APPENDICES

2003

Massachusetts Estuaries Project

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Activated Sludge - An aerobic, biological wastewater treatment process which uses the metabolic reactions of microorganisms to treat effluent.

Aerobic – Condition where free oxygen is present.

Algae Blooms - A growth of algae resulting from excessive nutrient (nitrogen or phosphorus) levels or other physical and chemical conditions that enable algae to reproduce rapidly. The overgrowth of algae can form scums and mats, and reduce the amount of oxygen as they decay.

Anaerobic – Condition where free oxygen is not present or is unavailable.

Anthropogenic – Of, relating to, or resulting from the influence of human beings on nature.

Aquifers – Geologic formations (rock, sand, or gravel) that are saturated and sufficiently permeable to yield significant quantities of water.

Attenuate – Reduce the force or amount or magnitude.

Benthic – Occurring at the bottom of the sea or lake (e.g., benthic organisms).

Benthic Regeneration – The regrowth of organisms on lake or sea floors.

Best Management Practices (BMPs)– Conservation practices to reduce nonpoint and point pollution from sources such as construction, agriculture, timber harvesting, marinas, and stormwater.

Biodiversity – Biological diversity in an environment as indicated by the numbers of different species of plants and animals.

Biological Assimilation – The process in which nourishment is absorbed into living tissue.

Biological Mediated Denitrification or Biologically Mediated Denitrification - The removal of nitrogen (nitrates, **nitrites**) via natural (microbial) processes resulting in the release of nitrogen gas into the air.

Biomass – A measure of the amount of living matter per unit area or volume of habitat.

Biota - A community of plant and animal organisms.

BoH - Board of Health.

Cluster System – A wastewater collection and treatment system where two or more facilities, but less that an entire community, is served.

CMR – Code of Massachusetts Regulations.

Combined Sewer Overflow (CSO) – A sewer pipe or system through which both sanitary wastewater and stormwater flows. During significant precipitation events, stormwater is mixed with sanitary flow, may bypass wastewater treatment, and can be released to a receiving waterbody without treatment.

Critical Resource Area – Localities that have been judged to be essential to the ecological well-being of the environment. They are subject to protection under MGL c. 131.

Cultural eutrophication – The accelerated aging process of waterbodies resulting from human sources of nutrients that stimulate the growth of aquatic plants and lead to the depletion of dissolved oxygen.

CWA - Federal Clean Water Act.

CZM – Massachusetts Office of Coastal Zone Management.

Deposition – The process by which pollutants absorbed by the atmosphere are released to land or water through precipitation or wind.

Depuration - Process of flushing toxins from shellfish before they are sold by holding them in tanks of clean water for a fixed amount of time.

Down Gradient - The direction that ground water flows; similar to "downstream" for surface water.

Ecosystem – The system of living organisms that interact with one another and their physical environment, functioning as an ecological unit.

Effluent – Treated or untreated wastewater from a treatment facility or unit that is discharged into the environment.

Effluent Trading – Strategies/tools to reduce problem pollutants in rivers and streams, lakes, estuaries, and coastlines. Trading allows a wastewater treatment plant, factory, or other facilities that discharge waste into a waterbody to purchase controls of a particular pollutant elsewhere in the watershed, instead of installing tighter controls for that pollutant at the plant or factory.

Embayment – A bay or a conformation resembling a bay. The terms embayment and estuary are used interchangeably in this Guidance.

EOEA – The Executive Office of Environmental Affairs.

EPA – The United States Environmental Protection Agency.

Estuary – Partially enclosed body of water that consists of fresh and saltwater where the tide meets the river's current. *(see embayment)*

Eutrophication – A waterbody's natural aging process due to enrichment in dissolved nutrients that stimulate the growth of aquatic plant life, usually resulting in the depletion of dissolved oxygen.

Flushing Rates – The time it takes for an entire volume of water to be exchanged, usually expressed in days or years.

GPD – Gallons Per Day.

Ground Water – Water below the land surface in a saturated zone.

Ground Water Discharge Permit Program– 314 CMR 5.00 establishes that discharges of pollutants to the ground waters of the Commonwealth will be regulated by DEP pursuant to MGL c.21, § 43, and that the outlets for these types of discharges and the treatment works associated with these discharges also be regulated by DEP.

Habitat – An environment in which plants and animals live, feed, find shelter, and reproduce.

Holding Time - Amount of time needed in a septic tank to allow for some decomposition of solids.

Infiltration - Downward movement of water through soil.

Innovative/Alternative (I/A) Systems - Advanced on-site wastewater treatment and disposal systems that provide additions or alternatives to one or more of the components of a conventional system while providing at least an equivalent degree of environmental and public health protection. I/A systems are becoming more widely used, particularly for cost-effective upgrades of failing systems on difficult sites that cannot accommodate a conventional system. I/A technologies also are used for enhanced treatment to reduce nitrogen in nitrogen sensitive areas.

Integrated Water Resources Management Planning– Process to evaluate all technical and management aspects of water and wastewater resources needed for ecological and human health and develop a strategy to meet these needs.

Interim Wellhead Protection Areas (IWPA)– Applicable to public water systems using wells or wellfields that lack DEP-approved Zone IIs. The IWPA is a half-mile radius measured from the well or wellfield for sources whose approved pumping rate is 100,000 gallons per day or greater.

Invasive Species – Aggressive and spreading plants or animals that do not naturally occur in a specific area and whose introduction may cause economic or environmental harm.

Local Residence Time - Average time for water to migrate from a point in a sub-embayment to a point outside the sub-embayment.

Mass Balance – Standard engineering and scientific calculations based on the law of conservation of mass.

Massachusetts Clean Waters Act – MGL c.21, § 26-53, which prohibits the discharge of pollutants to waters of the Commonwealth without a permit, unless exempted by regulation.

MDC - Massachusetts Metropolitan District Commission.

Mean High Water – A tidal datum. The mean of all the high water heights observed over the National Tidal Datum Epoch (*see National Tidal Datum Epoch*).

Mean Low Water - A tidal datum. The mean of all the low water heights observed over the National Tidal Datum Epoch. (*see National Tidal Datum Epoch*).

MEP – Massachusetts Estuaries Project.

MEPA – Massachusetts Environmental Policy Act.

Mg/L – Milligrams Per Liter.

MGD – Million Gallons Per Day.

MGL – Massachusetts General Laws.

Mitigate – To take corrective action to eliminate pollution or reduce its impact.

MPN - Most probable number.

National Pollutant Discharge Elimination System (NPDES) - A federal permit program established in 1972 by the Federal Water Pollution Control Act, known as the Clean Water Act. NPDES regulates the discharge of pollutants into waterbodies. Massachusetts is not authorized to administer the NPDES program.

National Tidal Datum Epoch - The 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken and reduced to obtain maen values for mean low water and mean high water.

Natural Attenuation – Using a naturally occurring system (wetland or pond) to reduce the amount of nitrogen impact on an estuary.

NEIWPCC – The New England Interstate Water Pollution Control Commission.

Nitrate – Component of fertilizer. Considered a broad indicator of the contamination of groundwater. The nitrogen species in marine systems that is most responsible for eutrophication.

Nitrite – A salt or ester of nitrous acid. An intermediate oxidation state of nitrogen, between nitrate and ammonia.

