hypsographic curve for Squibnocket Pond, the mean depth is 4.7 feet (Figure 22). This places the system just into the shallow category (mean depth less than 2 meters) for nitrogen loading limit calculations. In addition, over 40% of its area is less than 1 meter which also indicates it is a Shallow system. In Table 14, the range of acceptable nitrogen loading limits are shown for differing water resource quality targets.

Table 14-- Nitrogen Loading Limits for Squibnocket Pond

Based on the Buzzard's Bay Program Formula In Kilograms/Year

Embayment	Reduced Quality	Good Quality	Highest Quality
Shallow 43 days	17064	8532	2844
Shallow 354 days	3037	1519	760

The suggested goal for Squibnocket is the Good Quality rating which calls for a loading limit of 1519 kilograms per year. Unfortunately, this goal is probably not obtainable even with the lowest growth projections. In a Pond where the primary use of the resource is for shellfish production, high phytoplankton populations may not be a problem provided that hypoxia (low oxygen levels) does not impact the shellfish. The Squibnocket system was found to show some symptoms of eutrophication during the Gaines study (1990) and in a year long survey carried out in 1995 by the Wampanoag Tribe (Wilcox, 1999). These symptoms include high phytoplankton populations, poor water column transparency, occasional elevated levels of nitrogen and high levels of Total Organic Nitrogen. No problems with low levels of dissolved oxygen were reported by either study however, no continuous, overnight measurements were taken. There is a potential for overnight low oxygen and a survey of oxygen content over several 24 hour periods should be done in August at depth in the Pond. These early symptoms suggest the need for caution in adopting a nitrogen loading limit until further study of the pond system brings greater clarity to the nutrient cycling and limitations. **The loading limits for Reduced Quality waters are a reachable target with the longer flushing time of 354 days calling for a limit of 3037 kilograms per year.** However, steps should be taken to improve circulation and reduce the flushing time to improve the resulting water quality.

Tidal Flow through the Herring Creek:
A survey of the Creek bottom indicates that there are several points where the tidal flow is potentially restricted. While this survey has not yet been tied in to a bench mark or to mean sea level, it identified that there are places where adjustments could be made to enhance flow. These include the cement box culvert used for trapping the herring. While the width of the wooden structure leading in to the catching area is 5 feet, the box culvert is only 2.8 feet. The depth of water over the bottom of the wooden structure was 2.8 feet but was less than 1 foot over the floor of the cement culvert on August 17, 2000 near low water in Menemsha Pond (Menemsha Bight low at 3:15 p.m.).

Figure 23 (in a separate file) shows the Creek bottom elevations at mid-channel to scale on the vertical axis only. The distance from the elevation labeled box culvert to the State Road culvert is about 340 feet. There is an area behind the new shellfish hatchery indicated as "rapids" in Figure 23 where the bottom rises up to an elevation that is 0.5 to 1.5 feet above the elevation of the floor of the box culvert and 2.9 to 3.9 feet above the base of the wooden, drop-board structure. Further toward the culvert under State Road, the bottom of the Creek is very close to the elevation of the floor of the box culvert.

First step options to increase the flow through the Creek appear to include increasing the size of the cement box culvert and deepening the bottom of the Creek in the shallow area. The length of channel that would require deepening is about 150 to 200 feet. Deepening it to the level of the base of the cement box culvert would very likely increase flow into Squibnocket Pond.

Prior to taking any of these steps, a thorough evaluation is needed of the implications for Squibnocket Pond should increased flow bring higher salinity to the system. In addition, the survey should be tied in to mean pond level in Menemsha and Squibnocket Ponds to assess how much additional tidal flow might result. The portion of the Creek between State Road and Squibnocket Pond also needs to be examined to identify any other shoals or obstructions. The potential for long lasting water quality improvement through increased flushing of the system warrants a close look at this possibility.

Task 6 Menemsha Pond:

6.1 Menemsha Pond Watershed:

The watershed is 1793 acres as indicated from the Assessor's data and 1856 acres as measured by planimeter from the USGS Squibnocket quad sheet. The watershed is described more fully in Section 5.1 above.

6.1 Pond Bathymetry and Tidal Flushing

Menemsha Pond is a fully tidal pond of 665 acres (current study) up to 670 acres (Gaines, 1990). It is connected to Nashaquitsa Pond (90 acres) via a restricted channel. A large culvert under South Road joins Stonewall Pond (30 acres) to Nashaquitsa. The total system is 784 to 790 acres or 34.41 million square feet. The tidal prism on a daily basis is over 166 million cubic feet. Compared with this large volume, the daily fresh water input of 0.647 million cubic feet is insignificant and will not be used in determining flushing.

Menemsha Pond holds 134 million cubic feet of water at Low Tide. At High Tide, an additional 73.25 million cubic feet of water are in the pond. At Low Tide Nashaquitsa and Stonewall Pond hold about 5.9 million cubic feet while at High Tide about 18.55 million cubic feet are in these two ponds. The mid-tide volume for the entire system (179 million cubic feet) will be used to calculate nitrogen loading limits.

Tide gauges were placed at the West Basin, at Hariph's Creek and in the southwest corner of Menemsha Pond between October 26 and November 1999 recording water level at 10 minute intervals. See Figures 24 and 25 (separate file). The average tide range at the West Basin was 3.03 feet while it averaged 2.9 at Hariph's. A gauge at the southwest corner of Menemsha Pond near Herring Creek outlet averaged 2.34 feet but this was during a one week period only. The tide curve at Hariph's is strongly ebb dominated with 1.94 tidal cycles per 24 hour period. At West Basin the cycle is flood dominated with 1.93 cycles per 24 hour time period. The flushing time for the system is less than 0.95 days for tidal volume to equal mid tide volume and the estimated time required for 95% flushing is 3.2 days.

The average depth of Menemsha Pond is the same as Squibnocket Pond about 4.7 feet and 68% is less than 2 meters which is considered Shallow (Figure 22 in a separate file).

6.3 Nitrogen Loading Limits for Menemsha Pond

Table 15 summarizes the suggested loading limits as derived from the Buzzard's Bay Program's formula. Menemsha Pond is so well flushed that the formula indicates it can assimilate large amounts of nitrogen. Nitrogen input to Menemsha comes from Squibnocket Pond which drains into it as well as from the watershed surrounding the pond.

Table 15 Nitrogen Loading Limits for Menemsha Pond

Based on the Buzzard's Bay Program Formula In Kilograms/Year

Embayment	Reduced Quality Waters	Good Quality Waters	Highest Quality Waters
Shallow R=3.2 days	189706	94853	31618

The appropriate target for the loading limit for the Menemsha Pond system is the Highest Quality Waters limit of 31618 kilograms of nitrogen per year.

Projected Loading from Land Use Compared with Loading Limits:

The figures used here are developed in more detail in Task 7. This section is a summary only for purposes of continuity. The primary purpose of the land use projections is to estimate what the nitrogen loading to each pond system **may be** at buildout. When these loading numbers are compared with the loading limits for the system, it becomes clear whether loading is a concern or not. The total loading figures for each of the three pond systems were prepared to provide a range based on differing assumptions about the growth pattern that might develop in each drainage basin.

For systems where there are substantial wetlands within the drainage basin and a substantial amount of future growth will occur **upstream** of those wetlands, the Buzzard's Bay Program assumes that up to 30 percent of the future nitrogen load from upstream development may be extracted by the wetlands. The wetland's ability to extract nitrogen from future loading is not limitless but is a probable beneficial function for the type of low density residential growth to be expected in these watersheds.

Each of these systems has extensive wetlands in its watershed. These include the wetlands west of the Menemsha Crossroads along the Mill Brook for Chilmark Pond, the wetlands in and around Black Brook for Squibnocket Pond and the wetlands around the brook that discharges into Menemsha Pond at Peases Point. The wetland area around Mill Brook has some 9% (275 acres)of the watershed of Chilmark Pond upstream. Black Brook has about 27 percent (367 acres) of the pond watershed upstream of the wetlands. In addition, another 15 percent (207 acres) is upstream of the wetlands and stream discharging into the northwest corner of Squibnocket. About 172 acres or 9 percent of the Menemsha Pond watershed is upstream of wetlands connected to the streams flowing into the pond at Pease's Point and into Nashaquitsa Pond. These are substantial areas and there is a nitrogen loading reduction benefit that will accrue from these wetlands. This reduction would apply to both the sewage and lawn fertilization loading. Note that the reduction in nitrogen loading for sources upstream/upgradient from wetlands is now thought to be 50%.

Chilmark Pond:

The projected total nitrogen loading for this system ranges from 4946 to 6551 kilograms per year. The wetland reduction would account for 100 to 200 kilograms per year. The net loading is 4846 to 6351 kilograms. The loading limit for Good Quality waters is 2235 kilograms per year. The Reduced Quality loading limit for a 25 day flushing interval is 3802 kilograms. The Lower Pond demonstrates some symptoms of nitrogen loading today with the current loading at about 3700 kilograms per year. Steps should be taken to try to improve the circulation in the system by extending the lifetime of openings to the Atlantic.

Squibnocket Pond:
The projected total nitrogen loading for this system ranges from 2295 to 4059 kilograms per year. The wetland reduction applies to about 42 percent of the watershed and would account for 200 to 300 kilograms per year (Note this may be higher under our current understanding of wetland nitrogen attenuation). The net loading projected at buildout is 2095 to 3759 kilograms. The loading limit for Good Quality waters is 1519 kilograms and for Reduced Quality waters 3037 kilograms per year with a 354 day flushing cycle. It is possible that the diurnal tide observed during November 1999 may better flush the system allowing a higher loading limit. Gaines (1990) estimated a 180 day flushing time which would call for a loading limit of 2580 kilograms per year. It is certain that the flushing time (43 days) determined for the diurnal tide on a year round basis is too rapid. But it is possible that the annual flushing time may be better than 180 days. Further, extended study of the tidal flushing phenomenon is strongly recommended to develop a better loading limit and evaluate options to increase flushing.

Menemsha Pond:
The projected total nitrogen loading for this system ranges from 4409 to 6531 kilograms per year at build out. The wetland reduction would account for 100 to 150 kilograms per year. The net loading is 4309 to 6381 kilograms. Because Squibnocket Pond drains into Menemsha Pond, the loading to Squibnocket Pond should be added to the nitrogen load from the Menemsha Pond watershed. The resulting combined load at buildout ranges from 6404 to 10140 kilograms per year. The loading limit for Highest Quality waters is 34103 kilograms per year. This system will be well below its limit at buildout.

Task 7.1: Existing Land Use Summary:

Spreadsheets with lot identification and projected dwelling units are available as Appendix A on request from the Martha's Vineyard Commission.

7.1.1 Regulations Applying Within the Recharge Areas in *Chilmark*:

The Health Department regulations that apply provide some limitation on minimum lot size. The well on a lot must be separated by 150 feet from the leaching system on the same or adjoining lots. The leaching field must be 200 feet from the edge of wetlands associated with Squibnocket Pond and 500 feet from Squibnocket Pond itself.

A leaching field must be 200 feet from a saltwater pond if it is within the Coastal District of Critical Planning Concern. Within this DCPC, the leaching field must also be 300 feet from an adjoining leaching field. To get these separations, about 1.5 acres are required. This DCPC includes land below the 10 foot contour or within 500 feet of Mean High Water. A separation of 150 feet is required from other watercourses.

For all separations described above, the 3 acre zoning will create large enough lot sizes. For smaller existing lots, variances are possible with one possible limitation being a requirement for 15000 square feet of upland lot area per bedroom. Lots sized less than 30000 square feet (0.7 acres) would only support a single bedroom dwelling.

Zoning permits a single family dwelling and, for lots over 3 acres, a guest house on each lot limited to 800 square feet floor area. The guest house may be connected to a common sewage treatment system with the main dwelling, subject to Board of Health approval, provided there is adequate area for sewage disposal for the guest house alone. Guest houses are not allowed until the owner has ownership of the principal dwelling for 5 years unless the lot is 6 acres or more and the owner covenants against any subdivision of the parcel.

Zoning districts are shown in Figure 26. Minimum Lot sizes for the Zoning Districts are outlined below:

District I	**3 acres**
Agricultural/residential District IIA	**3 acres**
Agricultural/residential District IIB	**3 acres**
Agricultural/residential District III	**3 acres**
Agricultural/residential District IV	**1.5 acres**
Agricultural/residential District V	**2.0 acres**
Agricultural/residential District VI	**3 acres**

Wetlands may be counted as part of the lot area in determining the number of lots that may be created by a subdivision. In approving the subdivision of land, the Planning Board may require provision of open space.

The size required for a pre-existing lot **less** than the zoning minimums to be buildable, is set by setbacks from the lot lines and by the Health Code. While it is conceivable that the setback limits could permit dwellings on lots less than 10000 square feet, this would require a substantial variance from the separation required between well and leaching area and the 15000 square feet per bedroom mitigation measure. *For this reason, it is assumed that lots less than 0.5 acres will not contribute substantially to the buildout in the watersheds.*

In addition to the Coastal DCPC, several other overlay districts apply within the watersheds. The Squibnocket Pond District also affects the Health Code for all Chilmark lands in the watershed of this pond. In addition to the Health code regulations in this DCPC cited above, the Squibnocket Pond District regulations prevent guest house construction on lots less than 6 acres in size.

Within the designated DCPCs (Coastal District and Streams and Wetlands borders draining to great ponds), additions to existing dwellings of no more than 250 square feet are permitted provided additional sewage flow will not be generated by the addition.

7.1.2 Regulations that Apply in ***Aquinnah***:

Both Menemsha and Squibnocket Ponds include a portion of the Town of Aquinnah within their watershed boundaries. In Aquinnah, the minimum size for new lots is 2 acres. No more than 1 dwelling per 2 acres is allowed. Guest houses are assumed to be allowed only on lots 4 acres in size or more. Pre-existing lots down to 5000 square feet may be built provided requirements for well-septic separation in Title 5 can be met. Compact siting permits the creation of lots down to 5000 square feet in size provided an area equal to 2 acres per dwelling is left as open space. This could permit clustered wastewater treatment to obtain better nitrogen removal by the use of advanced technology. Wetlands may be counted as part of the lot area in determining the number of lots that may be created by a subdivision. In approving the subdivision of land, the Planning Board may require provision of open space. Since their creation, no subdivisions have gone through the Subdivision Control regulations process so it is not possible to use recent approved subdivisions as a model for future growth.

The minimum separation between a well and a sewage disposal system is set at 200 feet. A distance of 150 feet (200 feet for saltwater) is required between septic and wetland. In addition, 200 feet separation between adjoining sewage disposal systems is required. These regulations set the minimum buildable lot size without a requirement for a variance at about 1 acre. In estimating the dwellings for buildout in all watersheds, pre-existing small lots down to 1 acre are included as probable. Lots less than 1 acre are included as possible for maximum buildout down to the minimum permitted by Title 5 for a 2 bedroom dwelling which is 0.46 acres (assumed to be 0.5 acres for tallying small buildable lots).

Small Lots in the Watersheds:

Lots that may require a variance from the health code were identified to assess the scale of this issue. In the Menemsha Pond watershed, 54 vacant lots less than 0.5 acres were found. In the Squibnocket Pond watershed, there are only 5 such lots. In the Chilmark Pond watershed, there are 7.

Figures Used in Estimating Watershed Populations:
Census records for Chilmark indicate that 75.7 percent of the dwellings in Town are seasonal. In Aquinnah, the estimate for seasonal units is 75.1 percent of the dwellings. These estimates are based on the number of residences that are not occupied at the time of the survey.
Assumptions used to estimate the watershed population at buildout are:

- Aquinnah household size is 4.55 people per seasonal houses.
- Chilmark household size is 5.15 people per seasonal house.
- Aquinnah household size is 2.45 people per year round dwelling.
- Chilmark household size is 2.27 people per year round dwelling.
- Guest houses are assumed to hold 2.27 people each.

Seasonal occupation estimates are drawn from the MV Commission Data Report while year round estimates are from the Census figures.

7.1.3 Chilmark Pond Watershed

Land within the recharge area of the Pond occurs in five zoning districts *all within the Town of Chilmark*. These are District I, IIA, IIB, III and VI. All Zoning Districts are Agricultural-Residential districts. The minimum lot sizes in all districts is 3 acres. A total of 667 lots were identified within the recharge area. There are also a large number of lots which are intended for access or right of way only. These are not counted as vacant lots. Of the building lots, 437 had a residential structure, 230 were vacant and 17 of those vacant lots were open space lots within a subdivision, owned by the Town or by some conservation agency. This data is summarized by watershed in Table 16 below. Present day land use is mapped in Figure 27 at the end of the Task.

In Table 16 the category "# Lots Built Now +Future" refers to existing dwellings, vacant lots that will be built and future subdivisions of land that will create new building lots. The column labeled "Acres Vacant" is a summary of the acreage in existing vacant lots *both* pre-existing undersized lots plus large lots as yet not subdivided.

TABLE 16 Existing Lots within the Recharge Area: Chilmark Pond

Zoning District	# Lots Built Now	# Lots Built Now + Future	Acres Vacant	# Open Space Lots	Total Acres
All Districts Upper Pond	280	613	838	9	2075
All Districts Lower Pond	157	285	498	8	1084
TOTALS	437 exist. dwellings	898 future dwellings	1336 tot. acres	17 lots (315 acres)	3159 acres

Potential Maximum Buildout:
The vacant lots were examined to determine how many acres could potentially be subdivided within each zoning district. Vacant lots and those larger lots with an existing dwelling indicate areas where future growth might occur. The largest lots within each Zoning District that are possible candidates for subdivision in the future are summarized in Table 17 below. Each lot in excess of twice the zoning minimum was examined and

assigned a buildout dwelling potential. The sum of these plus small vacant lots, new lots created by subdivision and the existing dwellings is 898.

As a check, a quick estimate of buildout can be made. The 1148 acres of buildable, vacant land in large lots in Table 17 can be reduced by 10 percent for roads (40 foot right of way) and open space plus 75 acres to account for the 25 existing residences to yield 966 acres to develop. When divided by the zoning minimum of 3 acres the land subdivided yields 322 lots.

The existing lots that are 0.5 acres or larger are assumed to be buildable. Those between 0.25 and 0.5 are considered to be marginal and those less than 0.25 acres are assumed not to be buildable. There are 159 vacant lots less than 10 acres in size. If these are added to the 322 lots from subdivisions and the 437 existing dwellings the total is 918 dwellings at buildout. This agrees with the projected 898 dwellings in Table16.

Should development proceed as permitted by zoning, we can expect a maximum number of primary dwellings in the recharge area of 898, roughly double the present day number of dwellings. This is the sum of existing dwellings (437) plus 461 existing vacant lots and future lots created by new subdivisions. The maximum number of guest houses is estimated from the number of lots over 3 acres in size. There is a potential for 578 one or two bedroom guest dwellings. It is unlikely that every qualifying lot will have a guest house built on it but it is possible that the larger lots and those where a second income from seasonal renting is necessary will eventually have a second dwelling. For the higher growth scenario, 200 guest dwellings are assumed in the loading calculations.

A **lower growth scenario** would result if a trend toward larger lot size or inclusion of more open space lots were to occur. As a model for this possibility, the Peaked Hill Pastures and Flanders Farm subdivision proposals were examined. Peaked Hill Pastures proposed 22 residential lots on a total of 141.2 acres or an average of 6.4 acres per lot. The Flanders Farm subdivision proposal sited 18 residential lots on 111.2 acres or 6.2 acres per lot. If the average lot created by future subdivision in the watershed were 6 acres including open space and roads, when added to existing vacant small lots, the number of new lots would be 322. The total buildout would include 759 dwelling units in the combined watershed plus an assumed 100 guest dwelling units.

Chilmark Pond Watershed Population Estimate:
When applied to the high growth estimate of 898 dwellings, 680 houses are seasonal with a population of 3502 and 218 are year round with 495 occupants. For purposes of a nitrogen loading estimate, I assume that there will be 200 guest houses containing an additional 454 people. The total watershed population peaks at an estimated 4451 people.

For the low growth scenario, the population is derived by applying the same percentages and occupancy rates to the projected 759 primary dwellings and an assumed 100 guest houses. The peak watershed population is estimated at 3606 people.

Annual nitrogen loading from the sewage flow from all scenarios is developed from these figures but also based on the number of days that the residents occupy the dwellings. These calculations are described in Task 7.

Table 17: Future Potential Development- Lots Over 10 Acres

Chilmark Pond Watersheds							chilss3.wk4 march 2000									
												Portions	Future	Future D.U	Guest	Future D.U
Map#	Lot#	Acres	Built	Vacant	O.S.	Agricultur	Other	Zone	Shed	Local	Off-island	of lot Out	D. U.s	Low Grow	Units	Marginal
30	106.1	100.32	1					VI	U		1	5.28	29	15	29	
20	60	51	1					III	U			10.1				
25	20.1	51	1					III	U			6.63				
25	21	46.6		1				III	U	1			4	2	5	
26	66.1	46.4		1				III	U				5	3	5	
25	5	42.8	1					III	U	1			14	7	15	
26	101	39.3	1					VI	U	1		10.1	12	7	13	
24	1	36.5	1					IIB	L				14	7	14	
26	105	33	1					VI	U				14	8	14	
19	50	32.5		1				III	U		1		3	2	4	
17	8	31.8		1				I	L		1					
26	86.1	31.66		1				III	U				4	2	4	
11	1	27.1		1				I	L				4	2	4	
23	1	27.1		1				I	L				4	2	4	
19	56	26.3		1				III	U				4	2	4	
18	50.2	25.95	1					I	L		1		12	6	13	
18	106	24.6		1					L		1		3	2	4	
18	92	23.6		1				III	U				3	1	4	
20	51	20.4	1					III	U	1			10	5	11	
25	8	19.7		1				III	U				3	1	4	
20	54.3	19.4		1				III	U				3	2	3	
29	16.4	19.1	1					VI	U		1		9	6	9	
20	48	17.9		1				III	U			3.9			1	
25	7.2	17.5	1					III	U							
25	6.7	17.32		1			6.8	III	U				3	2	3	
25	19	17.1		1				III	U				2	1	3	
25	7.7	16.4	1					III	U			1.82				
19	57	16	1					III	U							
24	52	15.8	1				wetland	IIB	L	1		1	8	5	9	
26	66.2	15.1		1				III	U							
19	9	14.6		1				III	U							
26	65	14.4		1				III	U				3	2	3	
17	1	14.3		1				III	L				2	1	3	
20	53	13.9	1					III	U				9	5	9	
25	7.5	13.4	1					III	U		1		9	5	9	
25	7.6	13.4	1					III	U	1		32.35				
17	50	13		1				I	L				2	1	3	
24	33	12		1				IIB	L				3	2	3	
19	69.2	12	1					III	U				9	5	9	
24	58	11.5	1				combinedw/	IIB	L	1			8	5	8	
20	50	11.4		1				III	U				3	2	3	
25	77	11.1	1					III	U		1		8	4	8	
24	16	11	1					III	U		1		7	4	7	
18	109	10.8		1				I	L				2	2	2	
26	87.2	10.62		1				III	U		1					
25	7.14	10.6	1					III	U		1		6	4	6	
17	36	10.4		1				I	L			22.6				
17	54	10.3	1					I	L		1		7	4	7	
19	8.1	10	1					III	U	1			5	3	6	
30	100	10	1				combine w/ 1	VI	U		1		7	4	7	
TOTAL		1147.97	25	25	0	0							257	143	272	
OPEN	SPACE															
20	47.14	65		1	1		mv land bank	III	U							
23	6	61		1	1		smf	I	L							
23	5	35.6		1	1		smf	I	L							
30	107	34.58		1	1		town	VI	U							
18	12	33.6		1	1		SMF	III	U							
19	25	32.35		1	1		smf	III	U							
24	138	11.5		1	1		cemetary	III	U							
18	75.3	11.46		1	1		smf	III	L							
TOTAL		285.09		8	8											

7.1.4 Menemsha Pond Watershed

Land within the recharge area of the Pond occurs in five zoning districts within the Town of Chilmark and primarily one District in Aquinnah. These are District I, IIA, IIB, III and VI in Chilmark and the Rural-Residential District in Aquinnah. The regulations that apply are spelled out for Chilmark and Aquinnah in Section 7.1.1 and 7.1.2 above.

