

To: Sherborn Zoning Board of Appeals, ZBA

Date: February 25, 2024

From: Thomas Trainor, 97 Washington Street, Sherborn MA

Subject: Comments for ZBA on the proposed 40B Farm Road Homes: Septic Nitrogen (Nitrate) Loading, Threats to Groundwater and the Public Health.

Chair Novak,

I would like to bring to the ZBA's attention some concerns I have with the 8,360 gal/day septic system now proposed for this 32-unit multi-family affordable housing complex (76 bedrooms), and the serious risks it represents to nearby private drinking water wells in Sherborn (closest wells being at Farm Road #'s 49, 53, and 55). Comments are organized in sections A through D that follow here.

A. Project Nitrogen (nitrate) Loading study – available YTD information.

As of this writing (Sunday 2/25/24), the Town's Land Development webpage project document repository contains four documents about the site-specific nitrogen study:

Initial nitrogen loading study (CLAWE):

<https://www.sherbornma.org/DocumentCenter/View/2040/CLAWE-Letter-of-Response-to-BOH-Deficiencies-List-Appendices-February-2-2024>

Comment letter, Andrea Stiller, LSP:

<https://www.sherbornma.org/DocumentCenter/View/2059/Comments-from-Andrea-Stiller---Mounding-Analysis-February-6-2024>

Sherborn BOH preliminary questions and comments:

<https://www.sherbornma.org/DocumentCenter/View/2102/BoH-to-ZBA---Preliminary-comments-regarding-septic-effluent-impact-analyses-February-15-2024>

Letter with alternate nitrogen study, Scott Horsey, Water Resources Consultant:

<https://www.sherbornma.org/DocumentCenter/View/2141/Scott-Horsley-Comments-on-Farm-Road-Homes-February-22-2024>

Most unfortunately, I have yet to see a posting of the expected independent review of the developer's nitrogen loading study by the ZBA's peer reviewer, TetraTech. I trust that review will be available before the formal ZBA hearings on this project are completed, so all parties have time to review and comment.

B. Nitrate Concentrations of Concern in Groundwater within Massachusetts.

The Sherborn BOH (for private wells) and the MassDEP (for public water supplies, PWS) regulations both list a MCL of 10 mg/L (or 10 ppm) for nitrate (NO₃, which you may also see labeled as "nitrate-nitrogen" or NO₃-N) for a concentration limit in potable drinking water. Please know that this 10 mg/L limit was first proposed in this country by the US EPA back in 1975 (five years after the agency was first formed), about 49 years ago. Two very informative and frequently cited documents covering the practical challenges and many concerns of nitrate in groundwater/drinking water, and surface water in MA are attached here:

Appendix A – UMASS-Amherst Extension School, 2007, 5 pages:

<https://ag.umass.edu/sites/ag.umass.edu/files/fact-sheets/pdf/nitrate.pdf>

Appendix B – Cape Cod Commission, 1992, 25 pages: https://www.capecodcommission.org/resource-library/file/?url=/dept/commission/team/Website_Resources/regulatory/NitrogenLoadTechbulletin.pdf

Continued health concerns have been raised by the medical community across the country since 1975 and have hence led many authorities to lobby for an updated and lower national nitrate drinking water MCL, frequently suggesting that a limit of 5 mg/L nitrate would be much more protective of human health.

Examples of this lower 5 mg/L nitrate concentration of concern include published recommendations from five MA-based entities (illustrative list provided here, but by no means meant to be a comprehensive set). In brief:

1. **UMASS-Amherst Extension School:** *"Ingestion of drinking water with nitrate concentrations in excess of 10 mg/L may be fatal to infants. Concentrations in excess of 5 mg/l indicate a severe degradation of groundwater quality. In order to guard against nitrate concentrations reaching danger levels, if you have a nitrate concentration exceeding 5 mg/l in your well, you should monitor the nitrate for a trend of increasing concentrations."* See link above for Appendix A.
2. **Cape Cod Commission, Water Resources Office (CCC WRO):** *"The CCC WRO believes that the 5 ppm NO₃-N guideline is appropriate for use on Cape Cod and will protect the largely undefined potential future water supply areas, private wells, and the small volume community and noncommunity supply wells, and, in the absence of recharge area specific studies establishing critical nitrogen loading limits, will provide some protection for coastal resources."* See link above for Appendix B.
3. **Dover MA Board of Health:** Local BOH's in Massachusetts can set private well water contaminant limits below that of national US EPA and/or MassDEP public water supply limits, to better insure the protection of public health in their localities. Our neighbors across the river in 2018 amended their private well water regulations. Dover Chapter 233, Section 8B – Water Quality Testing: *"Prior to the sale of any existing house, a water quality test shall be performed on the existing well and shall be taken using a raw water sample. The sample shall be taken directly from the well, or in the event that is not possible, it shall be taken from the water line before it enters the holding tank. If the nitrate or nitrogen levels exceed five mg/L, a reverse osmosis (R.O.) system shall be installed. At a minimum, the system can be placed at the drinking water location and a deed restriction requiring maintenance of the R.O. system shall be recorded at the Registry of Deeds."* See Town of Dover MA: <https://ecode360.com/32765999>
4. **Plainville MA Board of Health** regulations: *Chapter 611 Groundwater and Water Supply Protection: 611-2 The applicant for construction of any subsurface wastewater system in the Town, except for repairs of existing systems which have failed and are not being enlarged to provide for additional building construction or use, shall submit a groundwater impact report (GIR) to the Board of Health. In the case of a subdivision, the GIR shall be submitted at the time*

of submittal of the preliminary plan. In case of lots not requiring approval as a subdivision, the GIR shall be submitted at the time of application for a disposal works construction permit.

§ 611-3 Method of calculation. A. *The GIR shall be based on the following methodology for determination of nitrate loading which is based on procedures that have been accepted by and have been adopted and used by governmental planning agencies, enforcement agencies, and the U.S. Geological Survey. The GIR shall determine whether or not the proposed project will cause unacceptable groundwater quality at the project boundary limits for the proposed use, based on the expected nitrate-nitrogen loading. The calculations shall follow the guidelines contained herein, using data which is appropriate for the Town of Plainville.*

B. *The maximum allowable calculated concentration of nitrate-nitrogen within each project boundary shall be five milligrams per liter in Zone II of the public water supply and areas of private on-site well water supplies. It shall be 7 1/2 milligrams per liter in all other areas within the Town. See Town of Plainville MA: <https://ecode360.com/15553666>*

5. Within the current MassDEP Title V septic regulations themselves, the 5 mg/L nitrate concentration limit also gets cited at times, for instance, see: 310 CMR: SUBPART D: INSPECTION AND MAINTENANCE OF SYSTEMS, 15.303: Systems Failing to Protect Public Health and Safety and the Environment, section C:

*"(c) Evaluation of systems with septic tanks and soil absorption systems near drinking water supplies: If any portion of the soil absorption system is within any of the dimensional criteria listed in 310 CMR 15.303(1)(c), unless the Approving Authority in its professional judgment, with the concurrence of the public water supplier, if any, **determines the system is functioning in a manner to protect the public health and safety, welfare and the environment.***

1. within 100 feet of a surface water supply or tributary to a surface water supply;
2. within a Zone I of a public well;
3. within 50 feet of a private water supply well;

*less than 100 feet but 50 feet or more from a private water supply well, unless a well water analysis, conducted at a laboratory that is certified by the Department for the parameters analyzed, indicates an absence of fecal coliform bacteria, **and the presence of ammonia nitrogen and nitrate nitrogen is equal to or less than 5 ppm.**"*

Additionally, medical professionals are now finding new troubling health concerns from even lower exposures of nitrate in drinking water, with peer-reviewed publications now identifying water supplies with greater than 2 mg/L nitrate concentrations detrimental to human health (for one example see: *"Examining Relationships Between Groundwater Nitrate Concentrations in Drinking Water and Landscape Characteristics to Understand Health Risks"*, 2022, *GeoHealth*, Hamlin et al, <https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021GH000524> .

C. Background Levels of Nitrate in Sherborn Groundwater.

It is challenging to find water quality data on local private wells, but within Sherborn there are currently 14 public water supply (PWS) wells that are regulated by MassDEP, with various contaminant monitoring requirements. All the historical testing data on these PWS's is available for review on a state website: <https://eeaonline.eea.state.ma.us/portal#/search/drinking-water>

A recent download of Sherborn PWS nitrate data from this database provides at least 519 nitrate values, covering the last 30 years (1993-2023). Reported nitrate concentrations vary from non-detectable (ND) to just under 10 mg/L in these Sherborn PWS wells (ND concentrations vary over this time but were typically at 0.1 mg/L years ago to about 0.03 mg/L today). Some of these PWS wells are Town of Sherborn-owned, and others are privately owned (office buildings, restaurants, shops, churches, etc.).