Nitrogen Cycle – Continuous cyclic progression of chemical reactions in which atmospheric nitrogen is compounded, dissolved in rain, deposited in the soil, assimilated and metabolized by bacteria and plants, and returned to the atmosphere by organic decomposition.

Nitrogen Loading - The input of nitrogen to estuaries and embayments from natural and anthropogenic sources.

Nitrogen Threshold - Maximum amount of nitrogen that an estuary or embayment can assimilate without adversely changing its character and use. Also known as the critical nitrogen limit.

Nonpoint Source – Pollution from many diffuse sources that is carried to surface waters by runoff or ground water. Nonpoint source pollution is typically caused by sediment, nutrients, and organic and toxic substances originating from land-use activities and/or the atmosphere.

NSFC – National Small Flows Clearing House.

Nutrient Sink – Waterbodies/wetlands that hold nutrients in the water column or in the sediments, making them either temporarily or permanently unavailable for biological processes.

Nutrient Trading - Strategies/tools to reduce problem pollutants in rivers and streams, lakes, estuaries, and coastlines. Trading allows a wastewater treatment plant, factory, or other facilities that discharge waste into a waterbody to purchase controls of a particular pollutant elsewhere in the watershed, instead of installing tighter controls for that pollutant at the plant or factory.

Nutrients – Any substance required by plants and animals for normal growth and maintenance e.g., nitrogen and phosphorus.

Off-Line - Stormwater treatment systems designed to retain a standing volume of stormwater to allow for a physical settling of suspended particles and for other biological and chemical treatment processes to occur.

On-Line - Stormwater treatment systems designed to treat stormwater at a designated flow rate. The retention time in these systems is very short.

On-Site Treatment and Disposal System– A natural system or mechanical device used to collect, treat, and discharge or reclaim wastewater from an individual dwelling without the use of community-wide sewers or a centralized treatment facility. It includes a septic tank and a leach field.

Organic pollutants – Carbon-based pollutants such as proteins, carbohydrates, and fats and oils, present in wastewater.

Pathogen – An agent such as a virus, bacterium, or fungus capable of causing disease.

Point Source – Pollution from discernable, confined, and concrete conveyances, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling rock, concentrated animal feeding operation, vessel or other floating craft from which pollutants are or may be discharged. This term does not include return flows from irrigation agriculture.

Pollutants – Any element or property of sewage, agricultural, industrial, or commercial waste, runoff, leachate, heated effluent, or other matter in whatever form, and whether originating at a point or nonpoint source, that is or may be discharged, drained, or otherwise introduced into any sewage system, treatment works, or waters of the Commonwealth.

Pollution Trading – A regulatory tool that allows pollution sources to reallocate responsibilities for pollution reduction among themselves and find the most cost-effective reduction measures in order to meet regulatory requirements.

POTW – Publicly Owned Treatment Works.

PPM – Parts Per Million.

Recharge – The return of water to an underground aquifer by natural or artificial means.

Remediation – Corrective action taken to eliminate pollution or reduce its impact.

Residence Times – The average time required for a particle of water or pollutant to migrate through an estuary.

Rotating Biological Contactor (RBC) - Wastewater treatment technology that uses bacteria grown on partially submerged plates to treat effluent.

Salinity – The measure of the salt content of water.

Sediment – Mineral and organic material that settles from suspension in the water column.

Septic tank – A buried tank designed to receive and pretreat wastewater from individual homes by separating settleable and floatable solids from wastewater. A component of an on-site wastewater treatment and disposal system.

Sequencing Batch Reactor (SBR) - Wastewater treatment technology in which aeration and clarification are carried out sequentially in the same tank.

Sessile - Describing a marine or freshwater organism that is permenantly attached to another surface.

Sewage – The water-carried human or animal wastes from residences, buildings, industrial establishments, or other places, together with such ground water infiltration and surface water as may be present.

SMAST – The University of Massachusetts School of Marine Science and Technology.

Soil Absorption System (SAS) – System of trenches, chambers, pits, fields, or beds, and distribution lines that receives effluent from a septic tank and transmits it to the soil for treatment in a biological mat and subsequent disposal to the underlying soils.

State Revolving Fund (SRF) – This program assists towns, cities, and wastewater districts in the financing of water pollution abatement projects. There are two types of funding through this program: the **Clean Water** and **Drinking Water** State Revolving Fund grants (**CWSRF** and **DWSRF**). The clean water fund supports low interest loans to help communities build/upgrade wastewater facilities. The drinking water fund supports low interest loans to help communities build/upgrade water treatment systems.

Sub-embayment - Cove within an embayment.

Surface Water - All waters other than ground waters within the jurisdiction of the Commonwealth, including, without limitation, rivers, streams, lakes, ponds, springs, impoundments, estuaries, wetlands, coastal waters and vernal pools.

System Residence Time - Average time for water to migrate through an entire estuarine system.

Tidal Flushing – The exchange of water from an estuarine system to the waterbody into which it empties.

Total Maximum Daily Load (TMDLs) – The greatest amount of a pollutant that a waterbody can accept and still meet water quality standards for protecting public health and maintaining the designated beneficial uses of those waters for drinking, swimming, recreation, and fishing.

Turbidity – A measure of soil or organic particles that cloud the water and do not allow light rays to pass through.

Water Column – The open-water environment, as distinct from the bed or shore, that may be inhabited by marine or fesh water organisms.

Water Quality – Pertaining to the presence and amount of pollutants in water.

Wetlands Protection Act (WPA) – MGL c. 131, § 40. Under the provisions of the Act, no person may remove, fill, dredge, or alter certain resource areas without first filing a Notice of Intent and obtaining an Order of Conditions. The Act requires that the Order contain conditions to contribute to the following interests: protection of public and private surface and ground water supply, flood control, storm damage prevention, prevention of pollution, protection of fisheries, land containing shellfish, and protection of wildlife habitat.

WWTP – Wastewater Treatment Plant.

Zone II – That area of an aquifer that contributes water to a well under the most severe pumping and recharge conditions that can be anticipated. See 310 CMR 22.00 for a more detailed regulatory definition: http://www.state.ma.us/dep/brp/dws/files/310cmr22.pdf

Documents in this Appendix are categorized by source: state, federal, and other. Documents are listed in the order in which they appear in the body of the Guidance.

Copies of regulations on DEP's web site are not the "Official Version" of Commonwealth regulations. In particular, they lack page numbers and the effective dates at the bottom of each page. Other unexpected differences may also be present. HTML versions are offered as a convenience to our users and DEP believes that the body of the text is a faithful copy of the regulations. If readers must know that the version being used is absolutely correct and up-to-date, they must purchase the document through the State Bookstore (at http://www.state.ma.us/sec/spr/spridx.htm). The official versions of all state statutes and regulations are only available through the State Bookstore.

State Regulatory Programs and Resources

Home page for the MEP, including maps and background articles: http://www.state.ma.us/dep/smerp/smerp.htm.

State Bookstore: Room 116, State House, Boston, MA 02133 617/727-2834; http://www.state.ma.us/sec/spr/spridx.htm

Surface Water Quality Standards, 314 CMR 4.0: http://www.state.ma.us/dep/bwp/iww/files/314004.pdf

Surface Water Discharge Permit Program, 314 CMR 3.00: http://www.state.ma.us/dep/bwp/iww/files/314cmr3.htm

Ground Water Quality Standards, 314 CMR 6.00: http://www.state.ma.us/dep/bwp/iww/files/314006.pdf

Ground Water Discharge Permit Program, 314 CMR 5.00: http://www.state.ma.us/dep/bwp/iww/files/314005.pdf

Comprehensive Wastewater Management Planning. Current guidance (1996): http://www.state.ma.us/dep/brp/mf/files/fpintro.htm.