All Chilmark Zoning Districts are Agricultural-Residential districts. Minimum lot sizes in all districts (except IV and V) are 3 acres. A total of 568 lots were identified within the recharge area. Of these, 373 had a structure, 195 were vacant and 21 of those vacant lots were open space lots within a subdivision, owned by the Town or by some conservation agency. Of the 373 with structures, 3 were on land that is otherwise classed as open space (town restroom, boat ramp etc.).

The total area of the watershed as indicated by the assessor's records for the two towns is 1747 acres. This figure does not include public roads which are separate from the lot acreage and are calculated at 46 acres. There are also a number of small lots with no acreage figure which are assumed to be unbuildable. The total acreage is estimated at 1793 acres.

The vacant lots were examined to determine how many acres could potentially be subdivided within each zoning district. Lots identified in this process are summarized in Table 18 below. Present day land use is mapped in Figure 28 at the end of this Task.

TABLE 18 Existing Lots within the Recharge Area: Menemsha Pond

Zoning District	# Lots Built Now	# Lots Now + Future	Acres Vacant	# Open Space Lots	Total Acres
Aquinnah	**34**	**105**	**326**	**3**	**478**
Chilmark	**339**	**537**	**393**	**18**	**1269**
TOTALS	**373 Exist. Structures**	**642 Future Dwellings**	**719**	**21 (212 acres)**	**1747**

Potential Maximum Buildout:

The vacant lots and those larger lots with a dwelling point out those areas where future growth might occur. The larger lots within each Zoning District that are more likely candidates for subdivision in the future are summarized in Table 19 below. The sites of potential future subdivisions are separated into vacant and those with a dwelling. These lots are also potential targets for open space acquisition. A total of 30 vacant lots greater than 0.25 acre and less than 1 acre were identified.

An estimate of the potential number of new lots which could be built should these larger lots be subdivided at permissible zoning density was calculated. Ten percent of the lot

TABLE 19 Large Lots in Menemsha Watershed

Map	Lot	Acres	Built	Vacant	O.S.	Ag.	Future DU	Future DU 6 acres	Guest DU	Town
26	102	10		1			1	1	1	CH
31	11.2	11.23		1			3	2	3	CH
33	3	13.6		1			4	2	4	CH
3	33	14.4		1						AQ
26	103	20		1			2	2	2	CH
20	87	20.5		1			6	3	6	CH
30	77&78	26		1			8	4	8	CH
30	76	26.6		1			8	4	8	CH
33	48	11.7	1						1	CH
30	75	12.5	1				2	1	2	CH
27.1	224	14.8	1				3	1	3	CH
33	85	15.5	1				4	2	5	CH
8	130	15.6	1				6	3	3	AQ
8	76,78,79,84	17.8	1				7	2	4	AQ
31	142.9	142.9	1				44	23	44	CH
TOTAL		373.13	7	8	0	0	98	50	94	
Open	Space									
4	63	24		1	1					AQ
3	1	145		1	1					AQ
		169		2	2[1]					

1 14.1 out; 46 acres are outside watershed

Table 22 Large Lots in Squibnocket Watershed

							Future Dwellings		Future Dwellings		
Map #	Lot#	Acres	Built?	Vacant?	O.S.?	Agric.	Likely	Marginal	Low Growth	Guest	Town
9	182[1]	32									AQ
9	177[1]	12									AQ
9	183[1]	29.5									AQ
11	3	19.1		1			9		4	4	AQ
12	43[2]	23		1			10		4	4	AQ
14	1[3]	38.6		1							AQ
11	4	21.4		1			10		5	5	AQ
34	1.8	26.6		1			8		4	4	AQ
35	2	19.1		1			6		3	3	AQ
12	60	15.1	1				6		3	3	CH
35	39	10.3	1				1				CH
33	47	22.9	1				6		3	3	AQ
35	38	13.8	1				1				CH
33	1	10.9	1				2		1	1	CH
11	1	173	1				45		22	22	CH
35	1.15	27.06	1							1	CH
11	23[1]	59.8	30				9		9	9	AQ
TOTAL		420.86	8	6			104		49	50	
Open	Space										
35	1.21	10.58			1	1					CH
35	1.3[4]	20			1	1					CH
35	1.18A	14.4			1	1					CH
35	1.24[4]	13			1	1					CH
35	1.17	11.59			1	1					CH
35	1.23	46.78			1	1					CH
35	1.29[4]	45			1	1					CH
35	TOTAL	161.35			7	7					CH

1 Property of the Wampanoag Tribe
2 Another 23.5 acres outside watershed
3 This parcel is beach and not developable
4 Additional acreage is outside the watershed

area was subtracted for roads and potential open space requirements. In Aquinnah, minimum lot size is 2 acres but pre-existing lots down to 5000 square feet may be built **provided** Title 5 requirements can be met. As discussed under the Chilmark Regulations, it is difficult to meet setbacks under Health Code without a half acre lot. In Chilmark, the minimum acreage for new lots is 3 acres in all but Districts IV(1.5 acres) and V(2 acres). Pre-existing lots down to 0.5 acre were considered buildable in both Towns.

Should development proceed as permitted by zoning we can expect a maximum number of primary dwellings in the recharge area of 642. This is the sum of existing dwellings (373) plus vacant lots and new lots from future subdivisions (269 combined) as in Table 20. There are about 256 lots large enough to have a guest house in the watershed under the existing regulations (projected 3 acre lots in Chilmark = 222 and 4 acre lots in Aquinnah = 34). The maximum growth scenario and the maximum number of guest houses cannot occur together because the zoning minimum of 2 acre lot sizes in Aquinnah is too small for a guest house.

Table 20: Future Land Use in the Menemsha Pond Watershed

TOWN	#Lots Built	# New Projected	Total Future Lots	Acreage
Chilmark	339	198	537	1269
Aquinnah	34	71	105	478
TOTALS	**373**	**269**	**642**	**1747**

As with the Chilmark Pond buildout figures, 10 percent of lot area is removed prior to determining the number of lots that could be created by subdivision. Pre-existing undersized lots are presumed buildable if they can meet the health code.

Menemsha Pond Watershed Population Estimate:
At buildout on the Chilmark side, there will be 406 seasonal and 131 year round dwellings in the **higher growth** scenario. The population (see page 48 for details) during summer on the Chilmark side of the watershed will be 2387 based on rates of occupation spelled out for the Chilmark Pond calculation. On the Aquinnah side, there will be 79 seasonal and 26 year round dwellings with a total population in the watershed of 423 people. Total watershed peak population in primary dwellings is estimated at 2810.

In the **lowest growth** scenario, recently approved subdivisions were examined to determine the average lot size including roads and open space. In the lower growth scenario, the average lot sizes created in future subdivisions are assumed to average 6 acres including open space and roadways. In Aquinnah, access sufficient to allow subdivision is a problem for many lots. For a low growth figure, existing lots under 10 acres are assumed to result in only one dwelling. An additional 129 dwellings are projected in Chilmark and 38 additional in Aquinnah. Total watershed buildout is projected at 540 primary dwelling units with a summer population of 2372 people.

The exact number of guest houses at buildout is difficult to estimate. Using the 3 acre requirement in Chilmark and 4 acres in Aquinnah for the minimum lot size, an additional 256 guest dwellings are possible.

125 guest dwellings are assumed for the higher growth scenario and 75 for the lower growth scenario. The guest dwellings population figure is assumed be equal to the year round household population. This adds 298 people under the high growth scenario for a peak summer watershed population of 3108 people.

Under the Low Growth projection, 179 guest house occupants in the 75 units bring the total summer peak population to an estimated 2551 people. In addition, there is a large seasonal visitor influx to Menemsha Pond and the Basin both on live aboard boats and to the public beach.

7.1.5 Squibnocket Pond Watershed

Land within the recharge area of the Pond occurs in the zoning district VI in Chilmark as modified by the Squibnocket Pond DCPC and, on the Aquinnah side, the Rural Residential District and, for the area along the Herring Creek, the Marine-Commercial District. The minimum lot size in all districts is 3 acres in Chilmark and 2 acres in Aquinnah. Due to the large drainage area of streams and wetlands that are connected to Squibnocket Pond, the Coastal District is extensive on the Aquinnah side.

A total of 292 lots were identified within the recharge area. One lot includes the 30 Tribal Housing Authority units. Of these, a total of 25 lots were so small or are access lots and another 14 lots are part of the Wampanoag Tribal lands and are not counted in either the vacant or built categories. Of the 292, 101 had a structure, 151 were vacant and 25 of those vacant lots are open space lots within a subdivision, owned by the Town or by a conservation agency. Five of these vacant lots are contiguous with a built lot and it is uncertain if all are buildable. The wastewater loading from the lands held by the Wampanoag Tribe (30 existing units) will be estimated based on the design flow of the sewage treatment facility as all units are either tied in or, in the case of the Tribal Headquarters building, use a no discharge system (composting toilets).

The vacant lots were examined to determine how many acres could potentially be subdivided within each zoning district. Lots identified are separated by Town in Table 21 below. Present day land use is mapped in Figure 27 (separate file) at the end of this Task.

TABLE 21 Existing Lots within the Recharge Area

Zoning District	# Lots Built	# Lots Now + Future	Acres Vacant	# Open Space Lots	Total Acres
Aquinnah	**76**	**287**	**375**	**13**	**865**
Chilmark	**25**	**63**	**260**	**12**	**395**
TOTALS	**101**	**350**	**635**	**25**	**1260**

Note the 101 built lots are on approximately 550 acres and the 25 open space lots include about 203 acres.

Potential Maximum Buildout:
The vacant lots and those larger lots with a dwelling point out the areas where future growth might occur. The larger lots within each Zoning District that are more likely candidates for subdivision in the future are summarized in Table 22 below. Some of these lots already have a dwelling while others do not.

An estimate of the potential number of new lots which could be built should these larger lots be subdivided at permissible zoning density was calculated. Ten percent of the lot area was subtracted for roads and wetlands for the Districts. The maximum number of new dwellings created by potential new subdivisions or from construction on existing lots is 249. Of these new dwellings, 9 units will be tied into the Tribal wastewater treatment facility.

Should development proceed as permitted by zoning we can expect a maximum number of primary dwellings in the recharge area of 350. This is the sum of existing dwellings (101) plus vacant lots and new lots from future subdivisions (249) as in Table 23. For nitrogen loading calculations, 39 of these units (30 existing and 9 projected) will be tied into the treatment facility.

The lowest expected future growth was developed as described for Menemsha Pond. This leads to an additional 131 dwellings in Aquinnah and 23 on the Chilmark side for a total of 255 dwellings at buildout. Of these, 39 will be tied into the Tribe's treatment facility.

Land Use in the Squibnocket Pond Watershed:

Present day and projected high growth scenario development is shown in Table 23.

Table 23 Projected Buildout Land Use

TOWN	#Lots Built	# New Projected	Total Future Lots	Acreage
Chilmark	25	38	63	395
Aquinnah	76	211	287	865
TOTALS	**101**	**249**	**350**	**1260**

The buildout number is based on the assumption that 10 percent of the lot area would be excluded from the acreage available to subdivide to account for roads, wetlands and open space. Pre-existing undersized lots are assumed to be buildable provided they meet health code requirements.

We estimate that, on the Chilmark side, there will be 48 seasonal dwellings and 15 year round dwellings at build out in the high growth scenario. The MVC Data report estimates 5.15 people per seasonal residence and the Census shows 2.27 people per year round residence on average in Chilmark. The projected high growth summer population in primary dwellings will be 281 on the Chilmark side.

In Aquinnah, census records indicate that 75.1 percent of the dwellings in Town are seasonal or 215 dwellings at build out and the rest (72) will be year round. The MVC Data Report provides a population estimate for the Town that indicates that there are 4.55 people per seasonal dwelling and the census indicates there are 2.45 per year round dwelling. The summer peak population on the Aquinnah side of the watershed at buildout is estimated at 1154 people. With the 281 projected for the Chilmark side of the watershed, the total population is 1435 people in primary units.

The lower growth scenario predicts 48 future dwellings on the Chilmark side and 207 on the Aquinnah side. Using the same seasonal-year round breakdown and occupants as above, the projected population in primary dwellings in summer is projected as 1044 people in the primary dwellings.

Within the Squibnocket Pond District, 6 acres are required for the construction of a guest house. This DCPC includes all of the watershed of the Pond within the Town of Chilmark. In Aquinnah, 4 acres are required for a guest house. The total number of lots that qualify for guest houses (before any subdivision of land) is 47. In both towns, the projected maximum number of lots that would qualify for guest houses after subdivision is 83. In season, they would hold an additional 114 to 201 residents at the average year round population figure for each guest dwelling. However, the maximum number of guest houses cannot occur if the highest growth scenario occurs because the lot sizes are smaller than the minimum required for guest houses in both towns. For this reason, the total projected watershed population is estimated to range between 1245 and 1549 residents during the summer peak.

7.1.6 Summary of Projected Watershed Population

The range of possible housing density and the expected peak population figures were derived in the preceding section. They are summarized in Table 24. The final buildout figure is unknown but will likely be within the range of figures defined by the low and high projections barring changes in zoning which either further limit growth or increase housing density. Further limits on growth in Chilmark are not likely to come from zoning changes as 3 acres is the limit beyond which the snob zoning issue becomes problematic. It is possible that Aquinnah might move to 3 acre zoning but this event is covered by the low growth projection.

Table 24 Summary Watershed Population Figures – Peak Season

Pond	Town	Main Dwelling # units in ( )	Guest Dwelling	*High Growth Total*	Low Growth Total
Menemsha	Chilmark	2383 (537)	95 (42)	*2482*	
	Aquinnah	423 (105)	203 (83)	*626*	
	Chilmark	2082 (468)	57 (25)		2139
	Aquinnah	290 (72)	122 (50)		412
	TOTAL			***3108***	**2551**
Squibnocket	Chilmark	281 (63)	39 (17)	*320*	
	Aquinnah	1154 (287)	162 (66)	*1316*	
	Chilmark	212 (48)	23 (10)		235
	Aquinnah	832 (207)	91 (37)		923
	TOTAL			***1636***	**1158**
Chilmark Pond	Chilmark	3997 (898)	454 (200)	*4451*	
	Chilmark	3379 (759)	227 (100)		3606
	TOTAL			***4451***	**3606**

NOTE: In addition, during the summer season there will be visitors adding to the short term population in year round homes. While not included here, these are estimated to equal the year round population figure for a 25 day period each year. As the time frame when the visitors arrive cannot be predicted, they are not included in this peak population estimate.

8.1: Nitrogen Loading Calculations – Introduction

Nitrogen is a naturally occurring gas in the atmosphere comprising some 78 percent of the air we breathe. As a gas, it is not soluble in water. It reaches water resources by conversion in the atmosphere to nitrate by lightning, by conversion from the air by nitrogen fixing bacteria and, once it is in vegetation, by way of the food chain waste cycle or by burning fossil fuels.

This means there are natural as well as man made sources of nitrogen which are soluble and can reach surface water resources. The sources which we have some control over include:

- acid rain
- fertilizers
- sewage effluent
- road runoff

Acid rain is a national level issue over which we, at the local level, can only exert influence by the legislative process. It can be a large percentage of the nitrogen load particularly for ponds with large surface areas to intercept the rainfall and small watersheds which may limit other sources such as septic systems.

This leaves sewage, runoff and both farm and landscape fertilizer application as the main focus of any effort to reduce the loading to our coastal ponds. In the sections which follow, loading from acid rain, sewage, runoff and from fertilizers are estimated to assemble a nitrogen loading estimate at buildout within the watershed. This figure is then compared with the nitrogen loading limit as estimated by the formula prepared by the Buzzard's Bay Program. This formula takes into account the characteristics of the water body including its area, depth and tidal flushing as well as the desired water quality goal for the water resource.

Nitrogen loading from all sources is summarized in Table 32 while methodology is discussed in detail in the sections which follow.

Phosphorus is also an important nutrient for the growth of phytoplankton and aquatic plants. Addition of phosphorus to a water resource, particularly fresh water, can stimulate excess plant growth. In coastal ponds, it is usually not the limiting nutrient. In addition, the methodology for determining appropriate phosphorus loading limits has not been developed for marine waters. For these reasons, phosphorus loading calculations are not emphasized here but are limited to Appendix B.

Task 8.2: Rainfall as a Source of Nitrogen Loading

Acid rain is a source of nitrogen to the recharge area and more importantly to the Ponds by direct precipitation on the surface of the pond. There is no high quality acid rain data available for the Vineyard specifically so we rely on the quality of rainfall being a regional phenomenon. The variables which are not calibrated for the Towns but rather for the region include: the volume of recharge and the amount of nitrogen in the recharge.

Precipitation and Recharge:

The average annual precipitation as recorded in Edgartown was 46.94 inches from 1951 to 1998 (New England Climatic Service- Climatological Summary). The portion of this rainfall reaching the water table is not precisely known but estimations made for the vicinity are listed in Table 25 below.

Table 25: Annual Recharge in Inches

Source	Location	Recharge
USGS, 1980	Vineyard	22.2
Leblanc, et al '86	Cape Cod west	22.2
Leblanc et al '86	Cape Cod east	18
Delaney et al '72	Truro	18.3
Leblanc 1982	Otis AFB	21
C. C.Comm '92	Falmouth	21

Note: A recharge rate of 28.7 inches is the accepted rate for outwash sand watersheds. This rate would increase the recharge from the outwash portion of the watershed only.

Using a figure of 22.2 inches of recharge per year in the Chilmark Ponds watershed (3173 acre recharge area) yields an annual average recharge of just over 1.9 billion gallons or 7.24 million cubic meters. This figure would approximate the annual discharge from the groundwater into the Pond. For Squibnocket Pond with its 1303 acre watershed, the figures are 0.8 billion gallons or 2.97 million cubic meters. The Menemsha Pond watershed (1856 acres) discharges 1.12 billion gallons or 4.24 million cubic meters.

Road runoff discharges into stream crossings that lead to the ponds. These streams include Mill Brook and Fulling Mill which flow into Chilmark Upper Pond, Black Brook and Witch Brook flowing into Squibnocket Pond and the Herring Creek which, depending on the tide will flow to Squibnocket or Menemsha Pond.

Nitrogen Content of Precipitation:

Acid rain contains nitrogen as inorganic and organic compounds. Rain falling on the uplands contributes some of its nitrogen content into the vegetative cycle and the portion reaching the groundwater is certainly less than that contained in the precipitation itself. The recharge water quality is modified by the decay and growth cycles that carry on in the soil. The source of nitrogen entering the groundwater from natural areas is probably a mix of acid rainfall and release from natural soil cycles.

One way to estimate the quantity of nitrogen entering the system as “background” concentration is to examine the quality of water in areas that are as yet undeveloped. Of 5559 groundwater samples analyzed by the Barnstable County Laboratory, twenty five percent contained less than 0.05 milligrams per liter of nitrate nitrogen. Many of the low concentration nitrate samples came from wells in undeveloped areas. This suggested that the rainfall nitrogen content and the organic cycle nitrogen was converted to nitrate and that this figure is the natural background level.

Rain falling directly on the Pond introduces all of its nitrogen into the nutrient cycle. The larger the pond, the greater the annual nitrogen load from acid rain. Large ponds with small watersheds will often have their nitrogen loading dominated by acid rain barring unusually large loads from other sources. Estimates of nitrogen concentration in rainfall vary widely as summarized in Table 26.

Table 26 Nitrogen Content of Rain in Milligrams/Liter

Reference	**Location**	**Form**	**Loading**
Gay &Melching '95	Mass	DIN	0.27
Risley et al '94	Quabbin	DIN	0.4
IEP 1987	Yarmouth	TN	0.74
Flipse et al 1984	Long Island	TN	0.87
Loehr, 1974	Lit. Review	TN	0.73 to 1.27
Howes et al 1995	Nantucket	DIN	0.46
Buttermilk Bay 1991	Wareham	DIN	0.3

DIN = Dissolved Inorganic Nitrogen TN = Total Nitrogen

Paerl (1993) discussed the importance of atmospheric nitrogen deposition to coastal eutrophication and estimated this source of nitrogen at 10 to 50 percent of the annual external nitrogen load. He reported a range of annual deposition for the eastern U. S. from North Carolina up to Maine at 25 to 37 millimoles per square meter per year. This translates to about 0.3 milligrams per liter of rain. This amounts to direct deposits on a 790 acre pond (Menemsha-Stonewall complex) of 1120 to 1658 kilograms per year.

Nixon et al (1995) cited a study which found annual nitrogen deposition into Narragansett Bay averaging 91 millimoles/m^2/year and ranging from 73 to 110 (about 0.87 to 1.31 milligrams per liter of rain). These figures include organic nitrogen as well as dry deposition of nitrogen gases and particulates. Using his lower end figures we get an annual deposition of 3270 kilograms per year on the Menemsha Pond complex.

Costa et al (1999) estimated annual deposition to Buzzard’s Bay at about 0.7 milligrams per liter (7.9 kilos per hectare) including wet and dry sources of inorganic nitrogen. This figure was derived from the National Atmospheric Deposition Programs figure for inorganic nitrogen (doubled to account for dry deposition). The National Atmospheric Deposition Program indicates an average annual deposition of inorganic nitrogen at Provincetown at 3.66 kilograms per hectare which translates to 0.31 milligrams per liter (assumed annual rainfall of 46.94 inches).

The inorganic portion of the nitrogen in rainfall is undoubtedly a source of this nutrient for phytoplankton. More complex sources of nitrogen such as organic molecules or particulates will require energy input from the environment or the organism to break down the source to more fundamental, readily usable forms of nitrogen. This takes time and these complex sources are more likely to exit the pond system or to be buried in the case of particulates before they have an impact on phytoplankton populations. Seitzinger and Sanders (1999) found that the biologically active portion of the dissolved organic nitrogen in rainwater was about 45 to 75 percent.

Selected Rainfall Loading:
For the low projection, I use an annual rainfall of 46.94 inches and concentration of 0.3 mg/l in rain falling directly on the ponds. I believe the more likely loading is that used for the high projection which is an acid rain content of 0.7 milligrams per liter. This figure is close to the figure used by the Buzzard's Bay Program and similar to Nixon's figure for dissolved inorganic and organic nitrogen. It is also close to what could be derived from the National Deposition Program if we assume that organic nitrogen in rain equals inorganic but that only 75 percent is biologically active.

Note the Massachusetts Estuaries Project has selected a nitrogen content of 1.06 milligrams per liter based on literature search for the area. This would result in a 50% increase in the annual load from precipitation shown in parentheses in Table 27.

The resulting total annual direct nitrogen loads are as in Table 27. If the recharging rain or natural cycle release load (so called background nitrogen) is added, the totals increase. These figures bracket the low end of Nixon's estimates, Paerl's figure and many of the references cited in Table 26 above. The higher figure being a more conservative one will be used in the final nitrogen loading estimates.

TABLE 27 Acid Rain Nitrogen Loading in kilograms

	Area Meters^2	Volume of rain	Concen. N in mg/l	Direct Fall Loading	Ground-water source	Total Hydro. Cycle Rain
Squibnocket	2415761	2809530	**0.3**	870	149	1019
			0.7	2030 (3045)	149	2179 (3194)
Menemsha	3176413	3694168	**0.3**	1142	211	1353
			0.7	2665 (3998)	211	2876 (4209)
Chilmark Ponds	723166	841042	**0.3**	252	362	614
			0.7	589 (884)	362	951 (1246)

Task 8.3 : Projected Nutrients from On-Lot Wastewater:

Nitrogen is the most mobile nutrient that is expected to be introduced from recharge area development. A literature review indicates that nitrogen concentration in raw sewage ranges from 20 to 100 mg/l (milligrams per liter). In a properly functioning system, 30 to 60 percent of this nitrogen is removed (Andreoli et al, 1979). Table 28, modified from The Buttermilk Bay Project (Horsley, Witten, Hegemann, Inc. 1991) indicates the range of nitrogen concentrations in the leaching area or in the groundwater immediately below the leach area.