For some perspective, here is a short summary of nitrate data on 3 of the 14 PWS wells in Sherborn:

PWS ID	PWS Location	Example Sherborn Nitrate Concentrations, mg/L					Time Period
		Average	Std Dev	Range	Low	High	
3269011	Town Campus	1.61	0.52	0.17	3.2	29	1994-2023
3269019	Pine Hill Elem School	0.53	0.34	0.08	1.1	33	1993-2023
3269032	Fields of Sherborn 40B	0.86	0.21	0.56	1.05	4	2020-2023

For all 14 PWS's, reported nitrate range now is 9.88 to non-detectable mg/L, 519 reportable values.

Four things to note from this table:

- 1) Typical Sherborn groundwater “background” nitrate levels (with no human influence) might be considered somewhere in the low range of these three example wells, or perhaps at about 0.1 to 0.2 mg/L. My home’s well, from a 2022 sampling had a reportable nitrate concentration of 0.32 mg/L (installed about 40 years ago), and of course has had a septic system operating this same time. Larger regional studies by the USGS also find typical groundwater background nitrate considerably less than 1.0 mg/L in New England. In Sherborn, since we have so many point sources of nitrate (perhaps 1500+ septic systems/cesspools), it is challenging to distinguish between “natural” and “anthropogenic” or human-induced nitrate background in either shallow or deep groundwater. Nitrate is a naturally occurring ion, and present at some level in all waters, soils, vegetation, foods, etc.
- 2) For all three PWS wells shown here, some human influence (septic leachate, roads, etc) is leading to an increase in nitrates above what might be considered pristine “natural” background levels.
- 3) At the Fields of Sherborn (also a 76-bedroom, 8,360 gal/day septic system), the nitrate trend has been tracking from 0.56 mg/L in 2020 to 1.05 mg/L in 2023 and will need to be watched in the future. Two co-located PWS wells serve this community and are located about 500 ft downgradient of the large leach field. Nitrate level has almost doubled in only 4 years.
- 4) Nitrate levels in groundwater wells with decades of monitoring do show some variability, which can be due to many factors not discussed here.

D. Post-Development Nitrate Concentrations of Concern for the Farm Roads Homes site.

Two nitrogen loading studies are available to the ZBA currently on this project:

1. From the developer’s team, Table G3 copied here:

Table G3. Output Nitrogen Concentration at downgradient Receptor- Budget Analysis

Scenario	Sewage flow GPD	Effluent Nitrogen mg/l	Lawn fertilize %	Off site Recharge	Calculated Nitrogen at Downgradient, mg/l	Assumptions for nitrogen budget analysis
1	8360	19	0	yes	3.89	1. Using Title 5 design daily flow for sewage nitrogen loading with I/A treatment 2. Assume all lawn will not be fertilized 3. Off site upgradient area recharge included.
2	8360	35	0	yes	6.95	1. Using Title 5 design daily flow for sewage nitrogen loading without I/A treatment. 2. Assume all lawn will not be fertilized 3. Off site upgradient area recharge included.
3	8360	19	0	no	5.6	1. Using Title 5 design daily flow for sewage nitrogen loading with I/A treatment 2. Assume all lawn will not be fertilized 3. Off site upgradient area recharge IS NOT included.
4	23271	19	40	yes	6.32	1. Using Title 5 design daily flow for sewage nitrogen loading with I/A treatment 2. Assume all lawn will be fertilized 3. Off site upgradient area recharge included.

If we consider say a conservative value of 0.5 mg/L nitrate groundwater concentration for Sherborn “groundwater background with human influences” pre-development for this site, that means for the calculated nitrate downgradient (property line) concentrations vs background, we see groundwater degradation post-development of about 7.8 to 13 times by this nitrogen loading study:

3.89/0.5 = 7.8X; 6.95/0.5 = 14X; 5.6/0.5 = 11X; and 6.32/0.5 = 13X higher nitrate in groundwater.

2. From an abutters consultant (S Horsley):

Table 1 – Summary of Nitrogen Loading Analysis

	Adjacent Lots	40B	40B
Wastewater design flow (gals/day)	880	8360	8360
Source Concentration (mg N/liter)	35	35	19
Concentration at Property Boundary (mg N/liter)	15.8	26.9	14.6

Again, if we consider the conservative value of 0.5 mg/L nitrate groundwater concentration for Sherborn “groundwater background with human influences” pre-development for this site, that means for the calculated nitrate downgradient (property line) concentrations vs background, we see degradation many folds by this second nitrogen loading study, by factors of 29 to 54:

26.9/0.5 = 54X; and 14.6/0.5 = 29X higher nitrate in groundwater.

Hence the estimated degradation at the property line for the groundwater are on the order of 7.8 to 54 times higher nitrate concentrations than what may exist today. Moreover, all the nitrogen loading analyses show groundwater nitrate concentrations above the new 2 mg/L health concerns threshold, and a majority predict nitrate concentrations above the consensus 5 mg/L health level. Please also know that nitrate is just one of many expected contaminants that would be traveling in the septic leachate plume (PFAS, pharmaceuticals, personal care products, cleaning agents, etc. etc.).

Based on either of these widely different nitrogen/nitrate loading estimates, I find the public health risks to the abutter’s private wells (Farm Road #'s 49, 53, and 55) very serious.

Please ZBA members: work with the developer, Town BOH and Conservation Commission, Select Board, and Sherborn residents to bring affordable housing to our town without sacrificing the long-term viability of our irreplaceable groundwater resources.

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MASSACHUSETTS

Safe and healthy lives in safe and healthy communities

Nitrate/Nitrite in Private Drinking Water Wells

Private well owners are responsible for the quality of their drinking water. The U.S. Environmental Protection Agency (EPA) does not regulate private wells. Homeowners with private wells are generally not required to test their drinking water, although local Boards of Health or mortgage lenders may require well water testing. While there is also no state requirement to have your well water tested, the Massachusetts Department of Environmental Protection (MassDEP) recommends that all homeowners with private wells do so, and use a state certified testing laboratory.

The Maximum Contaminant Level (MCL) for nitrate measured as nitrogen in drinking water is 10 milligrams per liter (parts per million) as established by the EPA. In addition, EPA has set an MCL for nitrite in drinking water at 1 milligram per liter (mg/L).

Summary

Nitrogen, a component of protein, is essential to all living things. Nitrogen exists in the environment in many forms. It can change its form as it moves through the nitrogen cycle—nitrate and nitrite are two forms of nitrogen.

- Both the nitrate and nitrite forms of nitrogen in drinking water are a health concern, especially for infants, pregnant women, nursing mothers, and the elderly.
- A water test is the only way to determine



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the presence and amount of these contaminants in well water.

- Proper well location and construction are important in avoiding nitrate and nitrite contamination in drinking water.
- Best Management Practices to reduce the risk of contamination from fertilizer applications and improper human and animal waste disposal also help to ensure a safe water supply.

Ingestion of drinking water with nitrate concentrations in excess of 10 mg/L may be fatal to infants. Concentrations in excess of 5 mg/l indicate a severe degradation of groundwater quality. In order to guard against nitrate concentrations reaching danger levels, if you have a nitrate concentration exceeding 5 mg/l in your well, you should monitor the nitrate for a trend of increasing concentrations.



UMassAmherst Outreach UMass
Extension

 EPA United States Environmental Protection Agency New England

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Nitrate/Nitrite in Private Drinking Water Wells

If the concentration of either nitrate or nitrite in drinking water is elevated, the choices for addressing the problem include obtaining an alternate water supply or treating the existing well water. An alternate supply may be bottled water for drinking—especially for infant formula—or installing a new well in a different location and at a different depth. Another alternative, if available, is connecting to a public water supply. Home water treatment options include distillation, reverse osmosis, or ion exchange.

It is also recommended that you determine if any practices in and around the home could be contributing to the elevated levels of nitrate/nitrite in groundwater. Take necessary steps to address these potential sources.

Potential Health Effects

The primary health hazard from drinking water with nitrate-nitrogen or nitrite-nitrogen is “blue baby syndrome”, in which blood lacks the ability to carry sufficient oxygen to the bodies’ cells. Most adults are not susceptible to this condition, but infants under six months of age (including pregnant and nursing mothers) and the elderly may be at greater risk than the general population.