Grant and Loan Programs: Opportunities for Watershed Protection, Planning and Implementation, updated November 2002: http://www.state.ma.us/dep/brp/mf/files/glprgm.pdf

Clean Water State Revolving Loan Fund: http://www.state.ma.us/dep/brp/mf/cwsrf.htm

Waterways Program, Chapter 91 License, 310 CMR 9.00, Chapter 91: http://www.state.ma.us/dep/brp/waterway/ch91regs.htm

401 Water Quality Certification, 314 CMR 9.00: http://www.state.ma.us/dep/bwp/iww/files/314009.pdf

Notice of Intent, Wetlands Protection Act, 310 CMR 10.00: http://www.state.ma.us/dep/brp/ww/files/310cmr10.pdf

Current Dredging Regulations: 401 Water Quality Certification, 314 CMR 9.00: http://www.state.ma.us/dep/bwp/iww/files/314009.pdf. Contact DEP for updated interim procedures on dredging and management of dredged sediments.

Massachusetts Environmental Policy Act: MEPA Certificate, 301 CMR 11.00: http://www.state.ma.us/envir/mepa/thirdlevelpages/meparegulations/301cmr11.pdf

Coastal Zone Management (CZM) Federal Consistency Review Procedures, 301 CMR 21.00: http://www.state.ma.us/czm/fcr.htm

Stormwater Management: Policy (Vol I) and Technical Handbook (Vol II), 1997.http://www.state.ma.us/dep/brp/stormwtr/stormpub.htm

Policy for Abatement of Pollution from Combined Sewer Overflows: http://www.state.ma.us/dep/brp/brppols.htm (Surface Water Section)

EOEA, Strategic Envirotechnology Partnership (STEP) Reports and Fact Sheets on innovative stormwater treatment systems: http://www.stepsite.org/progress/reports/

Wetland Program: http://www.state.ma.us/dep/brp/ww/rpwwhome.htm

Wetlands Protection Act Regulations, 310 CMR 10.00: http://www.state.ma.us/dep/brp/ww/files/310cmr10.pdf

EOEA, Massachusetts Wetlands Restoration Program: http://www.state.ma.us/envir/mwrp/index.htm

Title 5 Program: http://www.state.ma.us/dep/brp/wwm/t5pubs.htm#it

Title 5: Standard Requirements for … On-Site Sewage Treatment and Disposal Systems and for the Transport and Disposal of Septage, 310 CMR 15.00: http://www.state.ma.us/dep/brp/files/310cmr15.pdf

Certification of Operators of Wastewater Treatment Facilities, 257 CMR 2.00: http://www.state.ma.us/dep/bwp/iww/files/257cmr2.htm

Guidelines for the Design, Construction, Operation and Maintenance of Small Sewage Treatment Facilities with Land Disposal, 1988. Contact DEP for a copy.

Water conservation information: http://www.state.ma.us/dep/brp/dws/conserv.htm

Interim Guidelines on Reclaimed Water: http://www.state.ma.us/dep/brp/wwm/files/reuse.pdf

EOEA, Community Preservation Initiative: http://commpres.env.state.ma.us/

MDC: *Growth Management Tools: A Summary for Planning Boards in Massachusetts*, August 2002. http://www.state.ma.us/mdc/MDC%20Growth%20Management%20Tools.pdf

Rivers Protection Act, 1996 amendment to the Wetlands Protection Act: http://www.state.ma.us/dep/brp/ww/files/riveract.htm.

Federal Regulatory Programs and Resources

Total Maximum Daily Load Program: http://www.epa.gov/OWOW/tmdl/

National Pollutant Discharge Elimination System (NPDES): http://cfpub1.epa.gov/npdes/stormwater/swphase2.cfm?program_id=6; http://cfpub.epa.gov/npdes/; http://www.epa.gov/region01/npdes/

Army Corps of Engineers (ACOE), Permit Authorization under Section 10, Rivers and Harbors Act: http://www.spk.usace.army.mil/cespk-co/regulatory/regs/start.html

Wetlands Program, Office of Water: http://www.epa.gov/owow/wetlands/

Guidance on Constructed Wetlands: http://www.epa.gov/owow/wetlands/watersheds/cwetlands.html

Water efficiency programs: http://www.epa.gov/owm/water-efficiency/index.htm

Draft framework for watershed-based permitting and other background documents: http://www.epa.gov/owow/watershed/framwork.html

Office of Water: Final Water Quality Trading Policy, January 13, 2003: http://www.epa.gov/owow/watershed/trading/finalpolicy2003.html

National Small Flows Clearinghouse: http://www.nesc.wvu.edu/nsfc/

Other Resources

New England Interstate Water Pollution Control Commission: *Document TR-16: Guides for the Design of Wastewater Treatment Works*, 1988 Edition: http://www.neiwpcc.org/publication.html#16
Marine Studies Consortium, M.T. Hoover: *A Framework for Site Evaluation, Design, and Engineering of On-Site Technologies Within a Management Context*, 1997. Executive Summary: http://www.brandeis.edu/marinestudies/risk.html
Entire Report: http://www.state.ma.us/dep/brp/wwm/files/hoovered.doc
Pioneer Valley Planning Commission: *How to Create a Stormwater Utility,* 1999: http://www.pvpc.org/docs/landuse/pubs/storm_util.pdf
Northbridge Environmental: *Overview of Water Pollution Trading in Massachusetts*, June 2001. Printed copies are available from DEP.
Environomics: *A Summary of U.S. Effluent Trading and Offset Projects,* November 1999: http://www.environomics.com/Effluent-Trading-Summaries_Environomics.pdf
National Wildlife Federation: *A New Tool for Water Quality. Making Watershed-Based Trading Work for You*, June 1999: http://www.nwf.org/watersheds/newtool.html
World Resources Institute (WRI): *Fertile Ground. Nutrient Trading's Potential to Cost-Effectively Improve Water Quality, 2000.* www.wri.org/wri/water/nutrient.html
WRI Web site: http://www.nutrientnet.org/

Appendix C

Embayments in the Massachusetts Estuaries Project

2003

Massachusetts Estuaries Project

Community	Watershed and Embayment
	South Coastal Watershed
Duxbury	Duxbury Harbor
	Ellisville Harbor
Plymouth	Plymouth Harbor/Eel River
	Mt Hope Bay & Taunton River Watersheds
Fall River, Somerset, Swansea, Dighton, Rehoboth, Seekonk	Mt Hope Bay
24 communities: Taunton, Avon, Berkley, Bridgewater, Brockton,Dighton, East Bridgewater, Easton,Franklin, Foxborough, Freetown,Halifax, Hanson, Lakeville, Mansfield,Middleborough, Norton, Plympton,Raynham, Sharon, Somerset,Stoughton, West Bridgewater, Whitman	Taunton River System
	Buzzards Bay Watershed
Westport	Westport River - East & West Branch
Dartmouth	Slocums River
	Little River
Dartmouth/New Bedford	Apponagansett Bay
New Bedford/Dartmouth/Fairhaven	New Bedford Harbor (Outer)/Clarks Cove
New Bedford/Fairhaven/Acushnet	Acushnet River/New Bedford Inner Harbor
Fairhaven	Nasketucket Bay/Little Bay
Mattapoisett	Mattapoisett Harbor/Eel Pond
Marion/Mattapoisett	Aucoot Cove
Marion	Sippican Hbr/HammettCv/Blankenship/Planting Island
Wareham	Weweantic River
	Onset Bay/Shell Pt. Bay/Broad Cove
Wareham/Plymouth	Wareham River System (+Marks Cove)
	Agawam River/Wankinco River/Broad Marsh
Wareham/Plymouth/Bourne	Buttermilk & Little Buttermilk Bays