Table 28   Total Nitrogen Concentrations in Leaching Field Effluent **mg/l milligrams/liter**

SOURCE	Concentration mg/l		SOURCE	mg/l
Bouma et al 1972	30		Ellis 1982	34
Walker et al 1973	40		Canter &Knox 1986	40
Dudley & Stevenson'73	14		Nelson et al 1988	34
Magdoff 1974	31		Andreoli et al 1979	38.2
Magdoff 1974	41		SuffolkCty.Health '83	34.7
Reneau 1977	23			
Brown & Assoc. 1980	37		**Average**	**33.1**

Kroeger (1998) estimated that 66 percent of the nitrogen in wastewater was removed by the septic system, the soils and while in transit to Green Pond, Cape Cod. This estimate was based on groundwater sampling compared to loading estimates within the recharge areas. Applied to our range of 20 to 100 milligrams per liter in the original wastewater, we arrive at a range of 7 to 34 milligrams per liter for the pond loading calculation. Note that the MEP has selected 35 milligrams per liter with a 25% attenuation leading to a loading to the pond of 26.25 milligrams per liter.

Flow through a fringing marsh such as occurs around a large portion of the north shore of the Lower Chilmark Pond may be a major sink (removal) for nitrogen in groundwater. Portnoy et al (1998) found that this potential was circumvented by high velocity seeps which carried a large portion of the total groundwater seepage. Without documentation by thermal infrared aerial survey to determine where the groundwater seeps are in the Chilmark Ponds, a conservative approach is suggested. Both Menemsha and Squibnocket Ponds have extensive wetlands within their watersheds which may also remove nitrogen from groundwater en route to the pond. However, the presence of fringing marshes around these two ponds is highly variable. For example, there is very little marsh along the west side of Menemsha Pond but substantial amounts around Nashaquitsa and along parts of the east side. Because of this variability and the potential for nitrogen in groundwater to bypass the marsh sediment as seeps, no removal of wastewater and fertilizer nitrogen is assumed to occur in the fringing marsh.

The Buttermilk Bay Project selected a value of 40 mg/l as a conservative yet defensible value. For our calculations, I have selected a value of 35 mg/l as the nitrogen concentration in wastewater effluent reaching the groundwater from septic systems. This figure is intended to characterize the wastewater after any plant uptake in the leaching field and evaporative losses occur. The volume of wastewater in which this concentration of nitrogen is found determines the total load going to the system on an annual basis. We have selected a daily per capita water use of 60 gallons and a 20 percent evaporation loss figure to arrive at 48 gallons (181.7 liters) per capita per day infiltrating from the septic leaching system. Evaporation actually acts to concentrate the nitrogen in the remaining liquid effluent so the assumed effluent concentration leaving the leaching pipe is somewhat lower than 35 mg/l.

This assumption of 35 milligrams per liter and 48 gallons per person per day yields an annual per person nitrogen release that is very close to 2.32 kilograms per person per year. This figure is at the low end of a range of estimates that extends up to 4.24 kilograms (EPA, 1997). **This figure provides a per capita nitrogen load estimate from the on lot sewage source that is toward the low end of the range of figures used.**

<u>Population Estimates: MVC Data Report</u>

Population estimates within each watershed are derived in Sections 7.1.3, 7.1.4 and 7.1.5. These estimates are based on the occupation figures from the Census (year round rates) and from the MV Commissions Data Report (summer rates). For purposes of summarizing, the Census indicates an average of 2.27 people per year round dwelling in Chilmark and 2.45 people per dwelling in Aquinnah. The MVC Data Report indicates there are 5.15 people per summer dwelling in Chilmark and 4.55 people per summer dwelling in Aquinnah.

The number of people in the watershed and the number of days in residence will determine the annual nitrogen load from wastewater. For this purpose, we assume that, in seasonal homes, the summer occupation rates apply for a 75 day season which is followed by 30 days of occupation at the year round rate. The 30 days are meant to account for the increasing use of summer houses in the shoulder seasons. The year round dwellings are assumed to hold the number of people indicated by the Census for 365 days. In addition, we assume that there are visitors in year round dwellings equal to the year round Census figure for 25 days per year per dwelling. In other words, for 25 days of the year the population in a year round dwelling is twice what the Census indicates. Guest houses (both seasonal use and year round use) are presumed to house the Census figure population for the Town where they are situated.

<u>Other Household Population Estimates:</u>

A study of the Tisbury Great Pond Watershed (Saunders Associates, 1989) estimated summer house occupancy at 6 people per dwelling. A survey in Oak Bluffs (Planning Board Master Plan Survey) with over 400 responses found an average of 4.77 people per dwelling in the **seasonal** dwellings. The demographics in Oak Bluffs, with 88 percent of the homes in Town seasonally occupied, are different than Chilmark, however this number is a hard number which falls between the 4.55 and 5.15 estimates. It seems likely that seasonal dwellings would house a greater number of residents than year round dwellings over the course of a summer season.

Averaging the total summer population across all houses, the Tisbury Great Pond study indicates an average of 4.42. In Yarmouth, IEP (1988) figures averaged about 3.0 people per residence during summer based on 2.73 bedrooms per dwelling. With Yarmouth's estimated 5 percent seasonal dwellings, this lower number makes sense. On Nantucket, Howes et al (1997) used figures which imply an average summer occupation rate of 2.68 people per dwelling.

Projected Growth and Resulting Nitrogen Loads From Septic Systems:
Projections are made for low and high growth scenarios. The actual buildout land use remains to be seen and the caveat found at the end of this Section must be taken into account.

As calculated in Table 16 of Task 7.1, the expected maximum number of primary dwellings permitted under zoning in the recharge area of the Chilmark Ponds is 898. In addition, there is a potential for a large number of guest dwellings in the watershed. For purposes of nitrogen loading calculations, we assume that the maximum number of guest dwellings will be 200. It is assumed that 75.7 percent (151) of these are occupied seasonally and the rest on a year round basis. All guest dwellings will be occupied at the year round rate. The Low Growth Scenario assumes there will be 759 primary dwellings and 100 guest houses (76 seasonal and 24 year round).

In the Menemsha watershed, Table 18 projects 642 primary dwellings and 125 guest houses at maximum growth. The Low Growth projection is for 540 primary dwellings and 75 guest dwellings. The same seasonal and year round breakdown of guest houses is applied as was used for Chilmark Pond. In Aquinnah the guest house breakdown is based on 75.1 percent of all dwellings in Town being seasonal housing with residents equal to the Census figure for year round dwellings (2.45 people on average).

In the Squibnocket Pond watershed, the High Growth projection is for 350 primary dwellings (Table 21) and 83 guest dwellings. The Low Growth projection is for 255 primary dwelling units and 47 guest houses. For nitrogen loading calculations, at buildout, 39 of these units will be connected to the Tribal wastewater treatment facility and their nitrogen loading will be processed through the plant. Guest house projections are based on a requirement for 6 acres minimum on the Chilmark side of the Pond and, on the Aquinnah side, 4 acres minimum.

Assumptions include:

- 75.7 % of houses in Chilmark are summer only with 5.15 people for 75 days and 24.3 % are year round with 2.27 people for 365 days
- 75.1 % of the houses in Aquinnah are seasonal with 4.55 people on average and 24.9 % are year round with 2.45 people on average

- The same percentages of the total guest houses are occupied year round at the Census figure for 365 days. Seasonal guest houses are occupied by the Census figure for 75 days
- summer primary houses are occupied with 2.27 people in Chilmark and 2.45 people in Aquinnah for 30 days during the shoulder season
- year round primary houses have 2.27 guests for 25 days in summer

Present Day Sewage Flow and Nitrogen Load From Septic Systems
By multiplying the number of people by the number of days in occupation by sewage flow per capita (48 GPD) a total effluent volume in gallons per year is calculated as follows:

Pond	Growth Scenario	Flow (gallons/year)	Load (kg/yr.
Chilmark Pond	High	27.28 million	3613 (2710[1])
	Low	21.93 million	2906 (2179[1])
Menemsha	High	19.29 " "	2690*(1917[1])
	Low	15.71 " "	2216*(1561[1])
Squibnocket	High	9.62 " "	1440**(956[1])
	Low	6.51 " "	980** (647[1])

* Includes 134 kilograms from Menemsha Village sources
** Includes load from Tribal Wastewater Treatment Plant
1 Loads calculated based on a final attenuated nitrogen concentration of 26.25 milligrams per liter

These loading figures differ slightly from those in the Table 32 spreadsheet because these take into account the varying household populations in the two towns. The spreadsheet figures are modified to reflect the sewage loading figures above.

The nitrogen concentration in the effluent from the septic systems is estimated at 35 milligrams per liter. With advanced nitrogen systems, this loading can nearly be cut in half by producing an effluent with about 19 milligrams of nitrogen per liter.

Menemsha Village includes two substantial sources of nitrogen loading that would exceed the formula for residential nitrogen loading. These include a 130 seat restaurant open about 5 months per year and public restrooms and showers. There are also several take out snack bars which do not offer restroom facilities. Total annual nitrogen loading from the restaurant is estimated at 109 kilograms based on 35 gallons per day per seat wastewater flow. The snack bar sources are estimated to add another 11 kilograms. Total annual nitrogen loading from these "concentrated" sources is 120 kilograms.

Public shower usage data was provided by the Chilmark Board of Health. The receipts imply 5000 minutes of use during the 1999 summer and 11290 minutes in summer 2000. At 3 gallons per minute, the annual water use is estimated at 15,000 to 35,000 gallons per year for showers. Most (83 to 88%) of the shower use occurred in July and August and averaged an estimated 500 gallons per day during the summer of 2000. The restroom facilities include six toilets. Menemsha Village has a popular public beach and is a picturesque harbor drawing large numbers of visitors during the peak season. I estimate during the peak 60 day season, an average daily use from the toilets of 1000 gallons per day. Total annual flow is estimated at 1500 gallons per day for 60 days, 750 gallons per day for another 60 days and 250 gallons per day for 60 days. Total nitrogen loading at a wastewater concentration of 25 milligrams per liter is 14 kilograms per year.

Table 32 tabulates the projected wastewater flow based on the occupation rates and sewage flow per capita as described above. The calculation for Squibnocket Pond includes the loading from the Wampanoag Tribe's wastewater facility. This treatment plant is a Rotating Biological Contact (RBC) system with an anoxic unit with methanol added to remove nitrogen. The facility is designed for a maximum daily flow of 16000 gallons. From September 1998 through August 1999, the plant averaged 2700 gallons per day with a range from 1536 to 5460 gallons per day. The plant has a consistent record of excellent nitrogen removal. The average Total Nitrogen concentration for the 1999 calendar year was 3.31 milligrams per liter.

The Low Growth Scenario assumes effluent flow at the facility at current levels of about 1 million gallons per year adding 12 kilograms of nitrogen per year to the system. The High Growth Scenario projects an increase in sewage flow to the design capacity of the plant or 5.84 million gallons per year adding 73 kilograms of nitrogen per year. The nitrogen concentrations in the treated sewage effluent and the resulting loading to the pond are assumed to reflect current treatment levels. Even if the high loading were doubled, the loading would still be less than 10 percent of the total nitrogen loading from other man made sources in the watershed.

Demographics Caveat:

One of the fundamentals to these projections is the assumption that the current seasonal and year round proportions of the population will remain constant. Year round homes clearly produce larger amounts of nitrogen by about a factor of two. If, due to the aging of the population or the ability to conduct work via the Internet, greater numbers of people take up residence on a year round or even a three-season basis, then the projected nitrogen loading could increase dramatically. For these reasons, although loading from the Low Projection is seen as the most likely scenario, the High Growth Scenario should be considered as a real potential in making decisions about reducing future loading if necessary.

If occupation moves to year round use, nitrogen loading from sewage effluent will increase by about 50 percent over the High Growth estimate.

TASK 8.4 : Nutrients from Lawn and Farm Fertilizers

Lawns:

Standard recommendations for lawn fertilizer are 3 pounds (1.36 kilos) of actual nitrogen per 1000 square feet per year. Standard assumptions for nitrogen loading use 6500 square feet of lawn area per lot to estimate nitrogen from this source. Horsley et al (1991) reviewed the literature on nitrogen fertilizer lost via leaching from turf and reported a range from zero to 81 percent of the applied nitrogen. They selected a loss rate of 30 percent for the Buttermilk Bay Project. The actual amount leached depends on the type of fertilizer used (quick release versus timed release), the quantity applied and the irrigation practices or rainfall events that occur after the fertilizer is applied. A leaching loss rate of 25 percent was selected as a conservative figure for this study.

In Edgartown, a total of 34 lawns were examined on lots situated away from the shore. Lawn condition and expected fertilizer application breakdown for these lawns is detailed in Table 29. Average lawn size surveyed was only 2700 square feet. These low application rate figures are used to estimate the lowest expected input from turf in the watersheds of all three ponds.

TABLE 29 LAWN SIZE & PROBABLE FERTILIZER APPLICATION RATES—As in Edgartown Great Pond Watershed

CONDITION	#/1000 sq. ft.	%	Kg. of N
Good	3	8.8	1.36
Ave. +	5	14.7	0.91
Ave.	6	17.6	0.45
Poor	13	38.2	0
None	7	20.6	0

A similar examination of the lawns in the Chilmark Pond watershed was made using aerial photography both black and white and infrared. Of 145 lots examined in the Chilmark Pond watershed, 46 (32 percent) showed signs of being fertilized at regular intervals. The maintained area found for the fertilized lawns was substantially larger than found in Edgartown, averaging 16000 square feet. Lawns of this size and estimated condition are estimated to receive 2 pounds of nitrogen per 1000 square feet for a total of 32 pounds total for the average lawn.

Another 43 or 30 percent, may receive irregular fertilization. These lawn areas average nearly 22000 square feet. For purposes of estimating nitrogen loading, I assume an annual application of 1 pound of nitrogen per 1000 square feet to **half** of the area or 11000 square feet and no treatment for the remaining 11000 square feet. The remaining 56 of the lots examined (39 percent) are probably mowed but not fertilized. No nitrogen loading is assumed from these fields.

Future Lawn Loads:

At build out the additional lawns will add proportionally more nitrogen to the system. Table 30 summarizes the applied totals when 32 percent of the total dwellings have 16000 square feet of turf receiving 2 pounds of nitrogen per 1000 square feet. The turf area estimated to receive 1 pound of nitrogen per year is 30 percent of the total houses with an average turf area of 11000 square feet. The remaining 38 percent of dwellings have minimal lawns or turf that is not fertilized. Of the total application, 25 percent is assumed to reach the groundwater.

Table 30 Estimated Annual Nitrogen Applications to Lawns - *pounds*

Pond	Tot. D.U.	# of treated lawn @2#/year	Tot. N Applied	# of treated lawns @1#/year	Tot. N Applied	Tot. N to all lawns
Chilmark Pond Low	759	240	7680	225	2475	10155
High	898	285	9120	266	2926	12046
Menemsha Low	540	171	5472	160	1764	7236
High	642	203	6496	190	2090	8586
Squibnocket Low	255	80	2560	73	803	3363
High	350	107	3424	100	1100	4524

CHP= Chilmark Pond watershed MEN= Menemsha Pond Watershed SQB= Squibnocket Pond Watershed

Chilmark Pond Watershed: Under the low growth scenario there will be a total 759 residences of which 100 will be large enough to have a guest house. The annual loading at 25 percent of the total applied is 2539 pounds or 1151 kilograms of nitrogen.

Under the high growth scenario, a total of 898 dwellings will produce an annual nitrogen application of 12046 pounds of which 3012 pounds or 1366 kilograms will reach the groundwater.

Menemsha Pond: Under the low growth scenario there will be a total 540 residences. The projected nitrogen load will be 1809 pounds or 820 kilos to the groundwater.

Under the high growth scenario with 642 residences, a total load of 2147 pounds or 973 kilos will be released to the groundwater.

Squibnocket Pond Watershed: Under the low growth scenario there will be a total 255 residences. The projected nitrogen load will be 841 pounds or 381 kilos to the groundwater. Under the high growth loading from 350 residences will yield an annual total of 1131 pounds or 513 kilograms of nitrogen to the groundwater.

There is a considerable uncertainty in these projected figures but they present an incentive to encourage homeowners to reduce the scale of the manicured lawn and take advantage of the many low maintenance grasses that are currently available. ***On the other hand, should aesthetic practices change toward a more "mainland" approach to landscaping, lawns could become a significant loading factor.*** Application of nitrogen at recommended rates could double the total nitrogen loading from lawns.

Farms:

Farms currently comprise approximately 145 acres in the watershed of Chilmark Pond. There are no active farms found in the other watersheds. Of the total around Chilmark Pond, approximately 6 acres are in row crops, 134 acres in hay/pasture and 6 acres fallow (see Table 31). Recommended annual agronomic nitrogen application rates are 18 kilograms per acre for grass hay and pasture and up to 68 kilograms (150 pounds) per acre for row crops. Legume hay should not receive any nitrogen while the legumes are 40 percent or more of the crop. Nitrogen fertilizer leaching losses for hayland should exceed those seen on lawns as the fertilizer is not slow release and often is applied in one application. Losses are assumed to be 33 percent for hay and pasture for these reasons.

Table 31
Farms Within the Chilmark Pond Watershed

Farm Locus	Size (acres)	Type	Watershed
CH State Road/ Fenner	3.5	Livestock/pasture	LOWER
CH Quansoo Rd./Hancock	5.5	Fallow	LOWER
CH Meetinghouse @State	1.5	Livestock/pasture	LOWER
CH State Rd./Allen Farm	40	Livestock Pasture	UPPER
CH State Rd./Allen Farm	10	Pasture	UPPER
CH State Rd./Allen Farm	10	Hay/pasture	UPPER
CH Tabor House/Flanders	25	Livestock/Pasture	UPPER
CH Middle Rd.	25	Hay/pasture	UPPER
CH South Rd. near Gude	3	Hay	UPPER
CH Middle Rd./Scott	6	Organic Veg	UPPER
CH Menemsha Cross/Thorpe	4	Livestock/Pasture	UPPER
CH N. Road/Flanders Bliss	12	Hay/Pasture	UPPER

Fertilizers applied to row crops are typically not slow release and are applied to tilled ground presenting greater opportunity for leaching losses than from grassland. Best uptake of nitrogen occurs with regular side dressing which is commonly practiced. For these reasons a 40 percent leaching loss is assumed for row crop acreage for conventional fertilization.

The total acreage devoted to row crops in the Chilmark Pond watershed is 6 acres. These crops are managed as an uncertified organic crop. While, nitrogen can be over applied and become a threat to groundwater from organic operations too, the sources of nitrogen tend to be slow release which will maximize the potential for nitrogen to be taken up by the crops. Organic row crops receive nitrogen in a form where microbial breakdown is required to release 50 percent or more of the applied nitrogen. This requirement releases some of the nitrogen a year or more after the application is made. Over time, when annual applications are made, the accumulated slow release nitrogen can build up and cause nitrogen loss to the groundwater. Despite this potential, the leaching loss from organically fertilized row crops is assumed to average 25 percent instead of 40 percent.

The total acreage in hay is 50 all within the Chilmark Pond watershed. Of this total, the 10 acres at the Allen Farm are infrequently fertilized through an organic program as an adjunct to nitrogen fixing legumes in the crop.

Often pastures receive minimal fertilizer applications and the droppings from the animals may be used to supplement or replace chemical fertilizer applications. For purposes of developing a **low loading estimate**:

- It is assumed that recommended pasture fertilizer applications are applied to only about half the acreage. Total **pasture** land is estimated at 84 acres. The recommended annual nitrogen application to hay and pasture is 40 pounds of nitrogen per acre. If 45 acres are fertilized, then 1800 pounds of nitrogen are applied annually with 450 leaching to the groundwater.

- It is further assumed that about 75 percent of the **hay/pasture** is in legume hay and receives no nitrogen. I assume that 15 acres are conventionally fertilized with 40 pounds of nitrogen applied per year. The total annual nitrogen application is 600 pounds with 150 pounds reaching the groundwater.

- Finally, I assume that the **row crops** average 34.1 kilograms (75 pounds) per acre. On the 6 acres, an annual application of 450 pounds is expected with 25 percent lost (organic production) to the groundwater or 113 pounds.

The total annual nitrogen loading to the Chilmark Pond system from agricultural operations is estimated at 713 pounds or 323 kilograms.

For the **high loading scenario**, total leaching loss of nitrogen is based on the recommended agronomic application rates.

- I assume that about half of the hay is in legume at any one time and receives no nitrogen. The 25 acres that are fertilized would receive 1000 pounds applied nitrogen per year and 250 pounds would leach into the groundwater.
- All pasture land is assumed to receive recommended applications. This figure is 84 acres of land receiving 3360 pounds of nitrogen per year. Leaching losses (840 pounds) are as outlined above.

- Using the application rates (68 kilograms on row crops) and assumptions outlined above, an estimated 900 pounds are applied annually of which 225 pounds or 102 kilograms per year is lost to the groundwater.

The total annual nitrogen loading under the high loading scenario from farms is 1315 pounds or 596 kilograms.

Both lawns and farms have a large potential variation in their contribution to the nitrogen loading from the recharge area. This presents both an opportunity and a concern that they could substantially increase. Limitations to the lawn source is difficult if not impossible to enforce and requires on-going effort to shape the public perception of what is acceptable and appropriate. This effort should be directed at both minimizing the size of managed lawn and the selection of appropriate water insoluble (slow release) nitrogen fertilizers. The area in native meadow is not a nitrogen loading issue and should be encouraged as a means for developing open vistas without nutrient loading impacts.

Farming operations are designed to make the operator's income as opposed to the aesthetics of having a large lawn. Management practices can be shaped by what has potential to reduce input costs. Possibilities include the use of nitrogen soil testing prior to side dressing the crop as a means to reduce applied nitrogen. This approach has been shown to reduce average nitrogen applications by about 25 percent for sweet corn. A source of safe, well prepared compost at reasonable prices would also allow reductions in applied fertilizers. As soil quality improves, better retention of applied synthetic fertilizers should follow.