A potential cancer risk from nitrate in drinking water and food has been reported. The possibility exists that nitrate can form nitrosamine, which is known to cause cancer. Nitrate must be converted to nitrite before nitrosamine can be formed. The magnitude of the cancer risk from nitrate in drinking water is not known.

Indications of Nitrate and Nitrite

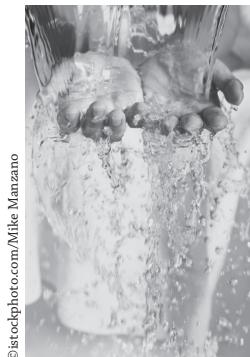
These contaminants are colorless, odorless, and tasteless in water. Nitrate testing is highly recommended for households with infants, pregnant women, nursing mothers, or elderly people. These groups are the most susceptible



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to health problems due to elevated nitrate and nitrite levels. In addition, if you live in an agricultural area, it is important to test for the presence of these contaminants.

Nitrate-nitrogen occurs naturally in groundwater at concentrations below 1.0 milligram per liter, which is well below the level of concern for drinking water safety. An initial water test for a new well is needed to determine the baseline nitrate concentration in the groundwater source. Nitrate testing should also be part of an annual, routine well water test. Nitrate-nitrogen concentrations above 1.0 milligram per liter indicate potential land use impacts to water quality. You should try to identify the potential land use source that is causing the elevated levels in your drinking water. This may include a malfunctioning septic system or improper fertilizer or animal waste use, storage, or disposal. Drinking water with nitrate-nitrogen concentrations greater than



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5.0 milligrams per liter should not be used to prepare infant formula. In this case, you can use bottled water or consider installing a point of use treatment system to remove the nitrate-nitrogen.

Sources of Nitrate and Nitrite in Drinking Water

Nitrogen occurs naturally in the soil in organic forms from decaying plant and animal residues. Bacteria in the soil convert various forms of nitrogen to the nitrate form. This process is part of the nitrogen cycle and is desirable because the majority of the nitrogen required by plants is the nitrate form. However, nitrate is also very soluble and readily moves with water through the soil. If there is excessive rainfall or irrigation water, nitrate can move below the plant's root zone and will eventually reach groundwater.

Sources of nitrate-nitrogen include: septic systems, leaking sewers, compost facilities, and other waste treatment systems, livestock manure, pet waste, excessive commercial fertilizers applied to lawns, gardens, cropland and recreational fields.

If elevated levels of nitrogen are detected in your well water, and you have a septic system, you should also test for bacteria (specifically fecal coliform) to insure that your leaching field is working properly and is not the source of the nitrogen. Refer to the fact sheet on Bacteria for more information.

Proper well siting, construction, and maintenance reduce potential drinking water contamination. This includes locating the well:

- Up-slope from potential contamination sources.
- With adequate separation distances between the well and possible contamination sources.

Testing for Nitrates and Nitrites

To determine if nitrates and nitrites are present, arrange to test your drinking water at a state certified laboratory. Follow laboratory instructions carefully to avoid contamination and to obtain a good sample. Although field test kits are available for measuring nitrate-nitrogen concentration, they are not as accurate as laboratory procedures. Results from field test kits can be affected by the presence of certain chemicals and by temperature variation. Use certified laboratory testing to assure the most accurate and reliable results.

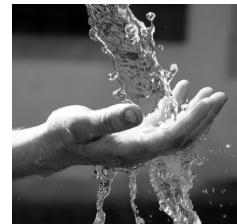
Interpreting Test Results

The laboratory will report the nitrate or nitrite concentrations as milligrams per liter (mg/L) or as parts per million (ppm), which are equivalent for the concentrations occurring in water (1 mg/L = 1 ppm). Most laboratories report nitrate as nitrate-nitrogen and nitrite as nitrite-nitrogen, which is the amount of nitrogen in that particular form.

Reducing Nitrates and Nitrites in Your Drinking Water

If a water test indicates the presence of elevated nitrate-nitrogen or nitrite-nitrogen levels, you have several choices: obtain an alternate water supply, connect to a public water supply if available, or use a home treatment method to remove or reduce the contaminant.

It may be possible to obtain an alternate water supply by installing a new well in a different location or a deeper well in a different aquifer (water-bearing, saturated zone beneath the earth's surface). If the nitrate-contaminated water supply is coming from a shallow groundwater source, there may be an uncontaminated, deeper aquifer protected by an impervious layer that prevents the downward movement of the contaminated water. A new well should



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be constructed to allow surface water to drain away from it, preventing surface water from entering and potentially contaminating the well. Locate the new well up-slope and at an adequate distance away from any potential sources of contamination, such as septic systems, feedlots, animal pens, or underground fuel tanks.

Purchasing bottled water for cooking and drinking is another option for an alternative source of drinking water. This source may be expensive over the long-term and you will need to weigh the costs of this versus installing a new well or a treatment system.

It is also recommended that you determine if any practices in and around your home could be contributing to the elevated contaminant levels in groundwater. These include: location of animal pens and waste, compost piles, septic system operation and maintenance, cesspools, leaky sewer pipes, or lawn and garden fertilizer use. Take necessary steps to address these potential sources.

Three methods can remove or reduce nitrate or nitrite from drinking water: distillation, reverse osmosis, and ion exchange. These home treatment methods are available from several manufacturers

When choosing a treatment system, consider both the initial cost and the operating costs. Operating costs include the energy needed to operate the system, additional water that may be needed for flushing the system, consumable supplies and filters, repairs, and



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general maintenance.

Regardless of the quality of the equipment purchased, it will not operate well unless maintained in accordance with the manufacturer's recommendations. Keep a logbook to record equipment maintenance and repairs. Equipment maintenance may include periodic cleaning and replacement of some components. Also consider any special installation requirements that may add to the equipment cost. For more information, refer to fact sheet: *Questions to Ask When Purchasing Water Treatment Equipment*.

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Resources

UMass Extension

This fact sheet is one in a series on drinking water wells, testing, protection, common contaminants, and home water treatment methods available on-line at the University of Massachusetts website:

http://www.umass.edu/nrec/watershed_water_quality/watershed_online_docs.html
and Cape Cod Cooperative Extension:
508-375-6699
<http://www.capecodextension.org>

MA Department of Environmental Protection, Division of Environmental Analysis

Offers assistance, information on testing and state certified laboratories: 617-292-5770

For a listing of MassDEP certified private laboratories in Massachusetts:

<http://www.mass.gov/dep/service/compliance/wespub02.htm>

U.S. Environmental Protection Agency, New England Office

Information and education on where drinking water comes from; drinking water testing and national laws; and how to prevent contamination:

<http://www.epa.gov/ne/eco/drinkwater>

US Environmental Protection Agency

For a complete list of primary and secondary drinking water standards:

<http://www.epa.gov/safewater>

MA Department of Conservation and Recreation, Division of Water Supply Protection

Maintains listing of registered well drillers, information on well location and construction: 617-626-1409

<http://www.mass.gov/dcr/waterSupply/welldrill/index.htm>

NSF International

The NSF International has tested and certified treatment systems since 1965. For information on water treatment systems: 800-NSF-MARK (800-673-6275)

<http://www.nsf.org/consumer/>

Water Quality Association

The Water Quality Association is a not-for-profit international trade association representing the household, commercial, industrial, and small community water treatment industry. For information on water quality contaminants and treatment systems:

<http://www.wqa.org>



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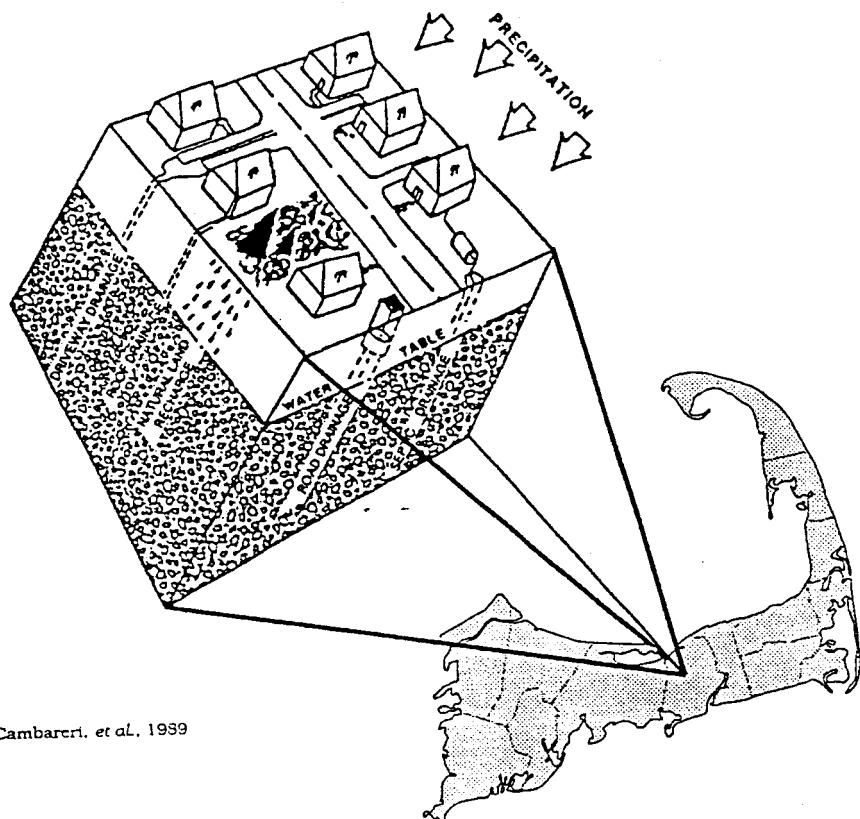
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Technical Bulletin 91-001 (FINAL)

NITROGEN LOADING

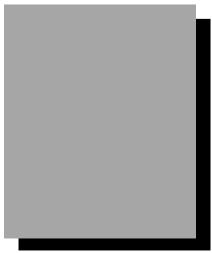
April, 1992



From Cambareri, et al., 1989

Cape Cod Commission Water Resources Office

3225 Main Street
P.O. Box 226
Barnstable, MA 02630
(508)362-3828



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NITROGEN LOADING

April, 1992

Prepared by

Water Resources Office

Eduard M. Eichner

Water Resources Planner/Environmental Scientist

Thomas C. Cambareri

Water Resources Coordinator/Hydrogeologist

Armando J. Carbonell

Executive Director

Cape Cod Commission

3225 Main Street

P.O. Box 226

Barnstable, MA 02630

(508)362-3828



A. INTRODUCTION

The protection of groundwater resources on Cape Cod is crucial. The almost complete dependence of the population on groundwater as a drinking water supply was officially recognized by the US Environmental Protection Agency (USEPA) in 1982, when the Cape Cod aquifer was designated as a Sole Source Aquifer (47 FR 30282). Because the groundwater lenses of Cape Cod also receive wastewater and stormwater discharges, introduction of contaminants needs to be monitored to ensure that the water remains safe for drinking water purposes. One of the primary contaminants of concern on Cape Cod is nitrate-nitrogen ($\text{NO}_3\text{-N}$).

Nitrogen loading is important to monitor for several reasons. High drinking water nitrate-nitrogen levels have been shown to cause methemoglobinemia (a potentially lethal decreased ability of the blood to transport oxygen) in infants and have been correlated with progeny malformations (NRC, 1977; Dorsch, *et al.*, 1984). High $\text{NO}_3\text{-N}$ concentrations in groundwater have also been correlated with higher concentrations of regulated drinking water contaminants, such as volatile organic compounds (VOCs) (Eckhardt, *et al.*, 1986). However, the link of high nitrate levels to methemoglobinemia is the most well established and extensive research has led to the calculation of a 10 ppm $\text{NO}_3\text{-N}$ concentration as a “no-observed-adverse-effect level” (NOAEL) for most infants (NRC, 1977; Fan, *et al.*, 1987).

In response to the concerns pointed out by research, the USEPA established an interim maximum contaminant limit (MCL) in drinking water of 10 ppm $\text{NO}_3\text{-N}$ in 1975 (USEPA, 1975). This standard has been repropose by the USEPA a number of times and is scheduled to be adopted permanently in July, 1992 (56 FR 3526). In addition, USEPA, based on recent research linking high nitrate concentrations to carcinogenic effects, has proposed that the Unreasonable Risk to Health (URTH) level for $\text{NO}_3\text{-N}$ be set at 10 ppm, along with additional monitoring requirements for public supply wells which exceed 5 ppm $\text{NO}_3\text{-N}$ (USEPA, 1990). Adoption of this proposed standard means that a well which exceeds the 10 ppm $\text{NO}_3\text{-N}$ MCL concentration could not obtain a variance or an exemption and would be shut down.



The health concerns about nitrate are compounded by its environmental persistence; once it reaches groundwater, it is not substantially removed by chemical reactions. In addition, most nitrogen introduced to aerobic subsurface environments, such as those encountered in the unconfined aquifers of Cape Cod, is converted to nitrate. Thus nitrogen added to the groundwater system is not attenuated and concentrations can only be lowered by dilution or by limiting the nitrogen introduced to the system.

A number of studies have attempted to quantify and understand nitrogen loading to groundwater systems. The Nassau-Suffolk Regional Planning Board (NSRPB) of Long Island, New York conducted extensive literature reviews and presented nitrogen loading levels from a number of sources, including wastewater, fertilizer applications, and domestic animals, as part of the *Long Island Comprehensive Waste Treatment Management Plan* (also known as the Long Island 208 study) (NSRPB, 1978). The forerunner of the Cape Cod Commission (CCC), the Cape Cod Planning and Economic Development Commission (CCPEDC), developed a wastewater nitrogen loading methodology as part of the *Draft Environmental Impact Statement and Proposed 208 Water Quality Management Plan for Cape Cod* (also known as the Cape Cod 208 study) (CCPEDC and USEPA, 1978). In 1979, CCPEDC modified the methodology to also include nitrogen inputs from fertilizers (CCPEDC, 1979). A 1986 study of nitrate concentrations on Cape Cod found a significant positive correlation between nitrate concentrations in groundwater and housing density (Persky, 1986). In 1988, IEP Inc. presented a nitrogen loading model, as part of their contract to assess the water resources of the Town of Yarmouth, to attempt to understand the observed concentrations at two public supply wells (IEP, 1988). Also in 1988, Frimpter, *et al.* presented a detailed nitrogen loading methodology for determining nitrogen loading within zones of contribution (ZOCs) to public drinking water supply wells. In 1991, the Buzzards Bay (BBP) recommended nitrogen management actions, which involved a synthesis of the methods in many of the previous studies, for "nitrogen sensitive embayments" in their Comprehensive Conservation and Management Plan (CCMP) (USEPA and MA EOEA, 1991). Planning boards and boards of health in many of the towns on Cape Cod have adopted density restrictions, water quality report requirements for new developments, and nitrogen loading methodologies based on the information included in these studies.

Nitrogen loading methodologies used on Cape Cod have based their conclusions and recommendations on various assumptions about nitrogen loading parameters (e.g., wastewater flows, nitrogen concentrations in wastewater, lawn sizes, etc.). As more research has been done and more papers have been published, a certain level of confusion has developed over which values and



methods are the most proper to use when performing nitrogen loading calculations. This bulletin presents the methodology which is used by the Water Resources Office (WRO) of the Cape Cod Commission to review Developments of Regional Impact (DRIs) and to evaluate cumulative nitrogen loading to Water Resource Areas as described in the Regional Policy Plan (RPP) (Section 2.1).

B. VALUES

All nitrogen loading methodologies involve a certain number of assumptions. This methodology will assume that the recharge (e.g., wastewater, stormwater runoff, precipitation) and nitrogen sources (e.g., septic wastes, fertilizers, nutrients in runoff) within the boundaries of the development site are well mixed prior to their mixing with the groundwater. While this assumption is not an accurate representation of actual contaminant plume behavior, it is an assumption which simplifies the nitrogen loading calculations and is appropriate in most cases where wastewater quantities are fairly low. An assumption is also made that no nitrogen is lost from the system once it is introduced to the groundwater. This assumption also is an approximation of actual nitrogen contamination behavior, but is appropriate in lieu of definitive research about the level of denitrification reactions at depth within the aquifers of Cape Cod.

B.I. 5 ppm NO₃-N

A statistical analysis, conducted by Porter and presented in the Long Island 208 study, of 865 NO₃-N observations from 54 wells in Nassau County on Long Island attempts to establish how often the 10 ppm NO₃-N USEPA MCL would be violated given a mean NO₃-N concentration (NSRPB, 1978). Porter found that a well with a mean NO₃-N concentration of 6.0 ppm would violate the 10 ppm MCL 10% of the time. Additional analysis of the same observations has indicated that a mean concentration of 3 ppm NO₃-N will violate the MCL one time out of a hundred (1% of the time) (LIRPB, 1986). Based, in part, on Porter's work, the Long Island 208 study recommended that in areas that exceeded a 6 ppm NO₃-N concentration, sewerage be undertaken to protect future drinking water supplies (NSRPB, 1978).