Community	Watershed and Embayment
	Cape Cod & Islands Watershed -- Cape Cod
Bourne	Phinney's Harbor
	Back River/Eel Pond
	Pocasset River
Falmouth/Bourne	Pocasset Harbor/Hen Cove/Red Brook Hbr
Falmouth	Megansett Harbor/Squeteague
	Wild Harbor
	Rands Canal
	Fiddlers Cove
	West Falmouth Harbor
	Quissett Harbor
	Oyster Pond
	Salt Pond
	Falmouth Harbor
	Little Pond
	Great/Perch Pond
	Green Pond
	Bournes Pond
	Eel River, Falmouth
	Waquoit Bay-Proper
	Childs River
Mashpee	Hamblin Pond/Jehu Pond/Quashnet River
Mashpee/Barnstable	Popponesset Bay
Barnstable	Rushy Marsh
	Three Bays
	East Bay/Centerville River/Halls Creek
Barnstable/Yarmouth	Lewis Bay System
	– Hyannis Harbor
	– Snows Creek
	– Lewis Bay
Yarmouth/Dennis	Bass River
Harwich	Saquatucket Harbor
	Allen Harbor
	Herring River
	Wychmere Harbor
Dennis	Swan Pond/River
Chatham/Harwich	Taylors Pond
	Muddy Creek

Community	Watershed and Embayment
Chatham	Sulfur Spring/Bucks Creek
	Stage Harbor System
Chatham	Bassing Harbor/Ryders Cove/Frost Fish Creek
Orleans/Harwich/Brewster	Chatham Harbor
Orleans/Eastham	Upper Pleasant Bay
	Nauset Marsh
Sandwich	Sandwich Harbor
	Scorton Creek
Barnstable	Barnstable Harbor/Great Marshes
Dennis	Sesuit Harbor
Orleans	Namskaket Creek
	Little Namskaket Creek
	Rock Harbor
Wellfleet	Wellfleet Harbor
Truro	Pamet Harbor
Provincetown	Provincetown Harbor
	Hatches Harbor
Gosnold	Cuttyhunk Harbor
	West End Pond, Cuttyhunk
	Penikese Island Harbor

Cape Cod & Islands Watershed -- Martha's Vineyard

Chilmark	Black Point Pond
Chilmark/West Tisbury	Tisbury Great Pond
Chilmark/Aquina	Chilmark Great Pond
	Squibnocket Pond
	Menemsha Pond
Tisbury	Tashmoo
Tisbury/Oak Bluffs	Lagoon Pond
West Tisbury	James Pond
Edgartown	Long Cove Pond
	Katama Bay/Edgartown Harbor
	Cape Pogue Pond/Pochet Pond/Calebs Pond
	Edgartown Great Pond

Community	Watershed and Embayment
Edgartown/Oak Bluffs	Oyster Pond Sengekontacket Pond/Trapps Pond/Majors Cove
	Cape Cod & Islands Watershed -- Nantucket
Nantucket	Nantucket Harbor Sesechacha Pond Madaket Harbor Long Pond Hummock Pond

The Massachusetts Surface Water Quality Standards in 314 CMR 4.00 (http://www.state.ma.us/dep/bwp/iww/files/314004.pdf) set forth classifications for coastal and marine waters. These classifications apply standards that are both quantitative and descriptive and, at a minimum, require "good aesthetic value." The three classes are SA, SB and SC. A description of each follows.

Class SA

314 CMR 4.04(4)(a): "These waters are designated as an excellent habitat for fish, other aquatic life and wildlife and for primary and secondary contact recreation. In approved areas, they shall be suitable for shellfish harvesting without **depuration** (Open Shellfish Areas). These waters shall have excellent aesthetic value." Class SA standards for specific parameters are in the table below:

Parameter	Standard
Dissolved Oxygen	a. Not less than 6.0 mg/L unless background conditions are lower. b. Natural seasonal and daily variations above this level shall be maintained; levels shall not be lowered below 75% of saturation due to a discharge. c. Site-specific criteria may apply where background conditions are lower than specified levels, or to the bottom stratified layer where the Director determines that the designated uses are not impaired.
Temperature	Shall not exceed 85°F or a maximum daily mean of 80°F. A rise in temperature due to a discharge shall not exceed 1.5° F.
pH	Shall be in the range of 6.5 through 8.5 standard units and not more than 0.2 units outside the normally occurring range.
Fecal Coliform	a. Waters approved for shellfishing shall not exceed a geometric mean **MPN** of 14 colonies/100 mL, nor shall more than 10% of the samples exceed an MPN of 43 colonies/100 mL. b. Waters not designated for shellfishing shall not exceed a geometric mean MPN of 200 colonies/100 mL, nor shall more than 10% of the samples exceed an MPN of 400 colonies/100 mL.
Solids	Shall be free from floating, suspended and settleable solids in concentrations or combinations that would impair any use assigned to this class, that would cause any objectionable conditions or that would impair the **benthic biota** or degrade the chemical composition of the bottom.
Color and Turbidity	Shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this class.
Oil and Grease	Shall be free from oil and grease and petrochemicals.
Taste and Odor	None other than of natural origin.

Class SB
314 CMR 4.05(4)(b): "These waters are designated as a habitat for fish, other aquatic life and wildlife and for primary and secondary contact recreation. In approved areas they shall be suitable for shellfish harvesting with depuration (Restricted Shellfish Areas). These waters shall have consistently good aesthetic value." Class SB standards for specific parameters are in the table below:

Parameter	Standard
Dissolved Oxygen	a. Not less than 5.0 mg/L unless background conditions are lower. b. Natural seasonal and daily variations above this level shall be maintained; levels shall not be lowered below 60% of saturation due to a discharge. c. Site-specific criteria may apply where background conditions are lower than specified levels, or to the bottom stratified layer where the Director determines that the designated uses are not impaired.
Temperature	Shall not exceed 85°F or a maximum daily mean of 80°F. The rise in temperature due to a discharge shall not exceed 1.5°F during the summer months (July through September) or 4°F during the winter months (October through June).
pH	Shall be in the range of 6.5 through 8.5 standard units and not more than 0.2 units outside the normally occurring range.
Fecal Coliform	a. Waters approved for shellfishing shall not exceed a geometric mean MPN of 88 colonies/100 mL, nor shall more than 10% of the samples exceed an MPN of 260 colonies/100 mL. b. Waters not designated for shellfishing shall not exceed a geometric mean MPN of 200 colonies/100 mL, nor shall more than 10% of the samples exceed an MPN of 400 colonies/100 mL.
Solids	Shall be free from floating, suspended and settleable solids in concentrations or combinations that would impair any use assigned to this class, that would cause any objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom.
Color and Turbidity	Shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this class.
Oil and Grease	Shall be free from oil and grease and petrochemicals that produce a visible film on the surface of the water, impart an oily taste to the water or an oily or other undesirable taste to the edible portions of aquatic life, coat the banks or bottoms of the water course, or are deleterious or become toxic to aquatic life.
Taste and Odor	None in such concentrations or combinations that are aesthetically objectionable, that would impair any use assigned to this class, or that would cause tainting or undesirable flavors in the edible portions of aquatic life.