TABLE 32					October 2000			no3tot.wk4											
Nitrogen Loading: Aquinnah & Chilmark Pond						YEAR ROUND			SEASONAL			Septic		Lawns	Acid Rain	Runoff	Farmland	Total	Corrected
Watershed	Type of D.U.	# Dwellings	People/du	Flow/person	#Units Yr. rnd.	Flow Total	Flow	# Units Seas.	Flow/pers	Flow Total	Flow	Total N/yr						Loading	Load*
HIGH INPUT SCENARIOS						Gal/yr.	Liters/yr.			Gal/yr.	Liters/yr.		kilos	kilos	kilos	kilos	kilos	kilos	
Chilmark Pond	Max Prime Unit	898	5.15	48	218	8669947.2	32859099.89					1408570131							
			2.27	48	0	0	0	680	48	14829984	56205639.36								
	Max Guest	200	2.27	48	49	1948749.6	7385760.984	151	48	1233972	4676753.88	2130883763							
'TOTALS		1098			267	10618696.8	40244860.87	831		16063956	60882393.24	3539453894	3539.454	1366	951	24.1	596	6476.554	6551
Menemsha	Max Prime Unit	642	5.15	48	157	6243952.8	23664581.11					991802189.3							
			2.27	48	0	0	0	485	48	10577268	40087845.72								
	Max Guest	125	2.27	48	31	1232882.4	4672624.296	94	48	768168	2911356.72	1504972085							
'TOTALS		767			188	7476835.2	28337205.41	579		11345436	42999202.44	2496774275	2630.774	973	2876	10.4	0	6490.174	6549
	Village Loading												134						
Squibnocket	Max Prime Unit	311	5.15	48	77	3062320.8	11606195.83					511727725.3							
			2.27	48	0	0	0	234	48	5103259.2	19341352.37								
	Max Guest	83	2.27	48	20	795408	3014596.32	63	48	514836	1951228.44	745240328.3							
	Total Units	433			97	3857728.8	14620792.15	297		5618095.2	21292580.81	1256968054	1330.008	513	2179	19.1	0	4041.108	4059
	Tribal Wastewa	39				5840000	22133600						73.04						
		Design Flow @ 16000 GPD																	
LOW INPUT SCENARIOS																			
Chilmark Pond	Max Prime Unit	759	5.15	48	184	7317753.6	27734286.14					1097313060							
			2.27	48	0	0	0	575	48	12540060	47526827.4								
	Max Guest	100	2.27	48	24	954489.6	3617515.584	76	48	621072	2353862.88	1745824160							
TOTALS		859			208	8272243.2	31351801.73	651		13161132	49880690.28	2843137220	2843.137	1151	614	24.1	323	4955.237	5015
Menemsha	Max Prime Unit	540	5.15	48	135	5369004	20348525.16					807158164.7							
			2.27	48	0	0	0	405	48	8832564	33475417.56								
	Max Guest	75	2.27	48	18	715867.2	2713136.688	57	48	465804	1765397.16	1233428515							
'TOTALS		615			153	6084871.2	23061661.85	462		9298368	35240814.72	2040586680	2174.587	820	1353	10.4	0	4357.987	4405
	Village Loading												134						
Squibnocket	Max Prime Unit	216	5.15	48	54	2147601.6	8139410.064					342910331.4							
			2.27	48	0	0	0	162	48	3533025.6	13390167.02								
	Max Guest	47	2.27	48	11	437474.4	1658027.976	36	48	294192	1114987.68	507680414.6							
TOTALS		302			65	2585076	9797438.04	198		3827217.6	14505154.7	850590746	863.8207	381	1019	19.1	0	2282.921	2295
	Tribal Wastewa	39				981980	3721704.2						13.23						
		Note: Visitors to year round dwellings (assumed to be equal to the year round resident population for 25 days)									and breakdown of population figures for Aquinnah				versus Chilmark				
			are included in the spreadsheet as Corrected Load. Figures quoted in text include this number.																

Task 9.1: Nutrient Reduction Techniques and Feasibility

This project has identified four sources of nitrogen within the recharge area of the Great Pond. These sources include acid rain, on-lot sewage disposal, road runoff and crop fertilization- both lawns and agricultural crops. At the present time, the Chilmark landfill is not considered as a likely contributor to Chilmark Pond and, in fact, is probably in the watershed of the Tiasquam system flowing to Tisbury Great Pond. The Aquinnah landfill is a small source situated in the Squibnocket Pond watershed. As both are in process of being capped (completed in the case of Aquinnah), they will be greatly reduced as future sources and are not considered as a part of the projected loading to these ponds. In addition to these external sources, there is an as yet undetermined but substantial cycling of nutrients from the bottom deposits into the pond waters.

The sources of nitrogen at buildout are summarized in Table 32. Present day estimates of nitrogen loading are summarized below in Table 33. A comparison of the present day loading to the projected **high** growth loading indicates an increase of 75 percent to Chilmark Pond, 56 percent to Squibnocket Pond and 34 percent to Menemsha Pond. For Chilmark Pond, the loading rates resulting from wetland attenuation are estimated and highlighted. Approximately 64% of the residences and 92% of the farms are in the Upper Pond watershed where 50% attenuation may occur. The resulting overall attenuated nitrogen load is 26% less than the unattenuated load. Similar reductions are likely to occur in the Squibnocket and Menemsha watersheds.

Table 33 Estimated Nitrogen Loading Breakdown in Kilograms—Current

POND	Septic	Acid Rain	Lawns	Farms	Runoff	TOTAL
Chilmark	1517	951	671	556	24	**3719**
attenuated	1031		456	301		**2763**
Menemsha	1424 *	2876	573	0	10	**4883**
Squibnocket	255**	2179	144	0	19	**2597**

***Includes loading from restaurant and public restrooms in Menemsha Village**
****Includes Tribal Wastewater Treatment Facility**

ATMOSPHERIC SOURCES:

Acid Rain Nitrogen: A Substantial Source with Little Potential for *Local* Change

Acid rain, as it is both an interstate as well as an in-state problem is best addressed on the national level through the reduction of stack emissions and auto exhaust. On the Vineyard, air pollution is occasionally evident through injury of such sensitive crops as white pine and green beans. In most instances this results from intact low quality air parcels reaching the Island from sources in New York, New Jersey and the Ohio valley. Certainly we should lend our support to the continued improvement in auto exhaust standards and to the upgrading of industrial air pollution sources. Due to the early stage of build out in all watersheds and the large portion of open land in the recharge area, atmospheric sources are a large percent of current total nitrogen loading, particularly for ponds with large surface areas. The total loading from acid rain varies with the size of the pond because the vast majority of the nitrogen in the annual 46.9 inches of rain is added by direct rainfall to the ponds. So a large pond like Menemsha Pond has an annual loading between 1353 and 2876 kilograms per year while a small pond like Chilmark ranges from 614 to 951 kilograms. A large pond like Squibnocket Pond with a small watershed may have a nitrogen load that is dominated by acid rain unless there is another unusually large source in the watershed.

The derivation of these figures is detailed in Task 8. Acid rain **and** the deposition of pollutant particulates (dry deposition) will contribute between 12 and 15 percent of the projected nitrogen loading to Chilmark Pond at build out (See Task 7). For Menemsha Pond, the percentage ranges from 31 to 44 percent. Acid rain will deliver between 44 and 54 percent of the nitrogen loading to Squibnocket Pond at build out. There is some hope that this source will be reduced over time with increased smokestack and auto exhaust regulatory activities.

LAND SIDE SOURCES:

Landscape Nitrogen: A Limited Source Today but Possibly a Moderate Source in the Future without Public Education and Cooperation

The typical practices associated with suburban lawn care are surprisingly limited within the watershed. Lawns are large in area in the Chilmark Pond watershed (average of 16000 square feet). However, most of the larger turf areas are probably maintained with a minimal level of fertilization. Lawns are projected to make up 10 to 25 percent of the future loading for all ponds. The standards used in the Commonwealth's Computer Model (Version 1.0) are 5000 square feet and three pounds of actual nitrogen applied per 1000 square feet of lawn. At this time, lawns in the recharge areas are probably much less fertilized than the model. It is possible that further reductions in treatment level can be obtained. The size of the grassed area is not important unless it is fertilized.

The focus should be directed toward public education on appropriate selection of fertilizers with water insoluble nitrogen (slow release) to minimize leaching losses. In addition, the benefits of the use of naturalized landscaping should be heavily stressed. Savings of time, money and environmental impact can be gained where native grasses and shrubs are used to augment the property's grounds without a large, maintenance demanding lawn and extensive plantings. The public should be encouraged to compost their kitchen wastes and garbage disposals should not be allowed as they only add to the nitrogen output of septic systems. Use of wood chip ground cover will actually absorb nitrogen in the breakdown of the wood cellulose. Appropriate sources of this information include the Martha's Vineyard Garden Club and the UMass Extension.

In addition, the size of the actively managed landscape could be limited throughout the pond recharge area as it is for the Squibnocket Ponds District. While difficult to enforce, it does serve an educational purpose at a minimum and, for most of the public, will be sufficient guidance to limit the size of their managed landscapes. A suggested target of 2500 to 3000 square feet of fertilized turf is appropriate. This should **not** restrict the area seeded to native grasses, forbs, naturalized wildflowers and low shrubs which would not be fertilized or treated with any pesticides. In fact, these native plantings should be encouraged through public education. If we can hold the line against conversion of lawns to the scale and fertilization practices implied in the Commonwealth's Model, it will be an important limitation of future nitrogen loading.

Actions Suggested:

- *Develop guidance for low maintenance landscaping to be handed out with building permits, conservation commission decisions and planning board approvals.*
- *Consider restricting managed turf in the Squibnocket Pond District.*

Farm Nitrogen: A Limited Source Today with Potential for Some Reduction

Farm fertilizers are a smaller source of nitrogen within the recharge area for the Chilmark Pond watershed only ranging from 6 to 9 percent of the projected nitrogen loading. Today, the primary crops which are regularly fertilized are pasture and hay land. Traditionally pasture is not frequently fertilized.

Common agronomic recommendations call for no nitrogen application for fields (pasture and hay) containing one third or more legume. This is recommended because the legume fixes nitrogen from the air and applied nitrogen only increases the growth of grasses which run out the legumes. This practice is widely known and followed by local farmers. Continued provision of current information relating to this practice by both the Natural Resource Conservation Service (NRCS) and UMass Extension are necessary to keep this practice in place. This is a no-cost source of nitrogen reduction.

Application of nitrogen based on soil test is the easiest way to reduce nitrogen applications to row crops. Savings will vary from farm to farm depending on soil organic matter content and past fertilization practices. Soil nitrogen tests are available at the UMass Soil Lab with interpretation and recommendation from Regional Vegetable Specialists. While row crops are not a substantial acreage, this approach is not widely followed at this time and should be encouraged. It is estimated that a 25 percent reduction in applied nitrogen can be gained on row crops where this practice is followed. The cost of the soil test and time to collect the sample is typically more than offset by savings of fertilizer. This testing program is most suited to row crops and will only have a minor application in the watershed.

The use of split applications of fertilizers allows less leaching loss by providing the nitrogen as it is needed instead of all being applied at planting. This practice is widely followed. While this practice takes time, it is also a potential money saver for farmers and should be encouraged both on that basis and as an environmental benefit.

Use of organic matter as a soil amendment and a source of nitrogen has limited potential for further application in the recharge area as the primary crops grown are grasses and legumes rather than row crops. Beetlebung Farm prepares a compost pile annually. This material is applied to fields farmed within the recharge area. Organic matter is a slow release source of limited amounts of nitrogen. The NRCS calculates that approximately

50 percent of the nitrogen in applied manure is available to the crop the first year. The second year, 50 percent of the remaining nitrogen is available and so on in an exponentially decreasing curve. The nitrogen in applied compost is probably available in a similar fashion. Soil testing on an annual basis will credit nitrogen in the organic matter fraction and so reduce the applied fertilizer. Composting has great potential to be increased through private enterprise or by the Refuse District to develop a composting program to bring in organic matter from a larger area and make the product available to farms and landscapers on a low cost basis.

Actions Suggested:

- *Farms which border streams draining to the pond or the pond itself should inspect the edges of these waters to assure that direct runoff is diverted into heavily vegetated buffers for filtration and removal of soil particles, manure and nutrients.*
- *Riparian buffers should be maintained along the edges of fields bordering water resources unless a limited area for watering stock is required.*
- *Limits on livestock access to Chilmark Pond and streams draining to it are suggested. Natural Resource Conservation Service is appropriate to assist.*

On Lot Septic System Nitrogen: The *Largest* Man Made Source Today and Tomorrow with Potential for Large Reductions Septic system leachate makes up the greatest projected source of locally generated nitrogen in the recharge area by far comprising 35 to 60 percent of the future loading. The projected percentages are:

- Chilmark Pond—54 to 57 percent
- Menemsha Pond—40 to 49 percent
- Squibnocket Pond—33 to 38 percent

In our calculations, we have kept our projections on the conservative side for this source and further reduction of this source will only come from actual nitrogen elimination of the waste stream source (short of zoning changes to reduce density). This can be accomplished by two approaches which can be applied independently or together.

- Reduce nitrogen in the septic effluent through the use of advanced on-lot treatment.
- Reduce nitrogen by collecting sewage from selected areas and treating it in advanced package treatment plants to reduce the net introduced nitrogen from 35 mg/L to less than 10 mg/L. Development clusters lend themselves to this approach.

There are a number of advanced treatment septic systems available for use as replacements for the conventional septic system. Nitrogen reductions in the range of 25 to 50 percent (some up to 90%) can be obtained from these systems. They typically require an additional structure and pumping capability and carry an added cost for these items. In some cases, a reduction in leaching area is allowed with some cost savings. There is a seasonal start up delay period during which the effluent contains higher nitrogen levels which reduces the success of some of these systems for strongly seasonal homes.

A program to encourage their use through tax incentives, density incentives to developers or low/no interest loans is the best scenario. The Chilmark health department has been supportive of the use of nitrogen removing technology. It is important to expand their use, to gather data on the quality of the effluent and to demonstrate their capability such that the second home owner who can probably afford it will insist on these systems to be environmentally friendly. Increased use should bring the prices for these systems down and the performance level up. However, if this is not workable, it may be necessary to require their use to meet the loading limits of Chilmark, and possibly, Squibnocket Ponds. This is typically done through the Health Code.

The discussion which follows is taken partly from the Barnstable County Health Department's Compendium of Information on Alternative Systems (Rask, 1998).

Recirculating Sand Filters: This system has a septic tank, pump chamber sand filter and leaching area. Denitrification is enhanced by returning about 80 percent of the filtered effluent back to the pump chamber. Biological Oxygen Demand was reduced by 90 percent and nitrogen by 32 percent after passing through the sand filter in 21 samples analyzed by the Barnstable County Health Department. The system costs about $5000 above the cost of a conventional septic system.

Peat Filter Septic System: This system operates in a similar arrangement as the RSF. Instead of a sand filter, a peat filter is provided. A removal of over 90 percent BOD and about 40 percent of the nitrogen is possible. Peat has a tremendous cation exchange capacity which allows it to bond positively charged particles in the effluent including ammonium, metals, pesticides and other organic molecules. The system costs about 2000 to 3000 dollars more than a conventional septic system.

RUCK System: In this system the gray-water (bath & sink) is separated from the back-water (toilet and kitchen sink) with separate plumbing to separate septic tanks. The back-water is nitrified in the RUCK filter and then returned to the gray-water septic tank where it undergoes denitrification. The finished effluent has a nitrogen content of about 19 mg/L (about 40 to 50% reduction). Higher levels of nitrogen removal may be possible. The system costs about 7000 to 9000 dollars more than a conventional septic system.

Trickling Filters: The effluent is trickled over a media of plastic structures between the septic tank and the leaching field. The effluent is treated by nitrifying bacteria growing on the media. The effluent then goes back to the anaerobic septic tank where it is denitrified. Nitrogen removal ranges around 50 to 60 percent. Costs vary from 2600 to 4600 dollars more than a conventional septic system.

Aerobic Units: The package unit aerates and settles the wastewater. By shutting the aeration unit off at night, a 50 percent nitrogen reduction was obtained. However, this function is still experimental. The unit costs an additional 5600 dollars above the cost of a septic system.

Fixed Activated Sludge Treatment: This unit is placed inside a conventional 1500 to 2000 gallon precast septic tank. The wastewater is aerated by an air blowing unit and then flows back into the settling area of the septic tank where anaerobic conditions prevail and denitrification can occur reducing the total nitrogen in the effluent to about 19 mg/L (a 40 to 50 % reduction). The FAST unit costs about 5000 dollars over the conventional septic system.

Sequencing Batch Reactors: The sewage is treated in batches which are alternately supplied and denied air. The two systems widely available include the Amphidrome and the Cromaglass systems. Both were designed to treat municipal scale wastewater and only now are they turning to house scale treatment. They can be applied as package treatment facilities to treat a subdivision or group of houses. Theoretically they should be able to reduce nitrogen in the effluent to under 10 mg/L (70 % reduction). A 67 percent reduction in leaching area has been approved for the Cromaglass system. The system costs about 8000 dollars more than a conventional septic system. Maintenance at 240 dollars per year is required.

Composting Toilets: These systems are allowed to upgrade a failed system or for new construction where a complying Title 5 system can be installed. The leaching facility may be downsized by 60 percent as it only handles gray-water. The solids are greatly reduced by the composting process however, proper handling of the composted end product is necessary. The compost has about 70 percent of the nitrogen in the organic form greatly reducing the likelihood for leaching. It can be used for landscaping purposes, landfilled or hauled by a septage hauler. Nitrogen in the effluent passing through the gray-water system is only about 10 percent of conventional wastewater. Cost for the composting system is about 5000 dollars. While a septic tank is required, the size of the leaching area is reduced resulting in a net cost of about 4000 dollars over the conventional system.

Effluent drip disposal: The effluent from the septic tank is pumped through small diameter tubing to drip emitters that are distributed at 6 to 12 inch depth throughout a lawn area. During the growing season, nitrogen uptake is significant and an overall nitrogen reduction of near 50% is likely. The system does require a pump chamber and pump but does not require a gravel leaching area.

Some of these systems may have difficulty in seasonal homes in that a start up period of reduced operational efficiency may occur until the biological activity begins. If an average year round house produces about 5.44 kilograms of nitrogen per year, these systems can save 2 to 2.7 kilograms or, in the case of the composting system, about 5 kilograms. Over a twenty year lifetime these systems save between 40 and 54 kilograms of nitrogen per dwelling at costs ranging from 2600 to 8000 dollars or 48 to 200 dollars per kilo saved. For the composting system, the cost per kilo is about 50 dollars. These figures do not include maintenance costs which will increase the cost per kilo somewhat.

Actions Suggested:

- *Encourage/require use of denitrification systems for new construction on small lots and lots with guest dwellings which do not meet the allowed per acre nitrogen loading limit.*
- *Devise a system to assure that tight tanks are not leaking sewage through a review of pump out records and on-site inspection.*
- *Consider use of cluster to allow communal, denitrifying septic systems for new subdivisions.*

Growth Control Measures:

Purchase of Title or Easement: This approach offers a method to limit loading which also provides other benefits: open space, population limitation, reduced demand for infrastructure and traffic reduction. It is perhaps the most costly in the short term but becomes more economical when the benefits are examined over a longer time frame. Potential acquisitions are tabulated in Tables17, 19 and 22 in Task 5. Priority properties to target for purchase are those with unknown owners as they will be least costly. In addition to purchases, it is sensible to examine open space within subdivisions to be certain the title is held in a manner which will exclude reversion to buildable land in the future.

Finally, other large properties should be investigated for easement/purchase as they will be less costly compared to purchase of small lots in terms of price and legal and administrative costs. Many of these large lots have a house on them and may already have covenants preventing further subdivision. This should be investigated. If there is potential for further subdivision, the owners may be approached for conservation easements rather than purchase. In addition, there are a large number of lots with substantial acreage that might be pursued. The Vineyard Conservation Society and Vineyard Open Land Foundation are sources of assistance for this approach.

Zoning and Health Codes Changes: At the present time there are two mechanisms effecting the size of lots in the recharge area: zoning lot sizes and health codes. The primary zoning limitations are for 3 acres in Chilmark and 2 acres in Aquinnah. It is unlikely that the courts will tolerate any increase in zoning minimums beyond the 3 acre size because of the snob zoning issue. An incentive for clustering to secure open space and encourage a village growth pattern might be provided for those developments offering nitrogen removal technology such that the net output from the development is less than would be produced from 2 to 3 acre lots.

Guest houses offer potential income through rental as well as meeting family needs. They also can dramatically increase the nitrogen loading from a given lot by increasing the sewage flow. The number of potential guest houses is reduced by the acreage requirements (3 acres in Chilmark and 4 acres in Aquinnah). Another approach to limiting the impact of guest houses is through nitrogen loading limits per acre. This allows some flexibility where an advanced, nitrogen removing sewage treatment is provided. Until a comfortable loading limit is developed for both Squibnocket and

Chilmark Ponds, a means to limit the added nitrogen from guest houses is needed in these watersheds.

Actions Suggested:

- *Consider adopting nitrogen loading limits within the watershed.*
- *Encourage the use of denitrification technology to meet these targets for lots that lack the acreage to meet the necessary nitrogen allocation.*
- *Focus land acquisition efforts for conservation in the Chilmark Pond watershed.*

POND SIDE OPTIONS:

Pond Management Options: These options address the receiving end rather than the source. This approach is often labeled "top down" management of nutrients in that it calls on consumers like shellfish to reduce the effect of the added nutrients by increased grazing on the food web. It is generally not as successful as reducing the nutrients at their source but never the less is a means to reduce impacts. For example, the increased production and harvest of shellfish resources removes nutrients from the system by converting them first to phytoplankton and then into shellfish meats which are removed. As Chilmark Pond and Squibnocket Pond are now flushed, the waters are not well suited to scallop production but oyster culture is a possibility. It is unlikely that a system to improve circulation in these Ponds can result in substantial increases in salinity necessary for scallop production. In Menemsha Pond, raft, taught wire subsurface and bottom culture of scallops may remove nutrients while providing an income for growers. Improved tidal circulation to Squibnocket and Chilmark Pond will offer an opportunity to remove some of the nutrient load from the system.

Increased Circulation: Non-Structural and Structural Options: Squibnocket and Chilmark Ponds

At present, flushing is very limited to Chilmark and Squibnocket Ponds. For Chilmark Pond this is because the typical inlet is open for less than one week. This is not enough time to flush out the nutrients that are in the system although it typically raises the salinity in the Lower Pond enough for oyster culture. Any increase in the duration of the pond opening in Chilmark Pond would increase flushing but the desired lifetime of an inlet is two to three weeks. Timing the opening to coincide with north winds and spring tides and the actual cut to coincide with a falling tide should improve the depth of the initial inlet. This may not translate to increased inlet lifetime as this is controlled by winds from the south and the wave action and sediment transport they generate. Dredging a channel through the tidal flats on the inside of the Pond should help to maintain an active inlet by increasing the ebb outflow velocity to help keep the channel clear of shoals on the beach face.

Chapter 203 of the Acts of 1904 enables the riparian owners on great ponds on Martha's Vineyard to organize and elect three commissioners who are empowered to do whatever is necessary to properly drain the low lands and meadows around the great pond

(Friedman et al, 1976). However, current DEP legal opinion indicates that all pond openings should follow the guidelines in DEP's Coastal Pond opening policy.

The option of allowing the entire system to revert to a fresh water system with periodic natural inlets is not considered a viable option. This approach would lead to catastrophic salinity changes, periodic lack of access for anadromous fish resources as well as flooding of shoreline residences and sewage disposal systems.

In the case of Squibnocket Pond, it appears that the pond is not consistently tidal. Further in depth research is recommended to gain a better understanding of the mechanism that switches the tidal action on and off. Better tidal action would probably result from removing the high spots in Herring Creek allowing continuous daily tidal action in Squibnocket Pond. While increased tidal action would reduce nutrient impacts, higher salinity levels might impact other resources in the Pond. Before deepening the Creek, an evaluation of herring spawning areas and the pond margin wetlands should be made to assure that significant ecosystems are not damaged by increased salinity.

No further circulation increases are necessary in Menemsha Pond, however, periodic dredging to improve navigation in the inlet will improve flushing at the same time.

Chilmark Pond: An exchange of about 95 percent of the water in the pond with the Atlantic is desirable for each opening to Chilmark Pond. When the pond is opened and lowered, there is an increase of nutrients brought on by increased flow from the ground water into the pond and increased flow from the Upper pond to the Lower. Paradoxically, influx of substantial amounts of sea water may stimulate productivity perhaps to excess. However, it seems likely that, with prolonged tidal action, the nutrient increase would be diluted with sea water with much lower nitrogen concentrations.

Inlets cut through the barrier beach close due to several factors. Weather is probably the primary cause of quick closure. Wind from the south builds waves that move sediment into the inlet causing it to cut to the east, become more meandering and gradually close due to reduced force of the flowing water. Second, the inlet cut by the initial discharge through the barrier beach is sized for a large volume of water. The height of the pond above Mean Sea Level (MSL) is a factor in the inlet forming process as it determines the volume of water that will discharge to the lower ocean at ebb tide. As the pond lowers, the outflow slows and tidal flow begins. At that point, the tidal flow is spread out in a large channel sized by the initial rush of water out of the pond such that the force of the tidal flow is insufficient to keep the channel clear of sand. Sand moves from west to east along the beach, pushing the channel in an easterly direction until the flow becomes so sluggish that the inlet closes. Arthur Gaines has found no correlation between the height of Edgartown Great Pond at opening and the lifetime of the opening (personal communication, 1998).