After reviewing the Long Island 208 study, CCPEDC adopted a 5 ppm $\text{NO}_3\text{-N}$ standard as a planning guideline (CCPEDC and USEPA, 1978). This concentration promises to keep violations of the USEPA MCL to less than one in 10 samples and "allows for a margin of safety during times of high loading with low recharge" (CCPEDC, 1979).

Although the 5 ppm $\text{NO}_3\text{-N}$ guideline gives some level of protection to drinking water supplies, the level of protection afforded by this concentration may be inadequate to protect the ecosystems of nitrogen limited coastal embayments on Cape Cod. Nitrogen loading limits for recharge areas to embayments (Marine Water Recharge Areas in the RPP) are referred to as critical nitrogen loading rates, i.e., maximum annual loadings without producing negative ecosystem changes, such as eutrophication. Each embayment has a unique critical nitrogen loading rate, as determined by an analysis of its morphology and tidal exchange or flushing rate. Although available analyses of critical loading based on flushing rates within coastal recharge areas are not extensive, most have identified critical nitrogen loading rates, which when converted to loading concentrations are less than the 5 ppm $\text{NO}_3\text{-N}$ guideline. K.V. Associates (1983) identified critical loading concentrations of 1.5 and 8.5 ppm $\text{NO}_3\text{-N}$ for Bournes Pond and Hamblin Pond, respectively, in Falmouth. Horsley Witten Hegemann (HWH) (1991) identified 3.68 ppm $\text{NO}_3\text{-N}$ as the critical loading concentration for Buttermilk Bay, and identified 3.8 and 2.0 ppm $\text{NO}_3\text{-N}$ as the critical loading concentrations for Oyster Pond and Mill Pond, respectively, in Chatham (HWH, 1990). The unique characteristics of nitrogen sensitive embayments will require additional studies, including flushing rate determinations, to ascertain critical loading rates.

The CCC WRO believes that the 5 ppm $\text{NO}_3\text{-N}$ guideline is appropriate for use on Cape Cod and will protect the largely undefined potential future water supply areas, private wells, and the small volume community and noncommunity supply wells, and, in the absence of recharge area specific studies establishing critical nitrogen loading limits, will provide some protection for coastal resources. Lower $\text{NO}_3\text{-N}$ loading rates based on flushing characteristics, will be necessary within the recharge areas to certain identified nitrogen sensitive embayments.

B.2. Sewage Flows and Concentrations

In the Commonwealth of Massachusetts, wastewater systems are required to be designed based on wastewater flows in 310 CMR 15 *Minimum Requirements for the Subsurface Disposal of Sanitary Sewage*, which is commonly referred to as "Title 5." The flow design criteria for wastewater disposal systems are pur-



posely inflated to ensure that the systems avoid hydraulic failure and “as-similate maximum daily flows” (310 CMR 15.02 (13)). For example, all bedrooms are assumed to have two people per bedroom, with a resultant flow of 55 gallons per capita per day (gpcd) (310 CMR 15.02). In contrast, average residential wastewater flows found in a number of studies averaged approximately 44 gpcd and occupancy levels found in a number of Cape Cod towns do not approach the two people per bedroom level (Bennett, *et al.*, 1974; Witt, *et al.*, 1974; NSRPB, 1978; Cambareri, *et al.*, 1989; Belfit, *et al.*, 1990). In spite of the obvious overestimation of usual wastewater flows. Title 5 wastewater flows have been used for analysis of nitrogen loading in most cases, including the Cape Cod 208 study and the analysis presented in Frimpter, *et al.* (1988).

Nitrogen concentrations reaching groundwater have also been assumed at a variety of levels. The literature search conducted for the Long Island 208 study resulted in a conservative estimate of average per capita nitrogen load in wastewater of 10 pounds per year, with a concentration of 41 ppm nitrogen reaching the groundwater (NSRPB, 1978). The Cape Cod 208 study assumed a concentration of 35 ppm $\text{NO}_3\text{-N}$ reaching groundwater (CCPEDC and USEPA, 1978). A modeling effort conducted by IEP, Inc. in Yarmouth found that a calibrated concentration of 33.9 ppm $\text{NO}_3\text{-N}$ reaching groundwater produced the closest fit for historic nitrogen concentrations within a specified study area (IEP, 1988). The BBP in their CCMP and guidance documents is using a loading rate of 5.86 lbs/person/year (USEPA and MA EOEA, 1991; Costa *et al.*, in preparation).

Actual studies of leaching field concentrations have found different results depending on the soil characteristics, percolation rate, loading rate, distance to impervious strata, and the distance to the water table (Canter and Knox, 1985). Andreoli, *et al.* (1979), in a study on Long Island, found that an average of 36% of total nitrogen applied to soil is removed after two feet of travel through sandy soil. Andreoli, *et al.* (1979) also found that nitrification (the conversion of ammonium to nitrate) occurs within 2-4 feet of vertical travel through the soil. A study by the Suffolk County Department of Health Services (SCDHS) found that nitrogen concentrations varied depending on the time of year and depth below the leaching field (SCDHS, 1983). Concentrations of total nitrogen varied between 15 and 49 ppm, with an average concentration of 34.7 ppm (SCDHS, 1983). A recent study by Robertson, *et al.* (1991) of two septic systems in sandy soils found $\text{NO}_3\text{-N}$ concentrations within the contaminant plumes averaging 33 and 39 ppm.

Wastewater flows and expected nitrogen concentrations from nonresidential land uses have not been the subject of comparable research. Wastewater



flows and nitrogen concentrations from other uses are more varied in character and quantity, even between similar uses. Frimpter, *et al.* (1988) has a more extensive list of flows from nonresidential uses than Title 5, but does not reference the additional flows. The same lists also have similar concentration ranges for both residential and nonresidential land uses (Frimpter, *et al.*, 1988). Wastewater from facilities which have mostly black water (i.e., toilet) flows tend to have higher $\text{NO}_3\text{-N}$ concentrations because lower $\text{NO}_3\text{-N}$ grey water flows, i.e., sinks and showers, are not mixed in for dilution. *The Yarmouth Water Resources Protection Study* model found that a calibrated nitrogen concentration of 50.8 ppm for wastewater flows from restaurants provided the best fit for historical nitrogen concentrations (IEP, 1988). Large corporations, such as McDonald's Corporation, with many similar facilities may have fairly accurate estimates of the expected flows from their facilities (P. Landry, McDonald's Corporation, 1991, oral communication).

Although the staff of the WRO acknowledges that the Title 5 flows are, by design, overestimates of usual wastewater flows, these flows will be utilized by the WRO staff to calculate nitrogen loading. The inclusion of actual town occupancy levels in nitrogen loading calculations for residential developments (see Section B.3.) will correct for some of the overestimation inherent in the use of these wastewater flows. Additionally, 35 ppm $\text{NO}_3\text{-N}$ has historically been used by the staff of the WRO as the concentration of nitrogen reaching groundwater from septic systems. While this concentration may overestimate concentrations in certain cases, it is also probably an underestimation in others, especially in the case of most commercial wastewater flows. The staff believes that the 35 ppm $\text{NO}_3\text{-N}$ concentration is an accurate number for all nitrogen loading calculations.

B.3. Occupancy Rates

As was stated in the Section B.2., Title 5 assumes that each bedroom is occupied by two people. The Cape Cod 208 study of nitrogen loading assumed that each housing unit was occupied by three people (CCPEDC, 1979). Frimpter, *et al.* (1988) made no implicit assumptions about occupancy, but demonstration calculations and wastewater flows included in the paper are based on Title 5 flows.

The WRO staff again acknowledges the overestimation inherent in the use of Title 5 flows for nitrogen loading analysis and, as such, requests that future nitrogen loading calculations on residential developments submitted for review include both Title 5 occupancy levels and occupancy levels based on



the levels that exist in the town of the proposed development. Regulatory reviews of residential developments will use the mean of the two resulting nitrogen loading values. Nonresidential developments will continue to be reviewed based on Title 5 flows, unless substantial documentation of wastewater flows from similar land use can be presented to the staff.