Class SC
314 CMR 4.05(4)(c): "These waters are designated as a habitat for fish, other aquatic life and wildlife and for secondary contact recreation. They shall also be suitable for certain industrial cooling and process uses. These waters shall have good aesthetic value." Class SC standards for specific parameters are in the table below:

Parameter	Standard
Dissolved Oxygen	a. Not less than 5.0 mg/L at least 16 hours of any 24-hour period and not less than 4.0 mg/L at any time unless background conditions are lower. b. Natural seasonal and daily variations above this level shall be maintained; levels shall not be lowered below 50% of saturation due to a discharge. c. Site-specific criteria may apply where background conditions are lower than specified levels, or to the bottom stratified layer where the Director determines that the designated uses are not impaired.
Temperature	Shall not exceed 85°F. The increase due to a discharge shall not exceed 5°F.
pH	Shall be in the range of 6.5 through 9.0 standard units and not more than 0.5 units outside the normally occurring range.
Fecal Coliform	Shall not exceed a geometric mean of 1000 colonies/100 mL nor shall 10% of the samples exceed 2000 colonies/100 mL.
Solids	Shall be free from floating, suspended and settleable solids in concentrations or combinations that would impair any use assigned to this class, that would cause any objectionable conditions or that would impair the benthic biota or degrade the chemical composition of the bottom.
Color and Turbidity	Shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this class.
Oil and Grease	Shall be free from oil and grease and petrochemicals that produce a visible film on the surface of the water, impart an oily taste to the water or an oily or other undesirable taste to the edible portions of aquatic life, coat the banks or bottoms of the water course, or are deleterious or become toxic to aquatic life.
Taste and Odor	None in such concentrations or combinations that are aesthetically objectionable, that would impair any use assigned to this class, or that would cause tainting or undesirable flavors in the edible portions of aquatic life.

The Surface Water Quality Standards apply additional minimum criteria to all surface waters:

Parameter	Standard
Aesthetics	All surface waters shall be free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance species of aquatic life.
Bottom Pollutants or Alterations	All surface waters shall be free from pollutants in concentrations or combinations or from alterations that adversely affect the physical or chemical nature of the bottom, interfere with the propagation of fish or shellfish, or adversely affect populations of non-mobile or **sessile** benthic organisms.
Nutrients	Shall not exceed the site-specific limits necessary to control accelerated or cultural eutrophication.
Radioactivity	All surface waters shall be free from radioactive substances in concentrations or combinations that would be harmful to human, animal or aquatic life or the most sensitive designated use.
Toxic Pollutants	All surface waters shall be free from toxic substances in concentrations or combinations that would be harmful to human, animal or aquatic life or wildlife. This includes consideration of site-specific limits, human health risk levels and accumulation of pollutants.

314 CMR 6.00 establishes the Massachusetts Ground Water Quality Standards http://www.state.ma.us/dep/bwp/iww/files/314006.pdf. These standards consist of ground water classifications which designate and assign the uses for which the various ground waters of the Commonwealth shall be maintained and protected. These Standards also include water quality standards necessary to sustain the designated uses and regulations necessary to achieve the designated uses or maintain the existing ground water quality.

All ground waters of the Commonwealth are assigned to Class I, II, or III based upon the most sensitive uses for which the ground water is to be maintained and protected:

- Class I - Ground waters assigned to this class are fresh ground waters found in the saturated zone of unconsolidated deposits or consolidated rock and bed rock and are designated as a source of potable water supply.
- Class II - Ground waters assigned to this class are saline waters found in the saturated zone of the unconsolidated deposits or consolidated rock and bed rock and are designated as a source of potable mineral waters, for conversion to fresh potable waters, as raw material for the manufacture of sodium chloride or its derivatives, or similar products.
- Class III - Ground waters assigned to this class are fresh or saline waters found in the saturated zone of unconsolidated deposits or consolidated rock and bed rock and are designated for uses other than as a source of potable water supply. At a minimum the most sensitive use of these waters shall be as a source of non-potable water that may come in contact with, but is not ingested by, humans.

Class I and Class II Ground Waters. The following minimum criteria are applicable to all Class I and Class II ground waters:

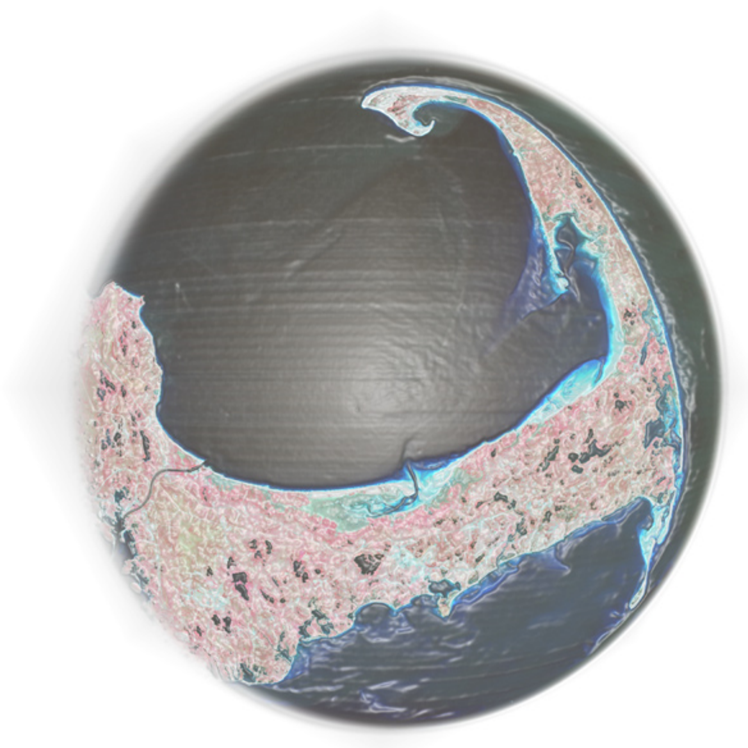
Parameter	Standard
Pathogenic Organisms	Shall not be in amounts sufficient to render the ground waters detrimental to public health and welfare or impair the ground water for use as source of potable water.
Coliform Bacteria	Shall not exceed the maximum contaminant level as stated in the National Interim Primary Drinking Water Standards.
Arsenic	Shall not exceed 0.05 mg/L
Barium	Shall not exceed 1.0 mg/L
Cadmium	Shall not exceed 0.01 mg/L
Chromium	Shall not exceed 0.05 mgL
Copper	Shall not exceed 1.0 mg/L
Fluoride	Shall not exceed 2.4 mg/L
Foaming Agents	Shall not exceed 0.5 mg/L
Iron	Shall not exceed 0.3 mg/L
Lead	Shall not exceed 0.05 mg/L
Manganese	Shall not exceed 0.05 mg/L