It is desirable to keep Chilmark Pond open long enough for 95 percent (or more) exchange of pond water with ocean water (at least 14 days) particularly during the period from late July to mid-September when water quality deteriorates. It may be possible to approach this level of flushing through a non-structural approach by **repeated excavation of the channel** filling sand after the pond has regained some head over a period of about a month. This approach will be most successful during spring when there is higher volume discharge of groundwater into the pond providing a sustained source of the necessary head. At a groundwater and stream discharge of about one million cubic feet per day in spring, a low pond (145 acres) would increase its height by one foot in 7 to 10 days.

The depth to which a channel is cut is controlled by the base level to which the channel drains i.e. ocean low tide level. There is some “blow out” effect which may cut the channel below base level however this probably is a short term phenomenon. If the depth of the outlet channel is shown to be a factor in the short life of inlets, it may be possible to cut a deeper channel through the beach by bringing deeper pond water closer to the barrier beach by **dredging** some of the tidal flats near the location where the opening is cut. This would provide a larger volume of water close to the beach which should speed the initial discharge through the barrier beach cutting a more substantial opening.

The delivery of Pond water to the inlet would be enhanced by clear, unobstructed flow that would result from deep and wide in-pond channels to the west and to the north of the inlet. Internal shoals interfere with the free flow of water both within the pond and in and out of the inlet particularly when the Lower Pond is at a low stage. These shoals include the flood tidal deltas deposited over the years by sand carried in on the flood tide which is not eroded on the following ebb tide. These shoals are typically found to swing in an arc around the inlet site. Excavation and removal of this sand to the outer beach will nourish the beaches down drift, increase the volume of water in the pond thereby increasing tidal flow and reduce the obstructions to the free ebb and flood tides. In addition, as the barrier beach retreats to the north the distance between the south tip of Long Point and the beach has been reduced to a very narrow stricture. This shoal area essentially cuts the Lower Pond in half in a north-south direction and severely limits internal circulation gyres. An evaluation of the circulation pattern as currently limited by Long Point should be undertaken to determine options to reduce this obstruction but in the short term, some plans should be initiated to remove the tip of the point to increase flow in and out of the inlet and to insure that storm washover will not shut down the flow from the western to eastern halves of Chilmark Pond.

Other approaches to prolonging the lifetime of the inlet would **interfere with movement of sand** along the shore into the inlet channel. It may be possible to reduce wave action with temporary, reef-like devices which would reduce sand movement into the inlet or even cause scour at the inlet site. If it is desirable to limit the dimensions of an inlet to keep a strong flow and lengthen the lifetime of the opening, it may be possible to confine the initial out rush of pond water with a structure situated on the pond side of the barrier beach designed to better channel the flow and minimize caving of the sidewalls. Without a means to raise pond head to periodically remove filling in the channel on the beach face, this option has limited potential.

Carrying this further, Gaines (1996), has proposed an investigation of a **temporary hard structure** crossing the barrier beach at Edgartown Great Pond to channel the outflow in such a manner that the inlet can be periodically cleared of accumulated sand by closing the structure, building head and releasing the water. The primary hurdle to this option is permitting a structure on a barrier beach. The structure was estimated to cost about $150,000 for design and installation. This structure would be placed with the understanding that it would be damaged and possibly destroyed by coastal storms and hurricanes. It is clear that the energy applied to the south shore by storms will be sufficient to periodically cause severe damage and perhaps destroy such a structure. It is worth watching the proposal to see if it accomplishes the desired goals.

Another possibility is placement of **a large conduit** to move water in and out of Chilmark Pond. Without a means to allow regular closing, the pond would average a lower level (about 3 feet lower) than today exposing large areas of mud flat because it presently spends considerable time at 3 to 4 feet above MSL. Such a structure would have to extend offshore into deep enough water so it would not be damaged by storm waves or filled by longshore sand movement. The pipe would need to be sized to pass enough flood water to force a tide of about ½ foot which calls for a flow of nearly 145 cubic feet per second over a 6 hour tide to raise a 145 acre pond by six inches. With a 3 foot head, a 400 foot long corrugated metal pipe flowing full 66 inches in diameter is required to carry 150 cubic feet per second when flowing at 6 feet per second (Highway Design Manual, Mass. DPW,1989).

The **timing of the opening** may be a factor in the summer water quality as the opening brings phosphorus into a pond which has a continuing supply of nitrogen from groundwater discharge. At present, an opening is required in April to allow alewives in and to lower spring high water in the pond. The summer opening usually follows in August. It was following an August opening in 1993 that an intense algae bloom substantially lowered water quality in the Edgartown Great Pond. Following the June opening in Chilmark Pond, the water quality deteriorated through August. Some further study of the impact of the timing of the summer opening is necessary. It may be desirable to allow the pond to become increasingly brackish over the late summer and starving the phytoplankton for phosphorus. Plans are underway to delay the summer opening to Tisbury Great Pond in an attempt to reduce the impact of the oyster disease, *dermo*. This trial effort may have implications for the management of Chilmark Pond.

Actions Suggested: *If the consensus is that Chilmark Pond should be revived as a shellfish producing system, the following steps are suggested:*

- *Bring deep water close to the inlet site through dredging*
- *Attempt trial repeat-excavation of the opening over 1 to 2 months during spring to increase tidal period to 15 days. Assess water resource impacts during the process.*
- *Remove shoal areas on the pond side particularly toward the tip of Long Point and to the north and west.*

- *Begin the planning and permitting process to remove a portion of the south tip of Long Point to increase circulation in the system and to prevent the Lower Pond from being bisected by northward retreat of the barrier beach.*
- *Devise a system for better timing of openings to coincide with spring tides, falling tide on the ocean side and predicted winds from the north.*
- *Evaluate trial delay of summer opening to Tisbury Great Pond until fall to assess water resource impacts. If successful, attempt a similar program.*
- *Keep records of dates and lifetimes of the inlets.*

Use of Herring Creek to Better Flush Squibnocket Pond:
The Creek is currently limited by depth and length as a flushing mechanism for Squibnocket Pond. The presence of shoal areas in the Creek appear to interfere with flood tide waters (see text for in-depth discussion). Through removal of the "high spots", it might be possible to allow a daily tidal flow sufficient to duplicate the tidal curve found during late October to mid-November 1999 on a continual, year round basis. Increased tidal flow would substantially adjust nitrogen loading limits upward and decrease the threat of further eutrophic response. This option is an inexpensive means to allow the development pattern in the watershed to proceed as under current zoning with minimal water resource impacts.

A preliminary survey of the elevations in the Creek shows the relationship between the elevations of the culvert under south road, rocky or shallow channel stretches and the herring catching box culverts. A clear understanding of the elevations of each of these natural and man made constrictions in the channel is the first step to outlining options to improve flow through the Creek. Additional tide gauge data from surveyed benchmarks will allow a better understanding of the relative heights and responses of the two ponds to tidal action.

Actions Suggested:

- *A more in-depth survey of the full length of the Creek is necessary. Identification of fragile ecosystems that might be impacted by better circulation should also be made.*
- *Additional tide level data is needed.*

Use of Windmills:
These devices have been suggested in the past as a way to bring salty water into a coastal great pond or to discharge pond water to lower the pond and remove nutrients from the system. One attractive aspect of windmills is that there is no need for an excavated opening through the barrier beach. The difficulties with windmills include the severe wind exposure which might lead to constant repair costs and the required volumes of water necessary to have some significant impact on the salinity of the pond. This second limitation is the most important.

The tide range in the Chilmark Pond when it is open is on the order of 3 to 6 inches. To add 5 inches to a low pond (145 acres) requires about 2.6 million cubic feet or 19.7 million gallons. If we desire to exchange this much water on a daily basis, the pumps must deliver over 13000 gallons per minute. To accomplish this, approximately 300 windmills moving 40 gallons per minute are necessary. This task seems beyond the potential of this technology to deliver at a reasonable price today.

Biological Productivity:
This approach utilizes the food web as a means of passing nutrients up from soluble form, to phytoplankton, to zooplankton which graze on them, to small fish or to shellfish which filter them out of the water column. It is attractive because the nutrient end products are shellfish and fish which can be harvested and consumed as a food product or by the larger predators which support our sport fishery. The Chesapeake Bay Program has estimated that 10 units of phytoplankton are required to produce 1 unit of zooplankton. Again, 10 units of zooplankton are required to produce 1unit of small fish. Finally, 10 units of small fish are required to produce one unit of a top level predator like a bluefish or bass. In other words, 1000 units of phytoplankton are converted into 1 unit of bluefish. It becomes obvious that a considerable amount of the nutrients we are interested in are passed up the food chain into a harvestable product. (Note: units are dimensionless and might be an ounce or a pound depending on the species examined).

The amount of protein locked up in oyster meats ranges from 6.1 to 8.4 percent expressed as a percentage of the **dry** flesh (Walne, 1974). One of the primary constituents of protein is nitrogen which is pretty consistently 16 percent of the protein weight (Millero, 1996). If we harvest 1000 kilograms of oyster meat (**dry weight**), we have harvested about 80 kilos of protein and 12.8 kilos of nitrogen. Nixon et al (1995) reports that quahog tissue (*Mercenaria mercenaria*) contains about 2.7 % nitrogen on a fresh weight basis. This indicates the possibility of removing 27 kilos per 1000 kilos of fresh meat removed if the same percentage holds for oysters. Michael Rice (no date) estimates about 17 kilos of nitrogen are removed for every 1000 kilos of shellfish meat harvested.

The relationship is much more convoluted because the shellfish consume many times their body weight in phytoplankton and excrete urea and fecal pellets as they grow. Both the food and the waste products contain nitrogen. Some of the fecal pellets and soluble nitrogen become food for other organisms and some may be buried in the sediment. While older, slow growing adults may not remove nutrients from the system, young, rapidly growing bivalves are net removers of nutrients from estuaries (Rice). Aquaculture is a means of growing large numbers of shellfish and harvesting them at a young growth stage when they have removed maximum nutrients from the system.

The system for herring is different but it seems clear that by spending part of their life in a coastal pond before migrating to the sea where many are consumed in the food chain they must remove some nitrogen from the system. As confounding as that cycling is, it seems certain that **the net effect of harvesting fish or shellfish is the removal of nutrients from the water column**. Bio-systems are subject to crashing due to disease or changes in light or oxygen. As we do not know the exact quantity of nutrients that they might remove and, recognizing the risks that are inherent in bio-systems, this nutrient removal option should be implemented but not depended on as a removal strategy.

Two options are seen as worth further investigation as ways to lower nutrients in the pond system. **First**, Chilmark Pond should be examined to determine the size of the anadromous fish population. DMF specialists should be consulted for their recommendations to enhance these species. The primary anadromous fish identified in Edgartown Great Pond (Skomal, 1998) is the alewife (*Alosa psuedoharangus*). Mixed in were a limited number of Atlantic menhaden (*Brevoortia tyrannus*). Establishing a new or larger fish run might require stocking and possibly improvements to Doctor's Creek. The success of the Upper Lagoon Pond Herring Run and stocking program indicates a high probability of similar success in Chilmark Pond. Squibnocket Pond has a large fish run but the numbers of fish should be estimated and the size and sufficiency of spawning grounds should be investigated. The alewife may also produce water quality problems that result from the nutrients they import from the Atlantic as well as their tendency to consume zooplankton that are important to maintain a low phytoplankton concentration.

An examination of the issues around limiting the population of cormorants may also be required if they are found to be significantly impacting the establishment of an alewife population. Paradoxically, as a predator, cormorants are a consumer of nitrogen but one which leaves much of their consumption behind as droppings. Apparently, these birds roost near where they are feeding (Hatch, personal comm.) so the net effect of their fish consumption is to convert fish proteins into organic and soluble forms of nitrogen and to put them back into the pond. It is likely that geese produce a similar result.

The requirements within the pond for alewives are outlined below. These requirements are generally met toward the heads of the coves. Any improvements to the tidal flushing of Squibnocket must be evaluated for their impact to herring spawning requirements. This option is a low cost, almost self-sustaining way to reduce nitrogen loading impacts to a limited degree.

Alewife Requirements	**Chesapeake Bay Executive Council, 1989**
Salinity	*0- 6.0 ppt*
DO	*5.0 ppm*
pH	*6.5-7.8*
Flow	*tidal or stream*

Second, development of a shell-fishery within the Chilmark and Squibnocket Ponds should be thoroughly investigated along at least two lines. The establishment of an oyster fishery may be possible in Chilmark Pond. If the oyster population comes back, openings timed to minimize impact on phytoplankton populations could provide the salinity to get high quality meat to satisfy market demands. Openings also must be timed to avoid flushing out the oyster larvae that are in the water column during July. Oysters not only sequester nitrogen in their tissues but they deposit large amounts in their feces and psuedo-feces into the bottom sediment where a considerable amount of the nitrogen they filter from the water column is converted to gas and enters the atmosphere. As an option, oysters raised in Chilmark Pond might be moved to a more saline pond such as

Menemsha on their way to market. The enhancement of the existing Squibnocket oyster population into a fishery should also be investigated.

Another, more remote possibility would be to restrict tidal exchange into one or more of the Chilmark Pond coves to reduce the salinity and process the nutrients in the recharging groundwater into oyster meat. As the Upper Pond is the primary site where nutrients are introduced with the groundwater and streams, a restriction would be designed to trap nutrients in the west end of Chilmark Lower Pond. This portion of the pond would become an intensive aquaculture area to process nutrients into shellfish meat. This approach will require extensive permitting, extraordinary in-pond construction and much more detailed evaluation before it is attempted.

Oysters are susceptible to a disease found in Edgartown and Tisbury Great Ponds. It appears that any oyster venture in Chilmark Pond would eventually have to deal with this problem. There may be substitute species such as blue mussel, soft shell clam and perhaps other species of oyster more tolerant to the dermo disease that can be successfully grown (*Crassostrea gigas*-western oyster). The blue mussel requires higher salinity than is currently available and may not thrive in summer water temperatures. This option may be initiated after the lifetime of openings is increased enough to offer appropriate salinity levels. Soft shell clams are not believed to be in Chilmark Pond and their culture has very limited potential focused mainly on the tidal flats at the site of the opening. Their presence in Squibnocket Pond is unknown. The western oyster is an exotic species which should only be imported after careful investigation. This possibility is under study and debate for the Chesapeake Bay where the oyster population (*virginica*) once was large enough to *filter the water in the entire Bay every 3 to 6 days. Now, due to population decline, the filtration cycle requires about 325 days.*

Draining the Upper Pond: Much of the nutrient loading to Chilmark Pond enters through the Upper Pond. The possibility of paired opening of the Upper and Lower Ponds as a means to divert the input of nitrogen bearing water from the Upper Pond into the Lower Pond is difficult to envision but may be worth some investigation. There would be salinity changes and significant associated impacts brought to the eastern part of the Upper Pond where a potential inlet site exists. Increased erosion due to the presence of two inlets may be a problem. The lifetime of the inlet into the Lower Pond could be greatly reduced due to decreased flow through the inlet. The most western part of the Upper Pond should be protected by a tide gate structure to exclude saline water. The reduced nitrogen entering the Lower Pond may well be a good trade off but this option needs thorough evaluation by a hydraulic circulation model before serious consideration.

Actions Suggested:

- *Conduct appropriate studies to characterize the fish, shellfish and ecological habitats around the perimeter of Chilmark and Squibnocket Ponds prior to any changes in current circulation/flushing practices.*

- *If shellfish productivity is agreed to as a priority use of Chilmark Pond, proceed to enhance circulation through dredging projects. Utilize the shellfish program and an enhanced herring run as nutrient removal techniques.*
- *Evaluate options to increase anadromous fish population.*
- *Investigate the feasibility of breaching the eastern part of the Upper Pond as a means of nutrient removal only as a last resort.*
- *Evaluate potential impacts from salinity increase to existing ecosystems. Proceed to develop the shellfish program as a means of nutrient removal.*
- *Enhance the herring run if feasible.*

Task 9.2: Nitrogen Loading Scenarios:

We have established a range of loading limits (Task 5) and a range of growth scenarios (Task 7) with varying nitrogen loads resulting. Loading projections are derived from growth assumptions detailed in Task 7. The following discussion juxtaposes the loading associated with different levels of growth with the loading limits. In section 9.3 ways to meet the loading limits are discussed in more detail. The range of predicted **loading** is:

Chilmark Pond LOW GROWTH: **5015 kilograms/year (kg/y)**

Growth Assumptions: Low Loading

In this scenario, new growth is held to an additional 322 primary dwelling units over the present day estimate of 437 for a total of 759 dwellings. The assumption is that all of the existing vacant small lots (164 lots) would be built as well as new subdivisions (158 lots). Average lot sizes would be 6 acres in new subdivisions. It is assumed that 100 of the larger lots would also have a guest house. It is assumed that lawns would continue to be treated as the present day lawns are. Farms are assumed to use low rates of nitrogen fertilization. Rain fall contributions would be at a low rate of 0.3 milligrams of nitrogen per liter of rain.

Chilmark Pond HIGHER GROWTH: **6551 kg/y**

Growth Assumptions: High Loading

Under this growth scenario, a total of 898 primary dwellings are projected with the larger lots having guest houses adding another 200 dwellings. It is assumed that lot sizes average 3 acres. No further conservation easements or purchases are assumed.

We assume that lawns are treated as today. Farm fertilization programs are projected to increase to the full agronomic rate. Acid rain loading is at the higher rate of 951 kilograms per year.

The **loading limits** as recommended by the Buzzard's Bay Program formula (See Task 5 for detailed discussion) range from 5.2 to 10.4 kilograms per day. On an annual basis the loading ranges from:

Chilmark Pond /25 DAY Residence/**Good Quality Rating:** 1901 kg/year
Chilmark Pond/14.9 DAY Residence/**Good Quality Rating:** 2261 kg/year
Chilmark Pond /25 DAY Residence/**Reduced Quality Rating:** 3802 kg/year

The lowest limit of 1901 kilos per year (5.2 kilos per day) is now and has been historically exceeded with little indication of persistent water quality problems beyond those outlined in the Water Quality Assessment in Task 2. Given the limited data to support this low limit and the tremendous changes within the recharge area before build out required to meet it, it is not considered a reasonable loading limit target at this time. A 14.9 day opening is within reach at this time but could not be repeated frequently enough to give a consistent 14.9 day average residence time over the year.

Recent research has suggested a target loading limit of 30 kilograms of nitrogen per hectare (12.1 per acre) of pond area to maintain the health of eelgrass beds by limiting the growth of fouling seaweed and algae (Hauxwell, 1998). While there are no eelgrass beds found within the system, it may be desirable to establish them to improve the habitat for fish species. If this limit is applied to Chilmark Pond (145 to 241 acres), this rate implies a loading limit of 1755 to 2916 kilograms per year. These figures bracket the loading limits for Good Quality rated waters. The Reduced Quality water rating carries with it a nitrogen limit of 3802 kilograms per year. The Reduced Quality rating is suitable for shellfish production but implies periodic algae blooms. It is the only limit that may be reached without extraordinary watershed loading reduction measures.

Menemsha Pond LOW GROWTH: **6700 kilograms/year (kg/y)**

Note: This loading includes the nitrogen contributed by Squibnocket Pond.

Growth Assumptions: Low Loading

In this scenario, new growth is held to an additional 167 primary dwelling units over the present day estimate of 373. The assumption is that all of the existing vacant small lots (119 lots) would be built as well as new subdivisions (48 lots) totaling 540 dwellings at build out. Average lot sizes would be 6 acres in new subdivisions. It is assumed that the 75 of the larger lots would also have a guest house.

In addition in the Squibnocket Pond watershed, the 101 existing dwellings would increase by 154 primary units to a total of 255 primary dwelling units. There would also be another 47 guest houses on the larger lots.

It is assumed that lawns would continue to be treated as the present day lawns are. Rain fall contributions would be at a low rate of 0.3 milligrams of nitrogen per liter of rain.

HIGHER GROWTH: **10608 kg/y**

Growth Assumptions: High Loading

Under this growth scenario, a total of 642 primary dwellings are projected with the larger lots having guest houses adding another 125 dwellings. It is assumed that lot sizes average 3 acres. No further conservation easements or purchases are assumed.

In the Squibnocket Pond watershed, a total of 350 primary dwellings are projected plus 83 guest houses.

We assume that lawns are treated as today. Farm fertilization programs are projected to increase to the full agronomic rate and rainfall adds nitrogen at a rate of 0.74 milligrams per liter.

The **loading limits** as recommended by the Buzzard's Bay Program formula (Task 5) range from 93 to 280 kilograms per day. On an annual basis the loading limit ranges from:

Shallow Pond /3.2 Day Residence/**Good Quality** Rating: 94853 kg/y
Shallow Pond/3.2 DAY Residence/**Highest Quality** Rating:31618 kg/y

The lowest limit of 31618 kilos of nitrogen per year (86.6 kilos per day) is well above the projected maximum growth in both watersheds. This target loading can be easily met. The eelgrass beds in Menemsha have shown some symptoms of reduced growth but the cause is uncertain at this time(Colarusso, 2000). Recent research has suggested a target loading limit of 30 kilograms of nitrogen per hectare (12.1 per acre) of pond area to maintain the health of eelgrass beds by limiting the growth of fouling seaweed and algae (Hauxwell, 1998). If applied to Menemsha Pond (790 acres), this rate implies a loading limit of 9486 kilograms per year. This limit will be exceeded at buildout under the High Growth Scenario. For this reason alone, growth as planned in the Town through zoning is a desirable limit to nitrogen loading which provides time to examine indicators of pond health in greater detail.

Squibnocket Pond: LOW GROWTH: **2295 kilograms/year (kg/y)**

Growth Assumptions: Low Loading

In this scenario, new growth is held to an additional 154 primary dwelling units over the present day estimate of 101. Total dwellings in the watershed at build out will be 255. Average lot sizes would be 6 acres in new subdivisions. It is assumed that the 47 of the larger lots would also have a guest house. It is assumed that lawns would continue to be treated as the present day lawns are. Farms are assumed to use low rates of nitrogen fertilization. Rain fall contributions would be at a low rate of 0.3 milligrams of nitrogen per liter of rain. **This loading estimate is somewhat less than the present day load estimate using the higher loading from acid rain. This implies that the likely low growth buildout loading will be greater than this estimate and at least in the range of the present day number.**

HIGHER GROWTH: **4059 kg/y**

Growth Assumptions: High Loading

Under this growth scenario, a total of 350 primary dwellings are projected with the larger lots having guest houses adding another 83 dwellings. It is assumed that lot sizes average 3 acres. No further conservation easements or purchases are assumed.

We assume that lawns are treated as today. Farm fertilization programs are projected to increase to the full agronomic rate.

The **loading limits** as recommended by the Buzzard's Bay Program formula (Task 5) range from 8.3 to 23.4 kilograms per day. On an annual basis the loading ranges from:

Shallow Pond /354 DAY Residence/**Reduced Quality Rating**: 3037 kg/y
Shallow Pond/43 DAY Residence/**Good Quality Rating**: 8532 kg/y

The lowest limit of 3037 kilos per year (8.3 kilos per day) is approached today from the combined effects of acid rain (up to 84 percent of the limit) and septic effluent (about 10 percent of the limit). There are several indications of water quality problems under the present loading including phytoplankton blooms and high levels of dissolved nitrogen (Wilcox, 1999). It is possible for a coastal pond system to show signs of eutrophication that are mainly from the natural inputs. Until the remaining uncertainties about the flushing of the system are clarified, this limit is a worthy target
Recent research has suggested a target loading limit of 30 kilograms of nitrogen per hectare (12.1 per acre) of pond area to maintain the health of eelgrass beds by limiting the growth of fouling seaweed and algae (Hauxwell, 1998). Eelgrass beds were not observed during the course of sampling in 1999. If applied to Squibnocket Pond (602 acres), this rate implies a loading limit of 7284 kilograms per year which will be easily met even under the High Growth Scenario.