B.4. Lawns

The Long Island 208 study conducted a survey of lawn fertilizer usage and lawn sizes in an attempt to understand potential nitrogen inputs from lawns. This survey, which contacted 460 households in 7 communities, found that rates of fertilizer application ranged between 1.70 and 3.75 lbs of nitrogen per 1,000 ft² per year (NSRPB, 1978). The survey also found that fertilizer application rates were positively correlated with household income levels. Other research cited in the Long Island 208 study had found lawn nitrogen application rates between 2.2 and 3 lbs N/1,000 ft²/yr.

The nitrogen loading calculations adopted by CCPEDC in 1979 included fertilizer inputs. Based on tables in the Long Island 208 study and consultation with the Barnstable County Extension Service, CCPEDC selected 3 lbs N/1,000 ft²/yr as the appropriate fertilizer application rate for nitrogen loading calculations on Cape Cod (CCPEDC, 1979).

Application rate surveys vary widely, depending on the population being surveyed. A study of four golf courses on Cape Cod found overall yearly application rates ranging between 1.7 and 3.1 lbs N/1,000 ft²/yr, with rates of up to 9.6 lbs N/1,000 ft²/yr for greens (Eichner and Cambareri, 1990). A survey of golf course turf managers cited in Petrovic (1989) found typical application rates ranged between 1 and 1.5 lbs N/1,000 ft²/yr. A lawn care consultant, who works extensively on Cape Cod, contacted for the *Yarmouth Water Resources Protection Study* typically applied 4.65 lbs N/1,000 ft² of lawn (IEP, 1988). However, the model developed for the same study calibrated to historical nitrate concentrations found a best fit with an annual application rate of 2.8 lbs N/1,000 ft² and a leaching rate of 60%.

Nitrogen leaching rates have been subject to more study than application rates. The Long Island 208 study presented tables with gross estimates of nitrogen leaching; based on gross estimates of nitrogen application and nitrogen reaching groundwater, leaching rates of 55.5% and 60% were determined (NSRPB, 1978). CCPEDC apparently selected a 60% leaching rate based on the estimates in the Long Island 208 study.



Research on golf courses over the last decade has provided some insights into actual nitrogen leaching rates. Brown, *et al.* (1982) fertilized bermudagrass at a rate of 3 lbs N/1,000 ft² of turf and found a leaching rate of 22%. Petrovic (1990) summarized 33 leaching studies conducted in sandy soil and found leaching rates which ranged between 0 and 56.1%. Leaching rates vary with soil type, application rate, precipitation, temperature, turf type, and applied nitrogen forms.

Average lawn sizes are also important to determine when application rates are presented in terms of pounds per unit area. The Long Island 208 study of application rates also included a section on lawn sizes, along with surveyors checks of a certain percentage of respondents. This survey found that lawn sizes were fairly constant, averaging 36-40% of total lot size in all categories except extremely low and extremely high densities (NSRPB, 1978). CCPEDC recognized that comparable information was not available for Cape Cod and selected a standard size lawn of 5,000 ft² based on a lot size of between 10,000 and 15,000 ft² (CCPEDC, 1979). Lawn sizes averaged 4,350 ft² in a survey conducted for the *Yarmouth Water Resources Protection Study* (IEP, 1988).

Historically, the WRO staff has used a fertilizer application rate of 3 lbs N/1,000 ft²/yr with a leaching rate of 60% off an average lawn of 5,000 ft². The application rate and standard lawn size seem to be appropriate in light of the lack of definitive information. However, the research which has been done on leaching rates seems to indicate that the 60% leaching rate figure is too conservative. Petrovic's work has indicated that controlled applications of fertilizers on healthy turf can substantially reduce leaching rates, sometimes allowing no leaching. Although Petrovic's work indicates that a percentage lower than 60% can reasonably be chosen, the CCC WRO believes that the objective of protecting groundwater quality should be the main criteria when selecting a standard leaching rate. Therefore, the CCC WRO will use a leaching rate of 25% in all nitrogen loading analyses. This rate recognizes the results of most of the controlled leaching experiments summarized in Petrovic's work, while acknowledging that fertilizer is often applied to unhealthy turf in an uncontrolled fashion. In summary, future nitrogen loading calculations submitted to the CCC WRO should use an application rate of 3 lbs N/1,000 ft²/yr and a leaching rate of 25% off an average lawn area of 5,000 ft².



B.5. Recharge

Recharge from precipitation is the only way to dilute NO₃-N loading on an aquifer-wide basis and provides an important source of dilution for NO₃-N concentrations on smaller scales. Approximately 45% of annual precipitation on Cape Cod becomes recharge (LeBlanc, *et al.*, 1986). The remainder is either transpired by plants or evaporates back to the atmosphere. Precipitation that falls on impervious surfaces (e.g., roofs, parking lots, roads) may be recharged to the water table at a much higher percentage.

Two methods of analysis have been used to estimate the average recharge on Cape Cod. LeBlanc, *et al.* (1986) used the Thornthwaite and Mather method, which is based largely on precipitation measurements, to calculate average recharge rates of 22 inches per year on western Cape Cod and 18 in/yr on eastern Cape Cod. Recharge at Otis Air Force Base has been estimated as 21 in/yr using the same method (LeBlanc, 1982). G. J. Larson of Michigan State University used a radioisotope method to estimate recharge in Truro at between 11 and 16 in/yr, while the Thornthwaite and Mather method calculated a recharge of between 17.3 and 19.4 in/yr (Knott and Olimpio, 1986; Delaney and Cotton, 1972).

Prior nitrogen loading methodologies have been based on conservative recharge rates to ensure a margin of safety when determining concentrations. The original CCPEDC loading methodology assumed a recharge rate of 16 in/yr across all of Cape Cod (CCPEDC and USEPA, 1978). Subsequent loading formulas have also used the same recharge rate (CCPEDC, 1979; Frimpter, *et al.*, 1988). The use of this value may be appropriately conservative for use in calculations on sites in eastern Cape Cod, but is certainly too conservative for western Cape Cod. In consideration of the above studies and the wish to adopt appropriately conservative rates, the CCC WRO staff have decided to utilize the following recharge rates for natural and lawn areas in the following towns: 21 in/yr (Bourne, Falmouth); 19 in/yr (Mashpee, Sandwich); 18 in/yr (Barnstable, Dennis, Yarmouth); 17 in/yr (Brewster, Harwich); 16 in/yr (Chatham, Orleans, Eastham, Wellfleet, Truro, Provincetown).

The WRO staff considered not using recharge associated with wastewater flows in areas which receive drinking water supplies from private wells, because water is not imported from a public supply well. The public health concern of so called "short circuiting" between wells and septic systems is a more crucial concern than site specific nitrogen loading in these areas. The wastewater in private well areas is not recycled back to a supply well, but flows with the groundwater from its recharge point towards the groundwater



discharge area. Thus, the private drinking water wells downgradient of numerous wastewater recharge points may intercept the contaminant load from the upgradient contaminant sources. Therefore, proposed developments under CCC review in areas which receive drinking water from private wells will be reviewed based on both the documentation of no negative effects on the nearby private wells, as indicated by Section 2.1.1.3 of the Regional Policy Plan, and the nitrogen loading components of the Regional Policy Plan.

Frimpter, *et al.* (1988) introduced the concept of atmosphere nitrogen loading to calculations done on Cape Cod. Frimpter, *et al.* (1988) assumed a concentration of 0.05 ppm NO₃-N for loading from precipitation to groundwater. This concentration was³ chosen based on analysis by the Barnstable County Health and Environmental Department of 5,559 groundwater samples from shallow private wells throughout Cape Cod between 1980 and 1986. Thirty percent of these samples had concentrations of less than 0.05 mg NO₃-N/l, which was the detection limit for the analytical method used by the laboratory (Frimpter, *et al.*, 1988). Literature reviews have established a range of 0.14-1.15 ppm NO₃-N for precipitation in the United States (Loehr, 1974). A study of precipitation in Truro found an average NO₃-N concentration of 0.26 ppm (Frimpter, *et al.*, 1988). Frimpter has proposed that nitrogen concentrations up to those found in Truro are removed by the soil zone prior to reaching the water table (M.H. Frimpter, 1991, oral communication). Nitrate-nitrogen concentrations in precipitation on Long Island from 1969 to 1974 ranged between 0.33 and 0.67 ppm (NSRPB, 1978). Regardless of the concentration chosen for natural recharge, the nitrogen load from natural recharge is small enough in comparison to loading from wastewater and fertilizers to ignore it when performing nitrogen loading calculations on individual parcels.