Class I and Class II Ground Waters. The following minimum criteria are applicable to all Class I and Class II ground waters:

Parameter	Standard
Mercury	Shall not exceed 0.002 mg/L
Nitrate Nitrogen (as Nitrogen)	Shall not exceed 10.0 mg/L
Total Trihalomethanes	Shall not exceed 0.1 mg/L
Selenium	Shall not exceed 0.01 mg/L
Silver	Shall not exceed 0.05 mg/L
Sulfate	Shall not exceed 250 mg/L
Zinc	Shall not exceed 5.0 mg/L
Endrin (1,2,3,4,10, 10-hexachloro-1,7-epoxy-1,4,4a,5,6,7,8,9a-octahydro-1,4-endo,endo-5,8-dimethanonaphthalene)	Shall not exceed 0.0002 mg/L
Lindane (1,2,3,4,5,6 hexachlorocyclohexane, gamma isomer)	Shall not exceed 0.004 mg/L
Methoxychlor (1,1,1- Trichloro-2, 2-bis(p-methoxyphenyl) ethane)	Shall not exceed 0.1 mg/L
Toxaphene (C10H10C18, Technical Chlorinated Camphene, 67-69 percent chlorine)	Shall not exceed 0.005 mg/L
Chlorophenoxys:2,4-D,(2,4-Dichloro-phenoxyacetic acid)	Shall not exceed 0.1 mg/L
2,4,5-TP Silvex (2,4, 5-Trichlorophenoxy-propionic acid)	Shall not exceed 0.01 mg/L
Radioactivity	Shall not exceed the maximum radionuclide contaminant levels as stated in the National Interim Primary Drinking Water Standards.
pH	Shall be in the range of 6.5-8.5 standard units or not more than 0.2 units outside of the naturally occurring range.
All Other Pollutants	None in such concentrations which in the opinion of the Department would impair the waters for use as a source of potable water or to cause or contribute to a condition in contravention of standards for other classified waters of the Commonwealth.

Class III Ground Waters. The following minimum criteria are applicable to all Class III ground waters:

Parameter	Standard
Pathogenic Organisms	Shall not be in amounts sufficient to render the ground waters detrimental to public health, safety or welfare.
Radioactivity	Shall not exceed the maximum radionuclide contaminant levels as stated in the National Interim Primary Drinking Water Standards.
All Other Pollutants	None in concentrations or combinations which upon exposure to humans will cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions or physical deformations or cause any significant adverse effects to the environment, or which would exceed the recommended limits on the most sensitive ground water use.



The Department of Environmental Protection has adopted a model developed at the University of Massachusetts Dartmouth School of Marine Science and Technology to calculate the capacity of estuaries to assimilate nitrogen and to run predictive scenarios to aid in planning nitrogen reductions. The model uses a linked approach to incorporate hydrodynamics (for flushing characteristics), water quality modeling (for calibration, validation and predictive scenarios), and land use modeling (to determine nitrogen inputs to the embayment or estuary from the contributing watershed). The model also accounts for regeneration of nitrogen from benthic sediments that can impart a significant seasonal impact on the nitrogen flux in a system. Once the model is calibrated and validated to show that it accurately predicts existing conditions, it is used to establish critical nitrogen thresholds that are attainable water quality targets, and to predict the impact of nitrogen reduction measures.

In establishing nitrogen thresholds, it would be ideal if we could input parameters such as dissolved oxygen, chlorophyll, light attenuation, and nitrogen (among others) and receive as an output a complete listing of the flora and fauna that could thrive in such an environment. However, this kind of ecological response model does not exist, so we have to rely on more indirect methods to determine loading limits. The two ways employed in the linked model are to use historical records or to run a “no-load” scenario.

The historical approach is the less common of the two because it relies on the rare confluence of a good historical record on both eelgrass coverage and water quality data. Eelgrass is a sentinel species indicator of pristine water quality. By correlating eelgrass coverage to nitrogen data in the same time period, we can identify the point at which the nitrogen concentration is high enough to initiate eelgrass loss and use that information to determine the nitrogen-loading limit.

The no-load scenario is the more common method of determining nitrogen-loading limits. Here, all anthropogenic sources of nitrogen are removed as model inputs under the assumption that this will yield the naturally occurring background nitrogen concentration in the water body. The specific characteristics of the watershed will dictate whether this scenario represents attainable water quality or whether there need to be allowances for nitrogen inputs in addition to those from natural sources.

It is important to realize that the model evaluates segments of an embayment and not the embayment as a whole. Therefore, there may be different nitrogen thresholds at different points in the embayment. Generally, the upper reaches of the watershed (i.e., farther from the mouth of the estuary) will exhibit poorer water quality than the lower reaches. Accordingly, attainable water quality goals may be lower for upper reaches than for lower reaches.

Mass Balance Calculations

The principle of **mass balance** forms the basis of the SMAST model. Mass balance calculations are standard engineering and scientific equations based on the law of conservation of mass. The SMAST model calculates a mass balance for a single component, in this case nitrogen. The control volume is the total volume of water in the embayment or estuary.

The principle of mass balance may be stated as:

Rate of accumulation within a control volume = Rate of mass input across a control **volume - Rate of mass output** across a control volume + **Rate of reaction of** mass within control volume (can be a positive or negative value)

Or, more simply as in Equation 1 below:

Accumulation = Input - Output + [Generation - (Consumption + Storage)]

In the context of estuary modeling, these terms consist of the following:

- Input: nitrogen coming into the estuary from such sources as wastewater, fertilizers, stormwater and atmospheric nitrogen. The model also considers nitrogen contributions from background boundary conditions (i.e. the ocean).
- Output: dictated by the flushing characteristics of the system and how nitrogen is physically circulated through the outlet of the system, or is retained due to circulation patterns.
- Generation: **benthic regeneration.**
- Consumption: natural attenuation, **biological assimilation,** and sedimentation.
- Storage: ambient nitrogen in the water column.

The Accumulation term quantifies how a constituent increases (positive accumulation), decreases (negative accumulation), or maintains a steady state (zero accumulation). In the linked model, we assume steady state conditions over the time period of the model run, because within a given year the inputs will not change significantly. The Accumulation term is set to zero to reflect the steady state assumption. With this assumption, the model will produce accurate results only if all the terms on the right side of the equation cancel each other out.

The following examples from a hypothetical embayment are a simplified illustration of mass balance calculations, analysis of the annual nitrogen load, and the impact of nitrogen-reducing measures.

Example 1: Modeling the Nitrogen Load

We assume the embayment's watershed has an overall land area of 1000 acres (43,560,000 square feet). The waterbody itself is 500 acres (21,780,000 sq. ft.) with an average depth of 10 feet. Therefore, the total volume of the waterbody is 217,800,000 cubic feet. Precipitation averages 40 inches per year and results in an annual recharge of 20 inches. Three years of monitoring data show that the average summer concentration of total nitrogen in the embayment is 0.47 milligrams per liter (mg/L). The embayment opens out to Nantucket Sound, which has an ambient nitrogen concentration of 0.30 mg/L.