9.3 MODIFYING LOADING PROJECTIONS TO MEET LIMITS:

These scenarios are described to provide a sense of how the Towns might meet the limits within the range of loading that we have identified. Each scenario requires a different level of management to achieve the loading limit target. The activities to reduce nitrogen loading are interchangeable. Those chosen for each loading projection are as described at the beginning of Task 9.2 above.

Scenarios for Chilmark Pond

1. Good Quality Waters Limits and Lowest Loads

Under this scenario the loading limit is 1901 kilograms per year. Even the low growth scenario (5015 kilos per year) cannot meet this guideline. If all sewage disposal systems in the watershed were converted to nitrogen removing systems with an effluent quality at 19 milligrams of nitrogen per liter, the loading from all sources would still exceed this limit by over 1700 kilograms per year in the Low Growth projection. (See Table 32 in Task 8 for loading projections). In order to meet this limit with the acid rain, road runoff and farm sources as givens, only 940 kilograms remain for septic systems and lawn sources. This implies a limit of about 188 dwellings with conventional Title 5 septic systems or, with advanced nitrogen removal, 346 dwellings. There are already 437 dwellings in the watershed. **This low growth limit is a worthy goal but cannot be implemented with current technology. It implies that a high water quality goal for these waters is not obtainable without a major increase in flushing and that the lower quality limits for Reduced Quality waters should be considered.**

2. Reduced Quality Waters Class Limits and Lowest Loads

The limits for this scenario range from 3802 to 4522 kilograms per year. Under this scenario, the loading projected (kilos/y) exceeds the loading limit by 493 to 1213 kilograms of nitrogen per year. If all new septic systems (322 primary dwellings) were advanced, nitrogen removing systems, the savings would be 600 kilograms per year. Reduction in lawn loading by half would remove another 550 kilograms per year. ***This scenario is a difficult one but it is workable.***

3. Reduced Quality Class Waters and High Growth Loading

To meet the Reduced Quality Class limits, a reduction in the High Growth scenario by over 2500 kilograms are necessary. If the projected 461 new dwellings were all to be required to use advanced septic systems, a savings of 800 kilograms per year would result. Reducing lawn sources by half could yield another 680 kilograms. It is clear that, short of somewhat extreme methods such as package treatment for new subdivisions, the High Growth loading is not compatible with acceptable water quality. This implies that at buildout under the High Growth scenario, unacceptable deterioration of the water quality in the Ponds will probably occur.

Scenarios for Menemsha Pond

The loading projections for all scenarios meet the loading limits established by the Buzzard's Bay Project formula.

Scenarios for Squibnocket Pond

These loading limits are based on the Reduced Quality water quality rating which seems to best represent current water quality conditions in the pond.

1. Lowest Limits and Lowest Loads

Under this scenario the loading limit is 3037 kilograms per year to meet the Reduced Quality waters rating. The low growth scenario meets this limit by 742 kilograms of nitrogen. If the higher acid rain loading is factored into the low growth scenario, the build out load will exceed the limit by just over 400 kilograms. This could be offset by reducing the size of lawns and denitrifying a small percentage of future on lot septic systems. However, as we now believe, this load limit is likely reached by precipitation alone. ***This is a workable scenario.***

2. Higher Loading Limits and All Projected Loads

This loading limit is based on the existence of a daily tide which is does not occur continuously at the present time. Therefore it is still not a realistic possibility without further manipulation of the system. If continuous tidal exchange can be established, the suggested loading limit target is 8532 kilograms per year for a Good Quality waters rating and all growth scenarios meet it. Under a daily tidal flow assumption, an Reduced Quality waters loading limit is not suggested because, under present day loading, the system already has some undesirable symptoms and an increase to loading that approaches 10 times current loading is not a prudent step.

9.4 Suggested Method to Calculate Available Nitrogen Loading Per Acre:

One way to view the potential to develop within the watershed areas is to determine what loading each acre could contribute such that the sum would equal the desired load limit. It seems straight forward enough to divide the loading limit by the total acreage in the watershed. However, there are fixed sources in the watershed including acid rain, runoff and farm land that should be deducted before an allocation for residential loading is made. These sources are somewhat offset by existing conservation lands which do not contribute nitrogen. For estimating how much nitrogen is saved by conservation lands, the allowed loading is divided by the total watershed acreage. This figure is then multiplied by the acreage of conservation lands and added to the available loading.

TABLE 34 Residential Nitrogen Load Allocation in Kilograms

Pond	Limit	Rain	Runoff	Farms/ Other	Load left*	Acreage	Load/ac.
Chilmark	3802	951	24	596	2573	3173	0.93
	Conservation Offset		*285 acres*	*X 1.2 kg per acre*	*== 342*		
Menemsha	31618	2876	10	134**	28598	1856	17.35
	Conservation Offset		*212 acres*	*X 17 kg per acre*	*==3604*		
Squibnocket	3037	2179	19	13***	826	1303	0.92
	Conservation Offset		*161 acres*	*X 2.33 kg/acre*	*==375*		

Note load per acre is calculated by adding the load left and the conservation add in and dividing by watershed acreage

*** Load Left includes the Conservation Nitrogen savings**

****Estimated Load from high flow sources in Menemsha Village inserted here.**

*****Estimated current load from Tribal wastewater treatment facility**

Residential Acreage Allowed to Meet Nitrogen Load Limit:

The average person in the course of a year will add about 2.27 kilograms of nitrogen to the groundwater. In a 2.5 person house this is 5.7 kilos. An average lawn is very difficult to characterize and therefore the nitrogen loading on an annual basis is approximate. For Chilmark Pond the average loading from lawns is estimated at 3.35 pounds (1.52 kilos). The other ponds are expected to be similar. This brings the total loading per **year round** dwelling to 6.5 to 7.5 kilograms. However, if averaged out across both seasonal and year round dwellings, the loading is about 5 kilos per residence. Resulting minimum lot sizes based on the present day year round-seasonal mix are as follows:

- **Chilmark Pond** **5.4 acres**
- **Menemsha** **No Limit as per current zoning**
- **Squibnocket** **5.4 acres**

It is clear that many existing residences exceed this per acre nitrogen loading limit as there are many lots that are less than 5.4 acres in these watersheds. Looking toward the future, it is possible that subdivisions might follow a low density pattern with large lots approximating this acreage. The 5.4 acre lot size falls within the low growth assumptions. If combined with increased conservation acquisitions and easements, this possibility becomes more realistic.

Denitrification systems can be relied on to eliminate **at least** one third of the nitrogen in the wastewater and often more than that. Their use could bring the necessary acreage on average across existing and future houses to 4.1 acres in both the Chilmark Pond and the Squibnocket Pond watersheds.

As discussed in Task 7.1.3, some recently proposed subdivisions in Chilmark had lot sizes which averaged over 6 acres when open space was included. Any increase to zoning lot sizes exceeding 3 acres is not likely. The best approaches are clearly to encourage provision of open space in subdivisions; to identify and acquire easements or fee title in key parcels; to minimize lawn sizes; and to encourage or require the use of denitrification systems.

Another Strategy to Meet Loading Limits: Transferable Nitrogen Loading Rights

Under the loading limits, each acre in the Pond's recharge area can contribute a portion of the total allowed annual loading. Chilmark Pond exceeds the loading limit under all growth scenarios and Squibnocket Pond exceeds the loading limit under any growth pattern more intense than the Low Growth Scenario. On the other hand, Menemsha Pond has a large buffer of available nitrogen loading and land located toward the north shore drains to Vineyard Sound. Clearly these areas are more tolerant of nitrogen loading than Squibnocket and Chilmark Ponds.

Through a program similar to the Transfer of Development Rights (TDR) often used to protect farmland, the Towns might devise a Nitrogen Loading Rights Transfer program. Each development proposal would be examined to determine its likely loading figure. If that loading exceeds the allowed per acre rate, then the developer must purchase or otherwise obtain loading from other owners outside the recharge area of the pond which needs a reduced loading. ***To work properly, the transfer must occur so that loading is transferred out of the watershed of the pond and into the watershed of a pond which can tolerate the added loading.***

Task 9.3: Summary and Recommendations:

These coastal salt ponds are important resources to the Towns which, in the case of Chilmark and Squibnocket, have had some seasonal water quality problems in the past. It is clear that there should be a concerted effort to assure that poor water quality events do not become a frequent occurrence in these two ponds. To get to that point will require a two component approach.

The **first component** is to manage the ponds in a manner to remove nutrients from the water column and to flush the system at appropriate times of year that do not stimulate nuisance algae blooms. It appears that this includes: prolonging openings to the ocean to better flush Chilmark Pond, increasing the tidal flow through Herring Creek to Squibnocket, increasing the fishery in both ponds and possibly timing openings to Chilmark Pond in spring, fall and winter to avoid creating nuisance algae blooms in late summer. (Note that the late summer tidal exchange is now considered vital to water quality but carries the risk that a failed opening can lead to poor water quality.) The last aspect of this plan requires additional research which should become the basis for managing the system and provide the information needed to carry out the second part of the plan.

The **second component** is to assure that land use in the watersheds contributes nitrogen to the system at an acceptable rate. Every acre within the recharge area carries a responsibility to help meet the limit. Every acre owns a share of the acceptable loading figure. Purchase of conservation lands should be seen **not** as an opportunity to increase the per acre loading rate for the remaining acreage but rather as insurance that our estimated loading limit will not be exceeded.

This report has recommended loading limits which allow growth projections to go forward unhindered in the Menemsha watershed, carefully in the Squibnocket watershed and with some limitations in the Chilmark Pond watershed. Some additional purchases of conservation easements or title are appropriate, particularly for Chilmark Pond. In the Chilmark Pond watershed, average lot sizes must be larger than allowed by zoning or nitrogen removing technology for on lot wastewater is necessary to meet the loading limit. We must keep in mind that technical limits to growth can always be overcome by technological solutions. It is acceptable to use nitrogen loading to limit impacts to the pond but eventually the desired growth pattern should be established through zoning.

The various methods to limit nitrogen loading are tabulated in the pages that follow. Each has some advantages and some disadvantages. These are spelled out. Those options which focus on on-lot sewage disposal and those which aim at better flushing and nutrient management in the pond are most important. A Decision Matrix is provided as Table 35 which helps to prioritize the options for best results and ease of carrying out.

Short Term Strategy: The following items should be the initial focus with a 3 to 5 year time horizon to set the stage for a long term management program:

Increase knowledge about the systems through additional field study:

- **<u>Chilmark Pond</u>**: fin fish and benthic invertebrate surveys, consistent record keeping about date and duration of openings, continued water quality sampling data, circulation enhancement evaluation, eradicate purple loosestrife, evaluate oyster fishery start up, evaluate stormwater discharge and potential to better treat runoff with vegetated buffer treatment.
- **<u>Squibnocket Pond</u>**: fin fish and benthic invertebrate survey, aquatic plant survey, Herring Creek elevation survey, continued tidal cycle data from Squibnocket and Menemsha surveyed to a common benchmark, continued water quality data collection, 24 hour dissolved oxygen/salinity/temperature survey, continue toward an active oyster fishery
- **<u>Menemsha Pond:</u>** fin fish and benthic invertebrate survey, eelgrass survey, continued water quality data collection, 24 hour deep basin dissolved oxygen/salinity/temperature survey

<u>Short Term Implementation Goals:</u>

Town Boards & Agencies:

- Together with the Commonwealth, designate Menemsha Pond as an Outstanding Resource primarily for the purpose of shellfish production and marine/brackish habitat. **Chilmark Selectmen, Shellfish Department and DEP**
- Subdivisions meeting the acreage requirements for Chilmark Pond (5.4 acres), Squibnocket Pond (5.4 acres) and Menemsha (as per zoning) meet the loading limits that presently are appropriate for the protection of these ponds. In the Chilmark Pond and Squibnocket Pond watersheds, guest houses should be considered to either require appropriate acreage or to be allowed with the use of nitrogen removing technology for both the primary and guest houses. **Both Town Planning Boards.**
- Request Division of Marine Fisheries (DMF) to carry out fin fish surveys in all three ponds. Request particular attention to impacts of increasing salinity in Squibnocket Pond. Request DMF to evaluate potential to enhance the herring run in Chilmark Pond. - **both Towns Selectmen & DMF**.
- Request Natural Resource Conservation Service to examine road runoff at stream crossings - **both Towns Selectmen**.
- Pressure Massachusetts Highways to evaluate and correct runoff problem on State Road at Herring Creek crossing and to evaluate Hariph's Bridge in response to NRCS evaluation. **Both Towns Selectmen.**
- Request NRCS to work with farms abutting coastal ponds and streams draining to them to improve runoff control and pollutant removal from pastures and to encourage continued use of legume mixes in hay and pasture - **Dukes Conservation District and Chilmark Conservation Commission**.
- Together with the Chilmark Pond Sewers obtain appropriate permits for regular pond openings and provide funding to evaluate and define dredging project(s) to enhance circulation and flushing of Chilmark Pond. **Chilmark Selectmen, Pond Sewers and Chilmark Pond Association.**
- Attempt to prolong the opening lifetime for a 14 day period through repeated channel excavation in spring over 4 to 8 weeks. **Chilmark Pond Sewers.**

- Schedule Chilmark Pond openings for spring tides during spring/early summer, late fall and winter until better information clarifies the impact of late summer openings. **Chilmark Pond Sewers**
- **Shellfish Department and Selectmen** consider desired uses and water resource quality goals appropriate for Chilmark Pond.
- Encourage shellfish production in Menemsha and Squibnocket Ponds through a program of bottom or water column grants with guidance from and in cooperation with the MV Shellfish Group. **Both Towns Shellfish Departments and Selectmen.**
- Work with MV Shellfish Group to evaluate possible oyster fishery start up in Chilmark Pond. **Chilmark Shellfish Department**
- Raise annual water quality survey funds to support Wampanoag Tribe of Gay Head (Aquinnah) (WTGHA) in Squibnocket and Menemsha Ponds. Suggested minimum budget for each pond is $10000 per year for three year period. **Both Towns**.
- Raise annual water quality survey funds for Chilmark Pond. Suggested minimum budget is $10000 per year for a three year period. **Chilmark Selectmen and Pond Sewers.**
- Consider establishment of Squibnocket Pond DCPC in Aquinnah as a means to implement nitrogen loading control. **Aquinnah Planning Board.**
- Seek/provide funding for a definitive evaluation of the acceptable loading of nitrogen to Squibnocket and Chilmark ponds based on primary production. **Both Towns.**
- Work with MV Land Bank Advisory Committee to identify and secure conservation lands in the watersheds of all three ponds. As per the Open Space Plan (1995) target lots in Tables 17, 19 and 22 in Task 7 for acquisition or easement. **Both Towns Land Bank Advisory Boards.**
- Within Squibnocket and Chilmark Ponds watersheds, encourage the use of nitrogen removing technology possibly by a real estate tax rebate plus the acreage incentive. Use 33 percent nitrogen reduction in calculating nitrogen loading from these systems until valid study of effluent quality provides a better figure. This technology may be used to reduce lot size minimums. **Both Towns Boards of Health and Selectmen.**
- Develop low maintenance landscape handout for all new homeowners. **Both Towns Conservation Commissions.**

Wampanoag Tribe:

- Continue annual water quality survey in Menemsha and Squibnocket Ponds.
- Survey Herring Creek channel to determine if channel deepening is feasible to improve circulation.
- Continue with shellfish propagation plans as a means of nutrient reduction. Work with MVSG on oyster fishery development in Squibnocket Pond.
- Lobby for correction of State Road runoff problems at Herring Creek and possibly at Hariph's Bridge.

Squibnocket Pond District Advisory Committee:

Continue public awareness/education campaign to reduce scale of landscaping in the watershed.

Martha's Vineyard Commission:

- Develop a public education program on denitrifying septic systems.

- Assist with preparation of a brochure on low maintenance landscaping.
- Assist with identifying sources of funding support for recommended actions.

Possible Sources of Financial Assistance Other than Town Meeting Appropriations:
Coastal Pollution Remediation Program: Ideal for correcting road runoff problems. Requires a local match that can be in-kind.
Section 319h Program: This program is directed toward non-point source reduction implementation.
DEM Lakes & Ponds Grant: This program funds up to $10000 with a required match for study of lakes or ponds aimed at developing management plans.

Long Term Program:

- For the longer term or as an alternative to the lot size requirements outlined in the Short Term Strategy, adopt the loading limit as revised by further research for **new** lots. Large lots that will not be further subdivided in recharge areas that do not use their allowed loading may be used as credit to smaller lots. This must be carefully done so that overall pond loading limits are not exceeded and so that the individual coves are not overloaded with nitrogen due to concentration of small lots. Nitrogen removing technology for sewage treatment would allow smaller lots. Allow guest houses only on adequately sized lots.
- As an option, devise a nitrogen transfer program to allow purchase of loading rights to reduce the size required for new lots particularly if availability of low/moderate income housing stock becomes limited. This program should only be implemented after careful scrutiny of the potential to overload restricted coves by transferring in too much nitrogen loading to their recharge areas.
- A one way transfer of development rights program to move development out of the recharge areas of Chilmark and Squibnocket Ponds may be used if necessary to move nitrogen loading to recharge areas of ponds with better flushing such as Menemsha Pond or the north shore.
- Exercise extreme caution in allowing privately owned wastewater treatment facilities as a way to meet nitrogen loading limits. These systems must be evaluated based on hydrology and a careful evaluation of loading to the pond system as well as the individual cove into which the system will discharge. Strict maintenance programs are necessary for optimal operation. As the number of houses in Menemsha Village converting to year round occupation increases, evaluate the potential for sewage collection and treatment.
- As indicated by further research, adopt a phosphorus buffer of 300 feet in the Squibnocket Pond District (if adopted) in Aquinnah or the Coastal DCPC where septic system leaching areas are not allowed without advanced treatment.
- Consider a similar restriction within the coastal DCPC around both Upper and Lower Chilmark Pond.

- Based on pond research adjust allowed nitrogen loading and enforcement programs to satisfy the required annual loading limit.
- As they are installed, implement a maintenance/inspection program for advanced on-lot septic systems. Initially, this might be done in partnership with other Towns as a regional inspection program. Older systems located within the Coastal District should be included to assure that they are in good condition and are properly operating.
- Target an annual shellfish harvest from Squibnocket Pond of 2000 bushels removing approximately 200 kilograms of nitrogen.
- As part of Squibnocket Pond District Advisory Committee newsletter, include regular articles on the need for and the means to reduce residential nitrogen loads. Encourage the use of compost piles instead of garbage disposal through the on site wastewater disposal system.

TABLE 35

Advantages & Disadvantages of Management Options

Recharge Area Options	Advantages	Disadvantages
Sewage Treatment Plant: Service to Menemsha Village	Substantial nitrogen reduction possible Does not require individual system O & M program as with on-lot upgrades	Cost of connection Risk of growth stimulation. Lack of treatment/disposal sites
Advanced On-Lot Sewage Treatment	Cost borne by homeowners not Town Moderate to Substantial reduction of Nitrogen Loading Could be done as a regional program with other Towns	Cost of upgrade Requires an inspection program Seasonal use may reduce nitrogen removal Regressive cost impact on less wealthy individuals.
Landscape Nitrogen reduction	Low cost item for all Only limited fertilization practiced- does not represent a major change in current practices Could provide a substantial loading reduction over possible future loading	Requires public interest and support Limited quantity of nitrogen saved over today's loading from this source Not an easily enforced program
Farm Nitrogen Loading	Low cost item & program is in place	Requires added management Requires operator dedication and interest Not easily enforced Could save only small amounts of nitrogen

Advantages & Disadvantages of Management Options *continued*

Recharge Area Options	Advantages	Disadvantages
Dredging Tidal Flats (Chilmark Pond) Circulation Improvement	Use spoil to nourish South Beach Dredging Long Point may improve internal circulation	Enhanced flushing may still be limited by South shore winds Permitting
Deepening Herring Creek (Squibnocket) Circulation Improvment	Probably would increase tidal exchange Nitrogen loading restrictions could be eliminated Possible reduction in nuisance algae and reeds Relatively low cost	Salinity increase may impact some species Permitting
South Beach Sluiceway (Chilmark Pond) Circulation Improvment	Allows precise control of flushing Not a high cost item	Needs Engineering to assess feasibility More saltwater may cause algae blooms Possibility of annual repair costs Possibility of periodic severe damage Edgartown has run into a permitting road block
Windmills Circulation Improvment	Reduces dependency on a successful inlet	Number and cost of windmills substantial Aesthetics of large number of windmills Annual O & M of windmills
Aquaculture	Convert nutrients into food Support shellfish industry Possibility for private industry operation Dollars earned cycle in local economy	Diseases limit potential success Production of waste products may need treatment strategy

Advantages & Disadvantages of Management Options *continued*

Recharge Area Options	Advantages	Disadvantages
Purchase Easement or Fee (Conservation lands)	Multiple uses allowed Multiple purposes realized	Cost of purchase Less land available may increase cost per acre
Zoning Changes	Reduces density and nitrogen loading fairly Lower density means lower population and reduces traffic and infrastructure costs	Larger lots may be less affordable Snob zoning limit at 3 acres Most of Chilmark is 3 acres now
Health Code Changes (Denitrification systems)	Easily adopted through a public hearing process. Not as fixed as a zoning change because an owner can meet requirements with technology.	Technology will eventually meet code requirements freeing up more growth.
Nitrogen Transfer Program	Allows growth to occur as lot owners desire yet meets overall recharge area nitrogen limit.	Requires some administration. Must be designed to protect other sensitive ponds. Regressive cost impact on less wealthy individuals.

		DECISION	MATRIX		1= Best	5= Worst/Leas
ACTION	**WHO ACTS**	**N REDUCTION POTENTIAL**	**COST FACTOR**	**IMPLEMENTATION DIFFICULTY**	**PUBLIC ACCEPTANCE**	**PRIORITY LEVEL**
Denitrifying Septic	BOH	1	3	3	2	1
Adopt Nitrogen Loading Limit/ac.	BOH PB PAC	1	3	2	2	1
Increase Lot Sizes	PB PAC	1	4 (purchase $)	3 (snob zoning if> 3 acres)	4	3
Expanded DCPC	PB PAC MVC	1	3	3	3	2.5
Buy Open Space	Cons.- Town- MVLB	1	4	2	1	2
Limit Turf Area	PB- CC -PAC	3	1	4 (enforcement?)	2	3
Reduce Farm Nitrogen	NRCS Farmers	3	2	3	2	2.5
Provide in Watershed Sewage Collection	SC- BOH	1	3 for individuals 5 for Town	5 (existing units spread out)	3 (Town) 4 (home owners to be tied in)	4
Nitrogen Transfer	BOH PAC	5	3	3	2	3
Recondition Herring Creek (Squibnocket)	SD- Selectmen-TRIBE	1.5 (better flushing)	2	3 (needs further study/permits)	1	2
Increase Herring Population	SD- DMF-TRIBE	4	1	1 (may not be feasible- more study)	1	2
Increase Shellfish Harvest	SD- MVSG-TRIBE	4	2	2 (need better understanding of today's yield)	1	2
Prolong Inlet Life	SD- CPA	2	1 For excavation 2 For structure	1 For excavation 4 For Structure	1	1
Pipe for Flushing	SD-CPA	3	3	5	1	3
Dredge Tidal Flats	SD-CPA-Con Com.	3	3	2	1	2

BOH =Board of Health **CC** = Conservation Commission **Cons.** = Conservation Organizations **CPA =** Chilmark Pond Assoc. **DC** = Dredge Comm. **DMF** = Division of Marine Fisheries **MVC** = MV Commission **MVSG** = M. V. Shellfish Group **NRCS** = Natural Resource Conservation Service **PAC** = Squib. Ponds Advisory Committee **PB** = Planning Board **SC** = Sewer Commission **SD** = Shellfish Dept.