By comparison, nitrogen loading off of impervious surfaces is more significant than natural loading. Howie and Waller (1986) conducted a study of two highway runoff sites in Florida and found concentrations of 1.4 and 0.58 ppm total nitrogen reaching groundwater. IEP, Inc (1988) conducted a literature review of impervious surface runoff concentrations and found ranges of 0.41 to 1.75 ppm NO₃-N and 1.13 to 10 ppm total nitrogen. The calibration of the nitrogen loading³ model detailed in the *Yarmouth Water Resources Protection Study* produced values of 1.5 ppm N reaching groundwater in recharge off pavement and 0.75 ppm N in recharge off roofs (IEP, 1988). The values chosen in the *Yarmouth Water Resources Protection Study* are also used by the BBP in their nitrogen loading calculations (USEPA and MA EOEA, 1991; Costa, *et al.*, in preparation).



Conventionally, previous nitrogen loading calculations performed by the CCC WRO staff have assumed that 90% of recharge off impervious surfaces and 40 in/yr reaches the groundwater. This percentage assumes that precipitation falls on Cape Cod at an average rate of 44.44 in/yr. Average amounts of precipitation have not been studied across Cape Cod. LeBlanc, *et al.* (1986) summarized National Oceanic and Atmospheric Administration (NOAA) weather station precipitation data for Cape Cod between 1947 and 1976. Although the data from the 10 stations provided the data for the determination of the recharge patterns discussed previously, a few of the stations annual average precipitation figures do not fall into the smooth gradient across Cape Cod that the recharge rates seem to follow (LeBlanc, *et al.*, 1986).

The 90% recharge rate off of impervious surfaces has been used in a number of other studies on Cape Cod (e.g. IEP (1988), CCPEDC and USEPA (1978), and CCPEDC (1979). Origins of this number are obscure, although members of the IEP study team for the *Yarmouth Water Resources Protection Study* state that this recharge rate is based on "the intuitive assumption that smaller, shorter storm events would not generate enough water for runoff to occur" (M.E. Nelson and S.W. Horsley, HWH, 1991, written communication). Stormwater modeling programs, such as TR-55, use a 98% runoff rate for parking lots, roofs, streets and driveways directly connected to catch basins, but these calculations are done on the basis of individual storms, not on annual precipitation data (SCS, 1986).

In light of the lack of definitive values for many of the stormwater and runoff attributes, nitrogen loading analyses submitted to the CCC WRO should utilize the values which have been historically used on Cape Cod: 40 in/yr recharge off of impervious surfaces, 1.5 ppm NO₃-N off of paved surfaces, and 0.75 ppm NO₃-N off of roofs. Nitrate-nitrogen³ loading from recharge on pervious natural areas can be ignored when performing loading analyses on individual parcels.



C. METHOD

C.1. Site Specific Mass Balance Analysis

The information presented above describes values that will be used to assess nitrogen loading by the WRO staff of the CCC. The staff expects that each development will perform a Mass Balance Analysis (MBA) of the nitrogen and water uses within the boundaries of the development, using the values selected in this bulletin. A MBA will consist of totaling the nitrogen inputs to groundwater and dividing the nitrogen inputs by the water inputs according to the parameters described above. Sample calculations following this section provide examples of the methods to be used for residential and nonresidential developments.

C.2. Cumulative Loading Analysis Methodology

If a proposed development is within one of the recharge zones defined in Section 2.1.1.2 of the Regional Policy Plan (RPP) and has a Title 5 wastewater flow of greater than 2,000 gallons per day (gpd), the proponent may also be required to complete a zone-wide Cumulative Loading Analysis (CLA), similar to those presented by the WRO staff of CCPEDC and CCC, respectively, in *Truro/Provincetown Aquifer Assessment and Groundwater Protection Plan* (Camareri, et al., 1989) and *Harwich/Brewster Wellhead Protection Project*, (Belfit, et al., 1990) and by Horsley Witten and Hegemann, Inc. in *Quantification of Nitrogen Inputs to Buttermilk Bay* (HWH, 1991).

If the CLA is being completed for a Wellhead Protection Area (RPP, Section 2.1.1.2.A.) or a Potential Public Water Supply Area (RPP, Section 2.1.1.2.F.), the CLA should include, at a minimum, current expected NO₃-N concentrations within the delineated area based on both actual occupancy³ values and full Title 5 wastewater flows and future expected NO₃-N concentrations within the area at full buildout also using the two wastewater flow estimates. The completed CLA buildout assessment will provide a worst case assessment of projected nitrogen concentrations based on current zoning laws. If the buildout assessment indicates that the critical loading concentration (i.e., 5 ppm NO₃-N) will be exceeded under current zoning, the CCC will work with an applicant and/or appropriate authorities to explore nitrogen limitation options.



If the CLA is being completed for a Marine Water Recharge Area (MWRA) (RPP, Section 2.1.1.2.C.), a mass loading approach, similar to the methodology utilized by the Buzzards Bay Project, will be applied to determine the critical nitrogen loading rate (Costa, *et al.*, in preparation). The critical loading limit is an expression of the mass of nitrogen an embayment ecosystem can assimilate without negative changes. This limit is dependent, in some cases, on the period of time it takes the water in the embayment to be completely exchanged (i.e., residence time). Thus, CLA's completed for MWRA's will require an assessment of the flushing characteristics of the embayment to determine the critical nitrogen loading rate. The existing and future nitrogen loading to a given embayment will be compared to the BBP recommended nitrogen loading rate limits for coastal embayments (USEPA and MA EOEA, 1991; see Table 1), unless more precise information about the embayment is available.

Masses for each of the nitrogen loading components, i.e., lawns, wastewater, impervious surfaces, will be determined as previously described, but the cumulative mass will not be divided by the recharge and other water flows. Since the mass loading within the recharge area, rather than the groundwater or surface water concentration, is the determining factor in protecting coastal embayments, the total mass of nitrogen from current land use and future buildup, will be used to assess proposed and future development within the recharge area. If the buildup assessment indicates that the critical loading rate (e.g., 200 mg/m³/Vr) will be exceeded under current zoning, the CCC will work with an applicant and/or appropriate authorities to explore nitrogen limitation options.

Many of the types of recharge areas have already been delineated, although few have had CLA's completed. Development proponents should refer to the studies previously referenced in this bulletin and contact the CCC WRO staff to obtain recharge area delineations and guidance prior to preparing a Cumulative Loading Analysis.

C.3. Additional Guidance

If the site is located within a recharge area for which a CLA has been completed, the site specific MBA nitrogen loading concentration or mass loading for the proposed development will be compared to the critical loading concentration or critical loading rate per unit area of the recharge area. If the MBA loading concentration or mass loading for a proposed development exceeds the critical loading concentration or critical loading rate per unit area



for a recharge area, the proposed MBA loading concentration or mass loading from the project will need to be lowered (e.g., decrease the wastewater flows). If a sewer connection is available for the proposed development, MBA nitrogen loading calculations will not be required if the proposed development will connect to the sewer and if the municipal wastewater treatment facility has adequate capacity and is operating within the parameters of its discharge permit. Proposed wastewater treatment facilities will be reviewed cooperatively with the MA Department of Environmental Protection. Projects involving nitrogen loading characteristics or situations outside the scope of those described within this bulletin will be handled on a case by case basis. It should be noted that the CCC discourages the use of excessive impervious surfaces to lower nitrogen loading concentrations and Developments of Regional Impact before the CCC must conform to the minimum performance standards concerning open space in the RPP (Sections 6.1.1.3 and 6.1.1.4).