We assume nitrogen inputs from wastewater, atmospheric nitrogen, stormwater, and fertilizers based on 1000 homes in the watershed served by on-site wastewater treatment and disposal systems, a 1.0 million gallon per day wastewater treatment plant discharging 10 mg/L total nitrogen, and 6,000,000 square feet of impervious surfaces (roads, parking lots, etc.). The hydrodynamic model indicates that the input from Nantucket Sound is 750,000 pounds per year (lbs/yr) of nitrogen and the output to the Sound is 775,500 lbs/yr.

Benthic regeneration accounts for 120,000 lbs/yr, biological assimilation and sedimentation for 130,000 lbs/yr, and the rate of natural attenuation in the marsh fringes of the embayment is 20%. Because of the location of the marsh fringe, only the plume from the wastewater treatment plant is intercepted.

Calculations are based on annual loadings, as follows:

Inputs:

1. *Treatment Plant Wastewater:*

1.0 **MGD** x 10 mg/L x 8.34 lbs · L/MG · mg x 365 days/yr = 30,441 lbs/yr

(MGD = million gallons per day, MG = million gallons, and 8.34.L/MG.mg is a conversion factor to calculate nitrogen loadings)

2. *On-site Systems:*

1000 homes x 2.5 persons/home x 5.9 lbs/person/yr = 14,750 lbs/yr

3. *Runoff:*

There is no infiltration from impervious surfaces so we assume 40 in/yr of rainfall at 1.5 mg/L of nitrogen.

6,000,000 sq. ft. of impervious surface x 40/12 ft/yr x 7.48 gal/cu. ft. x 1.5 mg/L x 1 MG/1 x 106 gal x 8.34 lbs · L/MG · mg = 1871 lbs/yr

4. *Fertilizer:*

Each home has 2,000 sq. ft. of lawn with an application rate of 3.5 lbs/1,000 sq. ft./yr.
We assume that 10% of the nitrogen in the fertilizer leaches into the embayment.
0.10(1,000 homes x 2,000 sq. ft./home x 3.5 lbs/1,000 sq. ft./yr) = 700 lbs/yr

5. *Atmospheric Deposition:*

40 in/yr of rain falls directly on the embayment. The land contribution is negligible.
21,780,000 sq. ft. x 40/12 ft/yr x 7.48 gal/cu. ft. x 0.05 mg/L x 1 MG/1 x 106 gal x 8.34 lbs · L/MG · mg = 226 lbs/yr.

6. *Boundary Waterbody (Nantucket Sound):*

We know from our hydrodynamic model that the nitrogen coming into the embayment from Nantucket Sound is 750,000 lbs/yr.

Total input: 30,441 + 14,750 + 1871 + 226 + 700 + 750,000 = 797,988 lbs/yr.

Output:

We know from our hydrodynamic model that the output from tidal flushing into Nantucket Sound is 775,500 lbs/yr.

Generation:

Direct measurement of the sediments shows that benthic regeneration is 120,000 lbs/yr.

Consumption through Natural attenuation and Sedimentation:

Natural attenuation will intercept the land-based nitrogen inputs at a rate of 20%.

0.20(30,441) = 6,088 lbs/yr

Sedimentation includes biomass settling to the bottom.

Direct measurement shows this term to be 130,000 lbs/yr.

Storage:

Storage is the ambient load of nitrogen in the water column, which we can determine based on the ambient nitrogen concentration of 0.47 mg/L.

(0.47 mg/L x 217,800,000 cu ft x 7.48 gal/cu ft x 1 MG/1 x 106 gal x 8.34 lbs · L/MG · mg)/yr = 6,386 lbs/yr

To calculate the mass balance of nitrogen in the embayment system, we insert the above numbers into our mass balance equation (Equation 1):

Accumulation = Input - Output + [Generation - (Consumption + Storage)]

Because the model assumes a steady state system, the Accumulation term is zero. Therefore, we can rearrange the equation to place the storage term on the left side in order to check that storage equals all the other terms on the right side.

Storage = Input - Output + Generation - Consumption

6,386 = 797,988 - 775,500 + 120,000 - (130,000 + 6,088)

6,386 ~ 6,400

The two terms agree within 1% of each other, so we are satisfied that the mass balance calculations accurately represent conditions in the watershed.

Conclusions from Mass Balance Calculations

We can derive several insights from Example 1. The most obvious is that, even in this simplified example, the linked model is a complex procedure that relies heavily on site-specific measurements within individual embayments. Components such as benthic regeneration, sedimentation, and biological assimilation cannot be accurately modeled and require data collected from the embayment system. Hydrodynamic behavior within an embayment system requires a sophisticated computer program to model the circulation patterns, which allow us to predict certain loading terms. Hydrodynamic modeling is also key in the calibration and validation steps of the final model output.

Second, the quality of the waterbody into which the embayment empties sets the lowest limit of ambient nitrogen that can be obtained; hence its designation as the boundary condition. In Example 1, this limit is 0.30 mg/L in Nantucket Sound, which is the "feeder" water for the embayment. We cannot expect to reduce nitrogen levels below 0.30 mg/L.

Third, we can see which sources of nitrogen we can control and those that we cannot. If we need to limit nitrogen inputs, our choices are obviously limited to those we can control. We can also analyze the proportional contribution from each source. Example 1 shows that the greatest input of nitrogen is in the tidal exchange coming in from Nantucket Sound, an input we cannot control. The next largest input is wastewater from the treatment plant and on-site systems, which are sources that we can control. In the majority of cases, source reduction efforts will focus on wastewater, because this is the most significant source of nitrogen that we can realistically expect to reduce.

Fourth, discharge locations are very important. In Example 1, the discharge from the wastewater treatment plant is eligible for the 20% credit for natural attenuation, because the salt marsh fringe intercepts the plume. If the marsh fringed the entire embayment, the 20% credit for natural attenuation could apply to more sources of nitrogen. In virtually all watersheds, there are marsh areas that can attenuate nitrogen loadings, but typically they do not extend along the entire shoreline of the embayment. Thus, it is important to locate discharges where natural attenuation can be maximized.

Fifth, tidal flushing significantly affects nitrogen-loading dynamics. The mass balance equation in Example 1 is dominated by the tidal flushing of the embayment system. Tidal input accounts for 750,000 lbs/yr of nitrogen, and 775,500 lbs/yr are flushed out on the tide. Given that the nitrogen concentration is higher in the embayment than in Nantucket Sound and there is a 25,500 lbs/yr difference between the input and output, it would appear that there is significant system residence time in the embayment. The figures further suggest that the outlet to the Sound may be restricted. Appropriate steps for outlet management, which may include dredging, inlet alteration, or culvert improvements, could possibly improve the flushing of the system and increase the amount of nitrogen transported out of the embayment. This may be a lower cost option than improved wastewater treatment or other source reduction measures.

The preceding exercise shows how each element in the linked model contributes to the condition of an embayment and which nitrogen sources are appropriate candidates for reduction efforts. However, before those decisions can be made, we have to know the ambient nitrogen level that will support a healthy ecosystem and how much nitrogen needs to be removed from the watershed.