Public Involvement:

October 30, 2000	Squibnocket Pond District Advisory Committee Meeting
August 2000	Squibnocket Pond District Advisory Committee Newsletter
August 30, 2000	Meet with Aquinnah Planning, Conservation and MV Commission members
August 28, 2000	Squibnocket Pond District Advisory Committee Meeting
July 2000	Draft Reports to Libraries and Planning, Health, Conservation and Selectmen in Chilmark and Aquinnah. Also to MV Commission members and Wampanoag Tribe.
June 21, 2000	Meet with Chilmark Board of Health
June 7, 2000	Public Presentation Advertised in Gazette and Times
April 29, 2000	Display at Earth Day celebration, MV Regional High School
July 21, 1999	Meet with Chilmark Board of Health
March 1, 1999	Meet with Squibnocket Pond District Advisory Committee

References Cited

Andreoli, A., et al (1979) Nitrogen removal in a subsurface disposal system Journal of Water Pollution Control Federation vol. 51 #4 pp: 841-854

Bodek, I. et al Editors (1988) Environmental Inorganic Chemistry: Properties, Processes and Estimation Methods. A Special Publication of SETAC: Pergamon Press, NY

Chesapeake Executive Council (1989) Chesapeake Bay Alosid Management Plan. Annapolis, MD

Colarusso, Phil (1999) PhD candidate researching eelgrass beds including Menemsha Pond

Costa, J.E., B. L. Howes, D. Janik, D. Aubrey, E. Gunn, A. E. Giblin (1999) Managing anthropogenic nitrogen inputs to coastal embayments: Technical basis and evaluation of a management strategy adopted for Buzzards Bay. Buzzards Bay Technical Report—Draft Final.

Costa, J.E., E. Gunn and B. Howes (1996) Report of the Buzzard's Bay Citizen's Water Quality Monitoring Program 1992-1995. Coalition for Buzzard's Bay & Buzzard's Bay Project

Cottle, Marguerite (2000) Personal Communication

ENSR (2000) Collection and Evaluation of Ambient Nutrient data for Lakes, Ponds and Reservoirs in New England. Interim Final Rept., NEIWPCC Doc. # 8726-780-600.

Environmental Management Institute (1976) Subsurface Leachate Discharges Into Johns Pond, Mashpee. Prepared for Town of Mashpee

EPA (1993) Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters. 840-B-92-002

EPA (1978) National Eutrophication Survey Methods for Lakes Sampled in 1972. Working paper #1, Corvallis Environmental Research Lab, Corvallis, OR

EPA (1993) Manual of Nitrogen Control. EPA/625/R-93/010 9/93

EPA (1997) The Potential for Nutrient Loadings from Septic Systems to Ground and Surface Water resources and Chesapeake Bay. #903-R-97-006

Friedman, J., R. Donnellan & G. Nickerson (1976) Regulation of Harbors and Ponds of Martha's Vineyard. Woods Hole Oceanographic, WHOI-76-56

Frimpter, M., J. Donahue and M. Rapacz (1988) A Mass Balance Nitrate Model for Predicting the Effects of Land Use on Groundwater Quality in Municipal Wellhead Protection Areas. Cape Cod Aquifer Management Project

Gaines, A. (1990) Areawide Planning and Management: Squibnocket Pond Coastal Resources Complex. Woods Hole Oceanographic Marine Policy Ctr.

Gaines, A. (1993) Coastal Resources Planning and Management: Edgartown Great Pond. WHOI, Woods Hole, MA.

Gaines, A. (1995) A Natural Systems Analysis of Sengekontacket Pond. Final Report. Marine Policy Center, Woods Hole Oceanographic Institution, Woods Hole, MA. 72 pp.

Gaines, A. (1996) An Artificial Inlet for Application on a Seasonally High Energy Barrier Beach. Proposal to Boldwater Homeowners by Coast & Harbor Consultants

Gaines, A. (1998) Nutrient Loading Limits for Edgartown Great Pond. IN: Wilcox, 1999 Op Cit.
Gaines, A. and J. Broadus(1990 Areawide Planning & Management: Squibnocket Pond Coastal Resources Complex. Marine Policy Center, WHOI
Hatch, J. (1998) Univ. of Mass., Boston: Personal Communication.
Hauxwell, J, J. Cebrian and I. Valiela (1998) Nitrogen Enrichment of Estuaries: Understanding the shift from Eelgrass to Seaweed Dominated Communities. NEERS Conference October 1998, Falmouth, MA
Healy, K. (1995) Mill Brook and Tiasquam River Inflow. IN: Wilcox, W. (1996) Tisbury Great Pond Watershed Study, MV Commission
Horsley, Witten, Hegemann, Inc. (1991) Quantification and Control of Nitrogen Inputs to Buttermilk Bay. Volume I
Howes, B.L. et al (1996) Nantucket Harbor Study. WHOI, Woods Hole, MA.
Jackson, Scott (1999) Wildlife Biologist, UMass Dept. Fisheries & Wildlife Mgmt.
Karney, R. (1998) MV Shellfish Group Marine Biologist. Personal Comm.
Kaye, C. (1964) Illinoian and Early Wisconsin Moraines of Martha's Vineyard, MA. USGS Prof. Paper 501-C, pp. C140-c143.
Kaye, C. (1972)Preliminary surficial geologic map of Martha's Vineyard, Noman's Land and parts of Naushon and Pasque Islands, Massachusetts. USGS Open File map
Kennish, M.J. (1996) Estuarine and Marine Pollution. CRC Press
Kerfoot, W.B. (1980?)Septic System Leachate Surveys for Rural Lake Communities: A Winter Survey of Otter Tail Lake, Minnesota. In: NSF 6th National Conference: Individual Onsite Wastewater Systems
Kroeger, K., D. Corcoran, J. Moorman, J. Michalowski and I. Valiela (1998) The Relative Sizes of Atmospheric Deposition, Fertilizer Use and Wastewater from Septic Systems and a Sewage Treatment Plant as Nitrogen Loads to Green Pond, Cape Cod MA NEERS Conference Abstract, Falmouth, MA.
Logan, G.T., F.B. Titlow & D.G. Schall (1996) The Scientific Basis for Protecting Buffer Zones. Working Draft
Lovewell, Mark (2000) National Weather Service Observer, Edgartown, Personal Communication
Martha's Vineyard Commission (1998) Data Report, Dukes County, MA. 1998
Mass. Dept. of Public Works (1989) Highway Design Manual
Mass. Division of Water Pollution Control (1977) Martha's Vineyard Water Quality Study
Mass. Dept. of Environmental Protection (1997) Massachusetts Surface Water Quality Standards. 314CMR4.00.
Metropolitan Washington Council (1987) See Schueler below.
Millero, F.J.(1996) Chemical Oceanography. Second Edition. CRC Press, Boca Raton, FLA.
NOAA (1996) Estuarine Eutrophic Survey; Office of Ocean Resources Conservation and Assessment, Silver Springs, MD.
Nixon, S. W. (1981) Remineralization and Nutrient Cycling in Coastal Marine Ecosystems. IN: Estuaries and Nutrients, Neilson and Cronin eds. Humana Press, Clifton, N. J.

Nixon, S. W., S.L. Granger & B.L. Nowicki(1995) An Assessment of the Annual Mass Balance of Carbon, Nitrogen and Phosphorus in Narragansett Bay Biogeochem 31: 15-61
Oldale, R.N.(1992) Cape Cod and the Islands: Geologic Story. Parnassus Imprints, East Orleans, MA.
Paerl, H. (1993) Emerging Role of Atmospheric Nitrogen Deposition in Coastal Eutrophication: Biogeochemical and Trophic Perspectives. Can. J. Fish. Aquat. Sci. 50: 2254-2269
Poole, B. (1988) Diagnostic/Feasibility Study for Lagoon Pond. SP Engineering Inc., Salem, MA
Portnoy, J.W., B.L. Nowicki, C.T. Roman & D.W.Urish (1998) The Discharge of Nitrate-Contaminated Groundwater from Developed Shoreline to Marsh-Fringed Estuary. Water Resources Research 34 #11: 3095-3104
Rask, S. (1998) Alternative Septic Systems: Results of Monitoring Reported to DEP as of March, 1998. Barnstable Cty. Dept. of Health & Environment
Redfield, A.C., B.H. Ketchum & F.A. Richards (1963) The Influence of Organisms on the Composition of Sea Water. In: N.M. Hill, Ed. The Sea, Vol. 2, Wiley Interscience, NY, pp. 26-77
Reid, G. (1961) Ecology of Inland Waters and Estuaries. Van Nostrand Co. NY.
Rice, M. (date?) Control of Eutrophication by Bivalves: Filtration of Particulates and Removal of Nitrogen Through Harvest of Rapidly Growing Stocks. Publication 3681 College of the Environment and Life Sciences, University of Rhode Island, Kingston, RI 02881
Schueler, Thomas(1987) Metropolitan Washington Council of Governments Controlling Urban Runoff
Seitzinger, S. & R. Sanders (1999) Atmospheric inputs of dissolved organic nitrogen stimulate estuarine bacteria and phytoplankton. Limnol. Oceanogr. 44(3): pp 721-730.
Shayan, A. and B.G. Davey (1978) A Universal Dimensionless Phosphate Absorption Isotherm for Soil, Soil Sci. Soc. Am. J. 42: 878-882
Sims, J. T. (1992) Environmental Management of Phosphorus In Agricultural and Municipal Wastes. In: Future Directions for Ag. Pollution Research, ed. F. J. Sikora. Tenn. Valley Authority, Muscle Shoals, Al. Bulletin Y224
Skomal, G.B. (1998) Fin fish Survey: Edgartown Great Pond. Third Quarterly Report: Mass. Div. Of Mar. Fish.
Smith, R.L., B.L. Howes and J.H. Duff (1991) Denitrification in Nitrate-Contaminated Groundwater: Occurrence in Steep Vertical Geochemical Gradients. Geochemica et Cosmochemica Acta 55, #7: 1815-1825
Taylor, J. (2000) Nutrient Loading to Tisbury Great Pond. MV Commission Draft
Uchupi, E. & R. Oldale (1994) Spring sapping origin of the enigmatic valleys of Cape Cod and Martha's Vineyard and Nantucket islands: Geomorphology, v. p pp. 83-95
Uchupi, E., G. Giese, D. Aubrey & D. Kim (1996) The Late Quarternary Construction of Cape Cod, Mass. GSA Special Paper 309

US Geological Survey (1994) Effects of Storm Paths on Precipitation Chemistry and Variations of Within-Storm Chemistry During Selected Storms in Central Ma., 1986-1987. Water Resources Investigation Report 94-4084
US Geological Survey (1993) Relation of Precipitation Quality to Storm Type, and Deposition of Dissolved Chemical Constituents from Precipitation in Mass., 1983-1985. Water Resources Investigation Report 94-4224
USGS (1995) A Nitrogen Rich Septage Effluent Plume in a Glacial Aquifer, Cape Cod, Mass. Open File Rept. 95-290
Valiela, I., J. Costa, K. Foreman, J.M. Teal, B.L. Howes and D. Aubrey (1990) Transport of groundwater-borne nutrients from watersheds and their effects on coastal waters. Biogeochem.10: 177-197
Valiela, I., et al (1992) Couplings of watersheds and coastal waters: sources and consequences of nutrient enrichment in Waquoit Bay. Estuaries, 15, 443.
Visher, S. (1966) Climatic Atlas of the United States. Harvard Univ. Press
Vollenweider, R. A. (1976) Advances in Defining Critical Loading Levels for Phosphorus in Lake Eutrophication. Mem. Ital. Idrobiologia 33: pp 53-83.
Wakeman, Seth (2000) Personal communication)
Walne, P.R.(1974) Culture of bivalve Mollusks: 50 Years Experience at Conwy. Fishing News Books, Ltd. Surrey, England
Walsh, D. T., J.L. Madison, L.C. Vanderhoop, G.L. Cook, J. Jeffers & D. Luce (1979) The Wampanoag Fisheries Project: Shellfish Production Improvement at Gay Head, 2nd Annual Report
Weiskel, P.K. and B.L. Howes (1992) Differential Transport of Sewage Derived Nitrogen and Phosphorus through a Coastal Watershed. Environmental Science & Technology, 26: 352-360
Weiskel, P.K., B. L. Howes and G. R. Heufelder (1996) Coliform Contamination of a Coastal Embayment: Sources and Transport Pathways. Env. Sci. & Tech. 30, #6 pp. 1872-1881
Wetzel, R.G. (1983) Limnology. Second edition. Harcourt Brace Publishers
Wilcox, W.M. (1999) Island Coastal Ponds Water Quality Survey, 1995-1996: Great Ponds Report. MV Shellfish, MV Commission, UMass Extension
Wilcox, W. M.(1999) Edgartown Great Pond: Nutrient Loading and Recommended Management Plan. MV Commission
Wilcox, W.M. (1986) Vineyard Farm Survey. Unpublished Survey.
Wolf, P. R. and R. C. Brinker (1994) Elementary Surveying. 9th Edition Harper Collins College Publishers, NY.

APPENDIX A NOT INCLUDED IN DIGITAL VERSION

APPENDIX B

<u>Phosphorus</u>

Phosphorus in the Water Column:

Phosphorus is another major nutrient required for production of phytoplankton, algae and rooted macrophtyes in the marine and brackish systems. From the ratio of inorganic nitrogen to orthophosphate found in the water column in the Edgartown and Tisbury Great Ponds, it appears that there may be time periods when phosphorus becomes limiting to the biological system (Wilcox, 1999). Typically these times occur during the winter and spring when biological systems are operating at lower levels. During the growing season (May through September) nitrogen is consistently the limiting nutrient. While these ponds have differences when compared to Chilmark Pond, there are enough similarities to support an assumption of a similar seasonal variation in limiting nutrients.

During the 1999 and 2000 growing seasons, the data collected from Chilmark Pond (both Upper and Lower Ponds) were nitrogen limited as indicated by the ratio of inorganic nitrogen to orthophosphate. However, during the early August 1999, sampling round, there was excess nitrogen in the Lower Pond with nitrogen to phosphorus ratios well in excess of 16 to 1. The increase in nitrogen may relate to the early June opening which dropped the Lower Pond by 3.5 feet. The increased flow into the Lower Pond from the Upper Pond and the streams and groundwater probably added nitrogen.

Average orthophosphate concentrations in the Upper Pond ranged from 1.01 to 2.09 micromoles per liter, two to three times the average concentrations found in the Lower Pond. The higher average values result from high concentrations in the July and August 2000, sampling rounds (see Table 2 in Task 2). Elevated phosphorus concentrations were not found in the Lower Pond in the 2000 sampling rounds. I would suggest that this phenomenon is the result of higher than average rainfall in the June through August period in 2000 and lower than normal rain in the same period in 1999. Excess phosphorus in the Upper Pond probably is a result of increased runoff from roads and bordering uplands.

Data collected from Squibnocket and Menemsha during 1995 (Wilcox, 1999), indicate that Squibnocket varies from being nitrogen limited to being phosphorus limited. Menemsha Pond was found to be consistently nitrogen limited. It appears that there is a close association between the tidal nature of a pond and its limiting nutrient i. e. the more tidal a pond system is the stronger and more persistent is the nitrogen limitation on growth.

Phosphorus Sources:

In a study of Edgartown Great Pond, Gaines (IN Wilcox, 1999) concluded: “Phosphorus inputs appear largely derived from ocean sources and is not associated with groundwater discharge to the pond.” In the literature, phosphorus from groundwater sources is generally thought of as being a minimal contribution to nutrient loading. In general, the literature indicates that phosphorus is only introduced from the land side in significant amounts from surface runoff and by stream discharges.

Sources: Street Runoff

Phosphorus may comprise 0.01 to 0.2 percent by weight of natural soils (EPA, 1993). Most cropped soils have increased phosphorus content to high or very high levels due to past fertilizer practices (Sims, 1992). In soils it occurs as dissolved inorganic, colloidal and particulate forms. Phosphorus is strongly bonded in acidic soils to aluminum and iron creating an insoluble precipitate. Native soils in the area are acid. Phosphorus is also relatively insoluble in water (10 to 15 ppb). For these reasons, it is not considered a mobile nutrient. Orthophosphate (dissolved inorganic) is the form directly available to algae. Because of this tendency to bind in the soil, erosion and runoff of soil particles directly into water resources is the prime means of entry from agricultural, forestry and other disturbed sites. The amount of phosphorus released from a site is proportional to the area disturbed and the nature and sufficiency of phosphorus removing treatments such as buffer strips and infiltration basins which bring the phosphorus discharge into contact with the soils which can bind it or through dense vegetation which filters out eroded sediment bearing phosphorus.

Runoff from paved areas discharging directly to surface waters is also a potential source of phosphorus. In addition to heavy metals, salt, sediment, bacteria and other pathogenic organisms, nutrients are carried with the rain as it washes down the streets. Suburban areas generate runoff with total phosphorus concentrations of about 0.26 mg/l and orthophosphate about 0.12 (Schueler, 1987). Runoff also carries dissolved inorganic nitrogen (0.74 mg/l) and total nitrogen (2 mg/L).

The portions of the watersheds that are most likely to generate runoff that will reach the ponds are the roads that cross streams flowing to the ponds or portions of the pond itself. The amount of runoff generated is dependent on the area of the road leading up to the discharge point. Many of our roads have had their discharge points relocated to release points that flow to vegetated borders on the margins of streams or wetlands in an attempt to minimize the impact on water quality.

The quantity of runoff generated from a paved area is dependent on the amount and rate of rainfall. Generally, about 60 to 80 percent of the rainfall events of less than 1 inch will generate some runoff. The percentage increases with the total amount of rain from the storm. For rainfall of 1 to 2 inches, runoff is 80 to 90 percent and for rain in excess of 2 inches, the percentage gradually increases to 95 percent. (All drawn from USDA Soil Conservation Service Field Manual).

Days with 1 inch or more of total rainfall averaged 10 per year from the Edgartown data set (New England Climatic Service). The majority of the annual rainfall in our area comes in events of less than 1 inch. In the calculations which follow, I assume that 75% of the annual rainfall falling on roads draining to streams will be released as runoff at the stream crossings. On average, this amounts to 35.2 inches or 2.93 feet. Table C-1 summarizes runoff estimates for the following stream crossings.

The discharges of street runoff directly to the streams flowing to Chilmark Pond include, both branches of the Fulling Mill Brook at the South Road crossings, the unnamed stream flowing from the Allen Farm at the South Road crossing and the Mill Brook at road crossings on South Road and the Menemsha Cross Road.

The South Road crossing of the channel connecting Nashaquitsa and Stonewall Ponds at Hariph's Bridge has some potential for runoff discharge into Menemsha Pond. In addition where South Road crosses the Herring Creek there is a likelihood of runoff discharge into the Creek which mostly flows to Menemsha Pond. The developed area at Menemsha Basin also will contribute runoff to the harbor area.

The Black Brook crossings of Moshup's Trail and South Road are the primary sites where road runoff may enter the Squibnocket Pond system.

Table C-1 Road Runoff Estimates for Stream Crossings in the Watersheds

POND	**STREAM**	**PAVED AREA feet^2**	**VOLUME feet^3 X 10^6**	**TOTAL Per Pond feet^{3}X 10^6**
Chilmark Pond	Fulling Mill	89976	0.264	
	Mill Brook	55008	0.161	
TOTAL				**0.425**
Menemsha Pond	Hariph's Bridge	62496	0.183	
TOTAL	Herring Creek	47496	0.139	
				0.322
Squibnocket Pond	Black Brook @ Moshup's	25008	0.074	
	Black Brook @ State Road	42504	0.125	
TOTAL				**0.199**

We do not have any analyses of actual runoff at these locations from which to determine an accurate, local loading estimate. However, by using the figures cited above for nutrient concentrations in suburban runoff a good estimate of annual loading can be developed.

CHILMARK POND

DIN	8.91 kilograms
Total Nitrogen	24.1 kilograms
Total Phosphorus	3.1 kilograms
Orthophosphate	1.4 kilograms

MENEMSHA POND

DIN	6.75 kilograms
Total Nitrogen	18.2 kilograms

Total Phosphorus	2.4 kilograms
Orthophosphate	1.1 kilograms
SQUIBNOCKET POND	
DIN	4.2 kilograms
Total Nitrogen	11.3 kilograms
Total Phosphorus	1.5 kilograms
Orthophosphate	0.68 kilograms

It is clear that nitrogen additions from runoff at the road crossings are not significant when compared to the other sources in the watersheds. The level of loading of nitrogen is less than 3 percent of the acid rain loading to Chilmark Pond and less than 1 percent for Menemsha and Squibnocket Ponds. Phosphorus loading will be compared later in this section.

Sources: Agricultural Runoff

Agricultural operations are primarily limited to the Upper Chilmark Pond recharge area. The farms which abut the Pond or streams flowing to it have a somewhat greater potential to contribute nitrogen and phosphorus loading to the system. These farms include the Allen Farm with pastures bordering the Upper Pond itself and the unnamed stream flowing to it. In addition, the farm at Bliss Pond and that along Menemsha Crossroad near the South Road intersection are situated near Mill Brook. These farms are animal operations where soil disturbance in the form of plowing is infrequent. In fact, much of the pasture area at the Allen Farm was established without plowing. Lack of soil disturbance greatly reduces the potential for sediment erosion and runoff carrying nutrients, particularly phosphorus, into the Pond.

The most appropriate practice to reduce phosphorus loading from these farms is the provision of vegetated buffer areas between farm fields and water resources. Vegetated buffers are very effective in the removal of total suspended solids from runoff. The level of treatment varies with slope, soil, vegetation type, the moisture conditions before the runoff event and the type of pollutant. Generally 50 to 100 feet of buffer appears to be effective in the removal of sediment and the retention of phosphorus (Logan et al, 1986). Bordering wetlands are also effective nutrient traps if their functions are not compromised by either sediment overload or by extreme volumes of runoff.

Fertilizer applications to these farms are not believed to represent a serious water resource threat. The Allen Farm uses minimal organic fertilizer applications, relying on legumes and animal droppings during grazing as the primary sources of soil fertility. Nitrogen loading from fertilizer applications on all farms is calculated in Task 8. Phosphorus loading from fertilizers is an even smaller concern due to the tendency for soil bonding of phosphorus and the relative large distance of most farms in the watershed from water resources.

Animal manure is dispersed over the area grazed. A considerable portion is left in areas where the animals loaf or are fed. Farm animal nutrient production in manure is substantial on an annual basis. It can be particularly a problem when concentrated in an uncovered stack which can generate runoff to a water resource. Proximity of areas where manure accumulates and the frequency of removal to storage or to spreading on fields are factors in the relative degree of threat from animal waste. EPA (1977) has estimated annual nutrient production as follows:

Animal Type	Total Phosphorus	Total Nitrogen
Cattle	17.60	57.49
Hogs	3.23	9.68
Sheep	1.47	10.06
Poultry	0.09 to 0.39	0.39 to 0.84

These figures are in kilograms per year per animal.

As it is closest to the pond resource and the farm operators were most helpful in discussing their operation, the potential phosphorus loading is discussed for the Allen Farm. The annual phosphorus budget from manure is estimated based on 3 horses, 4 pigs, 50 chickens and an average annual sheep flock of 125 animals at 240 to 300 kilograms. An inspection of the farm fields indicated a substantial buffer of 75 to over 100 feet along the unnamed stream as it approaches discharge into the Upper Pond. The animals in the eastern pasture bordering the Upper Pond do have access to the Pond for drinking water but only limited amounts of droppings were seen. The slope to the pond generally had good grass cover. Consultation with the Natural Resource Conservation Service was suggested to reduce the few areas where runoff potential was observed.