Table 1
SUMMARY OF NITROGEN LOADING VALUES

TARGET CONCENTRATION:	5 ppm (milligram/liter) NO ₃ -N					
WASTEWATER						
Residences						
Concentration:	35 ppm NO ₃ -N					
Flow:	Title 5 (310 CMR 15.02)					
Nonresidences						
Concentration:	35 ppm NO ₃ -N					
Flow:	Title 5; Frimpter, <i>et al.</i> (1988): Documented flows satisfactory to CCC WRO staff					
OCCUPANCY:	Range (Actual town rate to 2 people per bedroom)					
LAWNS						
Area:	5,000 ft ²					
Fertilizer:	3 lbs/1,000 ft ² of lawn					
Leaching:	25%					
RECHARGE						
Off of impervious surfaces:	40 inches per year					
Concentrations						
Road runoff:	1.5 ppm NO ₃ -N					
Roof runoff:	0.75 ppm NO ₃ -N					
Natural areas						
Barnstable:	18 inches per year	Mashpee:	19 in/yr			
Bourne:	21 in/yr	Orleans:	16 in/yr			
Brewster:	17 in/yr	Provincetown:	16 in/yr			
Chatham:	16 in/yr	Sandwich:	19 in/yr			
Dennis:	18 in/yr	Truro:	16 in/yr			
Eastham:	16 in/yr	Wellfleet:	16 in/yr			
Falmouth:	21 in/yr	Yarmouth:	18 in/yr			
Harwich:	17 in/yr					

Recommended Nitrogen Loading Limits for Coastal Embayments

<u>EMBAYMENT</u>	<u>WATERS CLASSIFIED SB</u>	<u>WATERS CLASSIFIED SA</u>	<u>OUTSTANDING RESOURCE AREAS</u>
Shallow			
• flushing: 4.5 days or less	350 mg/m ³ /Vr	200 mg/m ³ /Vr	100 mg/m ³ /Vr
• flushing: greater than 4.5 days	30 g/m ² /yr	15 g/m ² /yr	5 g/m ² /yr
Deep			
• select rate resulting in lesser annual loading	500 mg/m ³ /Vr or 45 g/m ² /yr	260 mg/m ³ /Vr or 20 g/m ² /yr	130 mg/m ³ /Vr or 10 g/m ² /yr

Note: Vr = Vollenweider flushing term

$$Vr = \frac{r}{1 + \sqrt{r}}$$

r = flushing time (yrs)

Source: USEPA and MA EOEA, 1991

EXAMPLE NONRESIDENTIAL LOADING CALCULATIONS

Office Building:

Lot Size: 5 acres (217,800 ft²)

Impervious Surfaces: Roof Area: 15,000 ft²; Paving Area: 30,000 ft²

Natural Area: 172,800 ft²; Lawn Area: 10,000 ft²

Title V Flow: 75 gallons/day per 1,000 ft²

WASTEWATER

$$15,000 \text{ ft}^2 \left[\frac{75 \text{ gpd}}{1,000 \text{ ft}^2} \right] \left[\frac{3.785 \text{ L}}{\text{gal}} \right] = 4,258.1 \text{ L/d} \quad \left[\frac{35 \text{ mg}}{\text{L}} \right] = 149,034.4 \text{ mg/d}$$

IMPERVIOUS SURFACES

$$15,000 \text{ ft}^2 \left[\frac{40 \text{ in}}{\text{yr}} \right] \left[\frac{\text{ft}}{12 \text{ in}} \right] \left[\frac{28.32 \text{ L}}{\text{ft}^3} \right] \left[\frac{1 \text{ yr}}{365 \text{ d}} \right] = 3,879.5 \text{ L/d} \quad \left[\frac{0.75 \text{ mg}}{\text{L}} \right] = 2,909.6 \text{ mg/d}$$

$$30,000 \text{ ft}^2 \left[\frac{40 \text{ in}}{\text{yr}} \right] \left[\frac{\text{ft}}{12 \text{ in}} \right] \left[\frac{28.32 \text{ L}}{\text{ft}^3} \right] \left[\frac{1 \text{ yr}}{365 \text{ d}} \right] = 7,758.9 \text{ L/d} \quad \left[\frac{1.5 \text{ mg}}{\text{L}} \right] = 11,638.4 \text{ mg/d}$$

LAWN

$$10,000 \text{ ft}^2 \left[\frac{3 \text{ lbs}}{1,000 \text{ ft}^2 * \text{yr}} \right] \left[\frac{1 \text{ yr}}{365 \text{ d}} \right] \left[\frac{454,000 \text{ mg}}{\text{lb}} \right] \left[0.25 \right] = 9,328.8 \text{ mg/d}$$

NATURAL

$$5 \text{ acres} \left[\frac{43,560 \text{ ft}^2}{\text{acre}} \right] = 217,800 \text{ ft}^2; \quad 217,800 \text{ ft}^2 - 45,000 \text{ ft}^2 = 172,800 \text{ ft}^2$$

$$172,800 \text{ ft}^2 \left[\frac{1.5 \text{ ft}}{\text{yr}} \right] \left[\frac{28.32 \text{ L}}{\text{ft}^3} \right] \left[\frac{1 \text{ yr}}{365 \text{ d}} \right] = 20,111.1 \text{ L/d}$$

SUMMARY

$$\frac{149,304.4 + 2,909.6 + 11,638.4 + 9,328.8 \text{ mg}}{4,258.1 + 3,879.5 + 7,758.9 + 20,111.1 \text{ liters}} = \frac{172,911.2 \text{ mg}}{36,007.6 \text{ liters}} = \boxed{4.80 \text{ ppm}}$$

EXAMPLE RESIDENTIAL LOADING CALCULATIONS

Home (3 bedrooms)

Lot Size: 1 acre (43,560 ft²)

Impervious Surfaces: Roof Area: 2,000 ft²; Paving Area: 500 ft²

Natural Area: 41,060 ft²; Lawn Area: 5,000 ft²

Title V Flow: 110 gallons/day per bedroom

WASTEWATER

Title V (2 people per bedroom)

$$3 \text{ bedrooms} \left[\frac{110 \text{ gpd}}{\text{bedroom}} \right] \left[\frac{3.785 \text{ L}}{\text{gal}} \right] = 1,249.0 \text{ L/d} \left[\frac{35 \text{ mg}}{\text{L}} \right] = 43,716.8 \text{ mg/d}$$

Actual (assume 2.5 people/unit average occupancy within the town)

$$3 \text{ bedrooms} \left[\frac{110 \text{ gpd}}{\text{bedroom}} \right] \left[\frac{3.785 \text{ L}}{\text{gal}} \right] \left[\frac{2.5}{6} \right] = 520.4 \text{ L/d} \left[\frac{35 \text{ mg}}{\text{L}} \right] = 18,214.6 \text{ mg/d}$$

IMPERVIOUS SURFACES

$$2,000 \text{ ft}^2 \left[\frac{40 \text{ in}}{\text{yr}} \right] \left[\frac{\text{ft}}{12 \text{ in}} \right] \left[\frac{28.32 \text{ L}}{\text{ft}^3} \right] \left[\frac{1 \text{ yr}}{365 \text{ d}} \right] = 517.3 \text{ L/d} \left[\frac{0.75 \text{ mg}}{\text{L}} \right] = 387.9 \text{ mg/d}$$

$$500 \text{ ft}^2 \left[\frac{40 \text{ in}}{\text{yr}} \right] \left[\frac{\text{ft}}{12 \text{ in}} \right] \left[\frac{28.32 \text{ L}}{\text{ft}^3} \right] \left[\frac{1 \text{ yr}}{365 \text{ d}} \right] = 129.3 \text{ L/d} \left[\frac{1.5 \text{ mg}}{\text{L}} \right] = 194.0 \text{ mg/d}$$

LAWN

$$5,000 \text{ ft}^2 \left[\frac{3 \text{ lbs}}{1,000 \text{ ft}^2 * \text{yr}} \right] \left[\frac{1 \text{ yr}}{365 \text{ d}} \right] \left[\frac{454,000 \text{ mg}}{\text{lb}} \right] \left[0.25 \right] = 4,664.4 \text{ mg/d}$$

NATURAL

$$43,560 \text{ ft}^2 - 2,500 \text{ ft}^2 = 41,060 \text{ ft}^2$$

$$41,060 \text{ ft}^2 \left[\frac{1.5 \text{ ft}}{\text{yr}} \right] \left[\frac{28.32 \text{ L}}{\text{ft}^3} \right] \left[\frac{1 \text{ yr}}{365 \text{ d}} \right] = 4,778.7 \text{ L/d}$$

SUMMARY

$$\begin{array}{rcl} \text{Title V Flow} & \frac{43,716.8 + 387.9 + 194.0 + 4,664.4 \text{ mg}}{1,249.0 + 517.3 + 129.3 + 4,778.7 \text{ liters}} & = \frac{48,963.1 \text{ mg}}{6,674.3 \text{ liters}} = 7.34 \text{ ppm} \\ \\ \text{Actual} & \frac{18,214.6 + 387.9 + 194.0 + 4,664.4 \text{ mg}}{520.4 + 517.3 + 129.3 + 4,778.7 \text{ liters}} & = \frac{23,460.9 \text{ mg}}{5,945.7 \text{ liters}} = 3.95 \text{ ppm} \end{array}$$

$$\text{Final Calculation} \quad (7.34 + 3.95)/2 =$$

5.65 ppm



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