Sources: Groundwater

Phosphorus tends to be attenuated in all but the very coarsest soils through precipitation reactions with aluminum and iron and inorganic adsorption (Bodek, et al, 1988). If steadily supplied, phosphorus can overwhelm these retention mechanisms and over time move further out away from the source. The complexity of the attenuation processes makes it very difficult to model the movement of phosphorus without an enormous input of information to calibrate the model. Simpler models that ignore the detailed mechanisms of attenuation and reflect the overall behavior of the pollutant have been developed (Freundlich and Langmuir models). The behavior of phosphate may follow one type of formula at low concentrations (Freundlich) and a linear formula at high concentrations (Shayan and Davey,1978). In field studies, phosphate has **both** been identified as a pollutant in the ground water and has been found to be an insignificant addition. A review of differing studies follows.

Phosphorus was identified entering Johns Pond in Mashpee from septic leachate (by an Endeco Type 2100 Septic Leachate Detector). The largest volume of wastewater discharge was identified along an area of shoreline down gradient from the Otis trailer park in excess of 100 feet from the Pond. The presence of elevated nitrate, ammonium and phosphorus in the water column correlated with heavy filamentous algae growth (Environmental Management Institute, 1976). In a similar study on sandy soils with high water tables in Minnesota, Kerfoot (ca. 1980) found that, with high groundwater flow rates (> 10 feet per day), the attenuation of phosphate from nearshore septic systems was not high. As the groundwater flow rate to the Chilmark Pond is estimated at about 1 foot per day, this second study offers limited guidance.

Weiskel and Howes (1992) found that phosphate was strongly retained by soils and aquifer materials in the Indian Heights study area in the Buzzard's Bay watershed. The watershed was sited on medium to coarse sandy soils similar to those in portions of the Pond recharge area. The housing density was on the order of one dwelling per quarter acre and had been constant for about 10 years. They attributed the high attenuation rate to inorganic adsorption and precipitation which was so dramatic that the post development increase in phosphate flux through the groundwater was found to be insignificant.

Valiela et al (1990) found that the ratio of nitrogen to phosphorus in sewage effluent plumes in groundwater increased by a factor of 3 to 4 in transit from the point of discharge in the watershed to the point of discharge at a coastal pond. The increase noted implies a mechanism either removing phosphorus or adding nitrogen. The data was developed from sites where sewage was the dominant source of nutrients.

Gaines (Appendix C IN Wilcox, 1999) sampled the Edgartown Great Pond water column in very shallow water around the perimeter of the eastern half of the pond. Strong nitrate and silicate signals were found at the heads of the coves after the pond was breached accompanied by lower salinity. Lower salinity indicated increased ground water discharge bringing these nutrients into the system at those points. No phosphate signal was found indicating it is not carried into the pond in substantial amounts by the groundwater.

Sewage Phosphate Source:

One logical way to address these different conclusions is to assume that effluent discharged from septic systems within a certain distance of the pond will eventually release phosphate into the pond. This approach was used in the Falmouth zoning bylaw where dwellings within 300 feet were considered to be phosphate sources. From an examination of aerial photographs (1998) of the shoreline, the houses found within 300 feet of the shore are as follows:

Chilmark Pond Lower	13 dwellings
Chilmark Pond Upper	10 dwellings
Squibnocket Pond	4 dwellings
Menemsha Pond	
Stonewall	13 dwellings
Nashaquitsa	23 dwellings
Main body	17 dwellings
Menemsha Village	30 dwellings
	1 restaurant
	1 public restroom

The average person releases 3.5 pounds of total phosphorus in their waste per year. The EPA National Eutrophication Survey (1978) estimated that 0.25 pounds (7%) of the total phosphorus in the discharge could reach a surface water body. Over time, as the soil is saturated with bonded phosphorus a somewhat higher annual percentage might reach the water resources.

Using the occupation rates found in Chilmark and Aquinnah as discussed in Tasks 7 and 8, the total annual phosphorus loading from the dwellings identified within 300 feet of shore is as follows:

Chilmark Lower	68.25 pounds (31 kilos)
Chilmark Upper	52.5 pounds (23.8 kilos)
Squibnocket Pond	21 pounds (9.5 kilos)
Menemsha Pond	435.8 pounds (197.6 kilos)
restaurant restrooms	210 pounds (94 kilos)

At 7 percent input, the annual loading of phosphorus from septic leachate to Chilmark Pond 3.84 kilograms. Over the course of the sampling rounds in Chilmark Pond the average total water column content of orthophosphate was 35 to 40 kilograms. Wetzel (1983) indicates that, in fresh waters, inorganic soluble phosphorus is approximately 5 percent of the total phosphorus in the water column. A reasonable estimate of total phosphorus in Chilmark Pond is around 700 kilograms. From this perspective, the annual loading from septic system leachate is insignificant.

Data from Squibnocket Pond collected in 1995 indicate average water column orthophosphate of 0.7 to 1.2 micromoles per liter. The total orthophosphate content of the water column based on this range is 138 kilograms. Using the same reasoning as for Chilmark Pond, total phosphorus is about 2765 kilograms. The addition of less than 1 kilogram per year from nearby dwellings is not a significant factor.

The addition to Menemsha Pond is more substantial amounting to 20 kilograms of total phosphorus per year. Average orthophosphate content of the water column during 1995, was 0.4 to 0.5 micromoles per liter. At mid-tide volume this amounts to 70 kilograms of orthophosphate or 1400 kilograms of total phosphorus. Each tidal prism amounts to nearly 50 percent of the pond volume leading to a 95 percent exchange of the pond every 3.2 days. Excess phosphorus can be quickly circulated out of the system.

Rainfall Sources:

Nixon (1995) sited a study in Narragansett Bay which measured the deposition of total phosphorus from the atmosphere at 390 micro-moles (12.1 milligrams) per meter square per year. A two year study by the USGS (1995) found that the two year average orthophosphate content at the Truro gauge was 2.89 milligrams per square meter (93.2 micro-moles/m^2). The difference may be accounted for by filtration at the Truro site through a 0.4 micron filter prior to analyses (therefore it does not include particulate phosphorus). Assuming these two figures as the range of release of phosphorus from the atmosphere into the ponds the total annual addition is:

Chilmark Pond	0.7 X 10^6 square meters	2.0 to 8.5 kilograms
Squibnocket Pond	2.43 X 10^6 square meters	7.0 to 29.4 kilograms
Menemsha Pond	3.2 X 10^6 square meters	9.25 to 38.7 kilograms

Background Orthophosphate Content in the Groundwater:

Background total phosphorus content on the Vineyard was estimated at 0 to 0.09 milligrams per liter (Main, 1986). A survey of private wells found total phosphorus ranging from 0 to 0.08 mg/l (Mass. Div. of water Pollution Control, 1975). The USGS (1995) found background orthophosphate levels at 0.02 mg/l.

With estimated annual discharge from the recharge areas of the ponds, the background phosphorus content can become an important source. If this background level is 0.02 mg/l then an annual discharge of orthophosphate is:

Chilmark Pond	255.7 X 10^6 cubic feet/year	145 kilograms
Squibnocket Pond	105 X 10^6 cubic feet/year	59.5 kilograms
Menemsha Pond	149.6 X 10^6 cubic feet/year	84.7 kilograms

Sources: Landfill and Sewage Treatment Plant:

Down gradient wells at the Aquinnah landfill show the impact of landfill leachate on the groundwater (Smith & Mahoney, 1991). However, phosphorus compounds were not monitored at any time during the course of the well water quality survey. Leachate from landfill materials can include phosphate. It is also high in iron and often acidified which should provide an ideal situation for forming insoluble phosphorus compounds. The landfill has been capped which should greatly reduce the amount of rainfall that passes through landfill waste and reaches the groundwater. The old contaminants may still be traveling toward Squibnocket Pond and should be considered.

Solid waste contains about 0.01 milligrams of phosphate per gram of waste (Fungaroli, 1971). A field experiment found phosphate concentrations on the order of 5 milligrams per liter or less in leachate generated from solid waste (Fungaroli, 1971). The annual recharge through the 3 acre landfill is estimated at 0.25 million cubic feet. If the content were 5 mg/l, a total annual release into the groundwater of 35.4 kilograms of phosphate would result. High iron concentrations in down gradient observation wells (0.4 to 2.4 milligrams per liter) imply large numbers of possible bonding sites for phosphorus. Therefore, somewhat less would arrive at the pond due to absorption. If 7 percent of the released phosphorus were assumed to reach the pond (as with the septic system leachate), the annual addition from the landfill would be less than 10 kilograms.

The sewage treatment plant releases phosphorus in the effluent discharge. The concentration has not been measured during the regular monthly testing. Secondary treatment plants release about 2.3 milligrams per liter (EPA, 1993) while advanced treatment reduces total phosphorus to an average of about 0.53 mg/l (EPA, 1993). The organic portion of the total phosphorus is more likely to be filtered out during seepage through the infiltration beds. Therefore, an appropriate estimate of the amount of orthophosphate reaching the groundwater from the plant would be well below 0.5 mg/l. If we assume that the plant operates at its design capacity on a year round basis, the annual flow is 5.84 million gallons. If the total phosphorus concentration were 0.5 milligrams per liter, the annual loading would be 11 kilograms. This loading would be reduced in transit through the groundwater perhaps as much as is assumed for septic system leachate bringing the loading to the pond to less than 1 kilogram per year.

Table C-2 summarizes the estimates developed in the preceding sections. These estimates are based on numerous assumptions however, it appears that the annual loading of phosphorus from the watershed ranges from 29 percent for Chilmark Pond, to 4 percent for Squibnocket and 30 percent for Menemsha Pond of the average total phosphorus content of the ponds at any one time.

Table C-2 Annual Phosphorus Loading Estimate from Land Based Sources:

	Chilmark Pond	Menemsha	Squibnocket
RUNOFF	3	2	2
NEARBY SEPTIC SYSTEMS	55	292	10
RAINFALL	9	39	29
GROUNDWATER BACKGROUND	145	85	60
TREATMENT PLANT PLUME	0	0	1
LANDFILL PLUME	0	0	10
TOTAL	**212**	**418**	**112**

Natural Sources:

Nixon (1981) concluded that benthic remineralization released nitrogen and phosphorus from bottom sediments with a low proportional ratio of about 3 to 4. His conclusion was that reworking of organic matter brought nitrogen into anaerobic zones where denitrification released nitrogen gas to the air and therefore preferentially released phosphorus into the water column. He estimated that 62 percent of the orthophosphate required to meet estimated primary production was recycled internally in the pond system. The benthic release ranged from 2 to 50 micromoles per meter square per hour. When a rate of 2 micromoles per meter square per hour is applied to these ponds, on an annual basis this would release 380 kilograms (Chilmark Pond), 1320 kilograms (Squibnocket Pond) and 1740 kilograms (Menemsha Pond). At 50 micromoles per hour the annual release increases to 9,500 to 43,500 kilograms per year. Whether these figures apply rigorously to these ponds or not, they probably provide a good indication of the order of magnitude of this source.

Tidal exchange in Menemsha Pond with the ocean has been estimated at 166 million cubic feet per day (Task 6). Offshore waters contain about 0.45 micromoles per liter of orthophosphate (Wilcox, 1999). On an annual basis, some 24,000 kilograms of orthophosphate enters the pond with the flood tides.

These two sources exceed 25,000 kilograms per year at the low end and 75,000 kilograms per year on the high end. It seems clear that land derived sources are relatively insignificant to Menemsha Pond when compared to ocean and in-pond sources.

In the Chilmark Pond and Squibnocket Pond systems, tidal action is a very small factor under present day conditions. On the low end, remineralization is about double the estimated man made loading to Chilmark Pond. At the high end, man made sources are only 2 percent of sediment release sources. For Squibnocket Pond, the man made sources range from less than 10 percent down to less than ½ percent.

Runoff sources including street and agricultural lands will vary from year to year depending on the size, frequency and duration of the storm. These sources may be substantial short term sources but they are a small percentage of the annual phosphorus budget within the ponds. Even so, steps should be taken to provide filtration of these two sources through vegetated buffers.

Recommendations:

- Request Natural Resource Conservation Service to make priority visits to farms that border streams and coastal ponds to assess need for buffer strips, need to divert runoff from areas of manure storage or concentration and to identify alternatives to direct access to water resources for watering stock.
- Request Natural Resource Conservation Service to inspect road runoff potential at stream crossings with an eye toward diverting runoff into vegetated areas. Sites that are identified may qualify for funding under the Coastal Pollution Remediation program.
- Encourage home owners to provide buffers between their turf and abutting coastal waters.
- Attempt to set back septic system leaching areas as far from the pond shores as can reasonably be accomplished within the confines of the lot and placement of the water supply well. The suggested goal for the separation of septic leach area from water resources is 300 feet. The Squibnocket Pond District in Chilmark with the required 500 foot set back should eliminate phosphorus additions from septic systems.

References Cited

Bodek, I., W. Lyman, W. Reehl & D. Rosenblatt (1988) Environmental Inorganic Chemistry. Pergamon Press, New York.
Environmental Management Institute (1976) Subsurface Leachate Discharges into John's Pond, Mashpee. Prepared for the Town of Mashpee
EPA (1977) Nonpoint Source- Stream Nutrient Level Relationships: A Nationwide Study. EPA 600/3-77-105 Ecological Research Series.
EPA (1978) National Eutrophication Survey methods for Lakes Sampled in 1972. Working Paper #1, Corvallis Environmental Research Lab. Corvallis, OR
EPA (1993) Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters. 840-B-92-002
EPA (1993) Manual of Nitrogen Control. EPA/625/R-93/010
Fungaroli, A.(1971) pollution of Subsurface Water by Sanitary Landfill. Interim Report Grant EP-000162 to EPA from Drexel Univ.
Kerfoot, W. (1980?) Septic System Leachate Surveys for Rural Lake Communities: A Winter Survey of Otter Tail Lake, MN. IN: NSF 6th National Conference: Individual On Site Wastewater Systems.
Logan, G. T., F. B. Titlow & D. G. Schall (1986) The Scientific Basis for Protecting Buffer Zones. Working Draft Fugro East.
MA. Div. Water Pollution Control (1977) Martha's Vineyard water Quality Study
C. T. Main Engineering (1986) geohydrologic Study for the Edgartown Water Pollution Control Facility.
Nixon, S. (1981) Remineralization and Nutrient Cycling in Coastal Marine Ecosystems. IN: Estuaries and Nutrients. Neilson & Cronin, Ed. Humana Press, Clifton, NJ.
Nixon, S. , S. L. Granger & B. L. Nowicki (1995) An Assessment of the Annual Mass Balance of Carbon, Nitrogen and Phosphorus in Narragansett Bay. Biogeochem. 31:15-61
Scheuler, T. (1987) Metropolitan Washington Council of Governments: Controlling Urban Runoff
Shayan, A. & B. G. Davey (1978) A Universal Dimensionless Phosphate Absorption Isotherm for Soil. Soil Sci. Soc. Am. Journal 42: 878-882
Sims, J. T. (1992) Environmental Management of Phosphorus in Agricultural and Municipal Wastes. IN: Future Directions for Agricultural Pollution research. F. J. Sikora, Ed. Tenn. Valley authority, Muscle Shoals, AL. Bulletin Y224
Smith & Mahoney (1991) Martha's Vineyard Landfill Groundwater Quality Monitoring Program Final Report.
USGS (1995) Relation of precipitation Quality to Storm Type and Deposition of Dissolved Chemical Constituents from precipitation in MA., 1983-1985. USGS Water Resources Investigations Report 94-4224
USGS (1995) A Nitrogen Rich Effluent Plume in a Glacial Aquifer, Cape Cod, MA. Open File Report 95-290.
Valiela, I., J. Costa, K. Foreman, J. Teal, B. Howes & D. Aubrey (1990) Transport of Groundwater-Borne Nutrients from Watersheds and Their Effects on Coastal Waters. Biogeochem. 10: 177-197

Weiskel, P. & Howes, B.(1992) Differential Transport of sewage Derived Nitrogen and Phosphorus through a Coastal Watershed. Env. Sci. & Tech. 26: 352-360
Wetzel, R. (1983) Limnology. Saunders College Publishing. Harcourt Brace Publishers.
Wilcox, W. (1999) Edgartown Great Pond: Nutrient Loading and Recommended Management Program. MV Commission
Wilcox, W. (1999) Island Coastal Pond Water Quality Study: 1995-96 Survey Data. Island Ponds Consortium.

APPENDIX C

GLOSSARY OF TERMS

GLOSSARY OF TERMS

Alga A type of phytoplankton. Plural is algae.

Anadromous Type of fishes which spend most of their lives at sea but migrate to fresh water for breeding (e.g. shad, salmon & herring).

Bathymetry The depth of a water body and information relating to it.

Biomass The weight of all living matter in a particular area at a particular time.

Blooms Dense concentration of phytoplankton which develops under optimum growth conditions. The term algal bloom or algae bloom refers to overgrowth of algae due to excess nutrient input. Usually not a desirable condition due to depletion of dissolved oxygen.

Chlorophyll The green pigment which allows plants to use solar energy to convert carbon dioxide and water into plant matter. The major pigment type is chlorophyll *a* which can be measured as an indicator of water column biomass.

Cubic Foot A volume of water equal to 7.48 gallons, 28.32 liters or 0.03 cubic meters.

Detritus Debris from formerly living organisms including dying plants and animals, broken and damaged plant fragments from feeding or wave action and the waste products from animals living in the pond.

Dissolved oxygen Also DO. Oxygen dissolved in water is essential for plants and animals in an estuary. The quantity dissolved is an indicator of water quality.

Diurnal Referring to an event that occurs within a 24 hour period. For example a diurnal tide is one tidal cycle in a 24 hour period.

Estuary A water body that forms the transition between fresh water and sea water.

Eutrophication The condition of a water body when supplied with excess nutrients.

Flushing Time The time required for a particular water input to a pond (e.g. tide volume or groundwater seepage) to equal the volume of the pond.

Limiting nutrient The nutrient which is lacking in sufficient quantities when compared to other necessary nutrients for an increase in phytoplankton productivity to occur. Used most often in reference to nitrogen phosphorus and silica.

Macrophyte The larger forms of aquatic vegetation including rooted forms such as eelgrass, attached forms such as *codium* and sea lettuce and very few free floating forms like *Sargassum*.

Meter Metric measure of length equal to 3.28 feet.

Microgram A mass equal to one millionth of a gram.

Milligram A mass equal to 0.001 gram or 2 millionths of a pound.

Microgram per Liter A concentration of one microgram in a liter of water equal to one part per billion. **ug/l**

Micromole per Liter A concentration of one millionth of a mole per liter of water. The equivalent in mg/l varies with the atomic weight. **um/l**

Milligram per Liter A concentration of one milligram in a liter of water equal to one part per million. **mg/l**

Moraine A glacial deposit put in place by active ice action and characterized by a diverse mix of particles from clay through boulders.

NTU Nephelometric Turbidity Unit—A measure of light transmission somewhat more precise than the Secchi depth.

Nitrogen One of the major nutrients necessary for growth of phytoplankton. While abundant in the air, it is not very soluble in water and is brought into coastal ponds by streams, groundwater and acid rain from both natural and man-made sources.

Nitrogen fixation A process where nitrogen is converted from gas in the air to organic and inorganic compounds. This process is only performed by a limited number of organisms such as blue-green algae and nitrogen fixing bacteria.

Nutrient loading The amount of nitrogen or phosphorus added to a water body from the air, groundwater and streams. In excess, nutrient loading will lead to algae blooms, loss of eelgrass and low dissolved oxygen.

Nutrients The elements required for life to exist and reproduce. The major nutrients required are nitrogen, phosphorus, oxygen, hydrogen, silica and carbon.

Outwash A glacial meltwater deposit characterized by sand and gravel deposits.

Parts per Thousand A concentration equal to one part of a substance in one thousand parts of water. Equal to 1000 parts per million. **PPT**

Phytoplankton Specifically the floating, single celled, photosynthetic plant life in natural waters also referred to as algae. They are at the base of the food chain.

Productivity A measurement of the amount of biological activity leading to the conversion of light energy, carbon dioxide and water into carbohydrates. Often measured by the rate of oxygen production, the rate of carbon dioxide uptake or the rate of increase of particulate matter.

Recharge The process where rain water filters through the soil to the groundwater.

Recharge Area The area where recharging rain water will flow in the groundwater to a coastal pond. Similar to watershed.

Residence Time The average age of a water particle in an estuary. Therefore, it is the average time required for tidal exchange to remove recently introduced nutrients entering with groundwater. The longer the residence time, the more productivity that can be stimulated by nutrients before they exit the system.

Salinity A measure of the amount of dissolved salts found in the water column, including sodium, calcium, magnesium, and potassium chlorides, sulfates bromides and other compounds. Full strength sea water has a salinity of 35 parts per thousand (PPT). Fresh water has a salinity of 0 PPT. Our coastal salt ponds vary from 28 to 34 PPT in the tidal ponds to 10 to 20 PPT in the Great ponds.

Secchi depth The depth to which a white disk, 1 foot in diameter can be seen in the water column.

Semidiurnal Referring to a process which occurs twice each day. A semidiurnal tide has two high tides and two low tides each day.

Tidal prism The total volume of water exchanged between an estuary and the ocean during the course of a tidal cycle.

Watershed The upland area that drains into a water body directly or into streams which flow to the waterbody. Where there is sufficient information on groundwater flow, the watershed may be drawn to include the area where recharging water moves into the pond. Otherwise, it is based on the surface topography.

ABSTRACT
Chilmark, Menemsha and Squibnocket Ponds:
Nutrient Loading & Recommended Management Program
Prepared by the Martha's Vineyard Commission
Prepared for the Department of Environmental Protection Under Grant #98-04-604
January 2001

The physiological parameters of these three coastal ponds situated on Martha's Vineyard island, Massachusetts were determined including: size and volume of the basins, area within the watersheds and tide range and residence time. Bathymetry and basin volume of Chilmark Pond was developed from field data while that for Squibnocket and Menemsha Ponds was based on existing data. Current water quality of Chilmark Pond was assessed in the field and based on previous study for Menemsha and Squibnocket Ponds. Nutrient loading estimates were prepared for each watershed based on current land use as indicated in Assessor's Office records. Nitrogen loading limits were determined based on residence time and desired water resource quality goals.

Due to its short residence time of 3.2 days, Menemsha Pond is not expected to exceed the appropriate nitrogen loading limit for highest quality coastal waters even under the highest projected loading rates. Squibnocket Pond will exceed the nitrogen loading limit for reduced quality coastal waters under the highest growth scenario but projected loading may be reduced by watershed nutrient management to an acceptable level through minor adjustment in land use controls. Chilmark Pond will exceed the appropriate nitrogen loading limit for reduced quality coastal waters under all projected growth scenarios and necessary land use controls to lower loading are more restrictive.

Five rounds of water samples were collected from Chilmark Pond and analyzed for nitrogen species, chlorophyll *a*, orthophosphate and particulate nutrient content. Simultaneously, field data was collected to assess dissolved oxygen, water column visibility and conductivity. This data indicates that the Lower (eastern) Chilmark Pond is a brackish pond which has limited tidal exchange during the lifetime of the inlets cut through the barrier beach. Nitrogen enters the Lower Pond from the groundwater and from the Upper Pond which has a much larger watershed and streams draining it. Water quality within the Lower Pond is within the moderate to low quality ratings as characterized by two sets of screening standards.

In addition, two rounds of water samples were collected from the streams that drain to Chilmark Pond and from within the pond itself and analyzed for fecal coliform bacteria. This data indicates that the streams draining into the Pond and runoff from immediately adjacent uplands and roads are sources of bacterial contamination.

Recommendations are made to gather additional field data in all three ponds. Recommendations for nitrogen removing sewage disposal technology, road and farm runoff control, acquisition of open space and in-pond nutrient removal are made for Chilmark and Squibnocket Ponds. The residence time for Squibnocket Pond may be easily reduced through improved tidal flow in Herring Creek which will eliminate the need for more restrictive land use controls. Options to improve tidal flushing in Chilmark Pond to raise the nitrogen loading limit and ease the restrictive development controls are explored.