The ultimate aim of a nitrogen management plan is to restore a eutrophic embayment or estuary to ecological health or to prevent eutrophication in the first place. The ambient water quality in our example, 0.47 mg/L total nitrogen, is not generally indicative of a healthy system. We also know that the theoretical lower limit of 0.30 mg/L in the boundary water is not an attainable goal. To determine the attainable nitrogen loadings, we can use the historical approach or the no-load scenario. Since we do not have enough historical data on eelgrass coverage and water quality to use the historical approach, we use the no-load scenario to run the model with no anthropogenic inputs from wastewater, runoff from impervious surfaces, or fertilizer. The output provides an ambient nitrogen concentration in the embayment that mimics natural conditions. These target limits can then be used to back-calculate the annual load of nitrogen from the watershed that can be safely assimilated within the embayment.

In this simplified example, we assume that the linked model shows that an ambient nitrogen concentration of 0.35 mg/L is necessary to restore shellfish beds and allow eelgrass to flourish, and that the 0.35 mg/L level is attainable. We are now ready to evaluate nitrogen-reducing approaches, as shown in Example 2.

Example 2: Modeling Nitrogen Reduction Approaches

We know that the ambient nitrogen concentration in the embayment is 0.47 mg/L.

0.47 mg/L x 217.8 million cu.ft. x 7.48 gal/cu. ft. x 8.34 = 6,386 lbs

The target concentration is 0.35 mg/L, or 4,755 lbs, which will require eliminating 1,631 lbs/yr of nitrogen.

Nitrogen Reduction Options:

1. Improved Flushing:

The model shows that improvements to the outlet channel of the embayment can increase flushing from 775,000 lbs/yr to 776,000 lbs/yr. This will reduce nitrogen loading in the embayment by 500 lbs/year.

2. Wastewater Treatment:

Because the wastewater treatment plant plume travels through a marsh system that can attenuate 20% of the nitrogen load, removing some of the on-site systems and connecting those homes to the sewer system may be the easiest way to attenuate that nitrogen load. The wastewater treatment plant discharges 10 mg/L total nitrogen and an on-site system discharges 35 mg/L. The difference of 25 mg/L translates to an annual reduction in mass loadings of 10.5 lbs/yr for each home that is connected to the treatment plant.

25 mg/L x 55 gpd/person x 2.5 persons/home x 1 MGD/106 gal x 8.34 x 365 days/yr =10.5 lb/yr/home

In order to remove 1,131 lbs/yr of nitrogen, we estimate that 108 homes would need to be sewered. The additional flow from these homes to the treatment plant is 108 homes x 2.5 persons/home x 55 gpd/person = 14,850 gpd. We now need to adjust our mass balance terms to see if we meet our target of 0.35 mg/L in the embayment.

On-site systems:

(1,000 - 108) homes x 2.5 persons/home x 5.9 lbs nitrogen/person/yr = 13,157 lbs/yr

Wastewater treatment plant:

1.01485 MGD x 10 mg/L x 8.34 x 365 days/yr = 30,893 lbs/yr

Natural attenuation:

0.20 x 30,893 lbs/yr = 6,178 lbs/yr

Our adjusted input term is:

30,893 + 13,157 + 1871 + 226 + 700 + 750,000 = 796,847 lbs/yr

Using our total mass balance equation (Equation 1):

Storage = Input - Output + Generation - Consumption

4,669 = 796,847 - 776,000 + 120,000 - (130,000 + 6,178)

Since the calculated storage term is less than the target storage term of 4,755 lbs/yr, this combination of sewering and improved flushing will achieve our water quality goal.

The full model runs and technical reports for each estuary or estuary segment will include evaluation of other appropriate nitrogen-management approaches such as improved treatment at the wastewater treatment plant, use of nitrogen- reducing on-site systems, reduced fertilizer use, and stormwater controls. In order to keep this example simple, they are not included here.

A district can be an effective means of managing wastewater in one or more municipalities. In simple terms, districts can be established (1) pursuant to a general state law; (2) a special act of the Legislature; or (3) through the exercise of a municipality's home rule authority (e.g., by enactment of a bylaw). Set forth below is a summary of how districts are established by means of these three pathways.

Establishing a water pollution abatement district pursuant to general state law

DEP-Mandated Districts

Under the Massachusetts Clean Waters Act, DEP is authorized to propose, and in some cases mandate, the establishment of water pollution abatement districts consisting of one or more cities or towns, or designated parts thereof. *[M.G.L. c. 21, §28 – 30, 32, 35 and 36.]* When proposing the formation of a district, DEP must first obtain the approval of the Massachusetts Water Resources Commission (WRC). Within 90 days of a municipality's receipt of DEP's proposal to establish a district, the municipality must take a vote, of its city council or at town meeting as applicable, whether to accept DEP's proposal. If the municipality votes no, DEP is directed to hold a hearing pursuant to M.G.L. c. 30A to further consider the matter. Upon completion of the hearing, DEP may, upon finding that the creation of the district "is necessary for the prompt and efficient abatement of water pollution" and with the approval of the WRC, declare the mandatory formation of the district.

An established district may only be dissolved by an act of the Legislature. DEP, with the approval of the WRC, may also propose the enlargement of a district or the consolidation of one or more districts, subject to the approval of the Legislature or pursuant to the process outlined above for establishing a district by agreement of the affected municipalities or mandatorily by DEP.

Each water pollution abatement district established under the Massachusetts Clean Waters Act is an independent entity administered by a "district commission." When the district is established with the agreement of the affected municipalities, representatives of the municipalities comprise the members of the district commission. When the district is established mandatorily by DEP, each member of the district commission is appointed by DEP, with the approval of the WRC. The district commission is required to employ a registered professional engineer to serve as the executive director of the district, and a person with accounting and financial experience to serve as the treasurer of the district.

A district commission's powers include authority to:

- adopt bylaws and regulations;
- acquire, dispose of and encumber real and personal property, including acquiring real property by eminent domain;
- construct, operate and maintain water pollution abatement facilities; and
- issue bonds and notes; and raise revenues to carry out the purposes of the district by means of apportioned assessments on the member municipalities.

Regarding the latter assessment authority of the district, the member municipalities may, in turn, impose assessments on those residents, corporations, and other users served by the district. If a municipality fails to pay the district commission their apportioned assessment, the state may pay the amount owed the district commissions from other appropriations designated by the state for the municipality.

A district is required to present a plan for the abatement of water pollution within the district to DEP within one year after its establishment or such greater or lesser time period established by DEP. The plan must include detail as to the:

- sources of pollution within the district;
- means by which and the extent to which such pollution is to be abated;
- project(s) for the construction, acquisition, extension or improvement of facilities required by the plan, and the estimates of the capital costs associated with such projects;
- amount of federal financial assistance applicable to such project costs for which the district proposes to apply; and
- method of apportioning among the member municipalities the capital and operation and maintenance costs associated with such projects.

After approval, the district's plan may be altered only with the approval of DEP.

In summary, DEP has broad statutory authority to propose and mandate the establishment of a district under the MA Clean Waters Act, and to require the district to implement a water pollution abatement plan subject to DEP's approval. To date, DEP has not exercised this authority. However, municipalities and other interested parties should be aware of the availability of this authority when evaluating the district option as a means of more effectively managing wastewater on a regional basis.

Independent Water and Sewer Commissions and Intermunicipal Agreements

Massachusetts general laws also authorize municipalities to establish an independent water and sewer commission within the boundaries of a municipality pursuant to M.G.L. c. 40N, and to enter into intermunicipal agreements pursuant to M.G.L. c. 40, §4A for the purpose of jointly performing a service that the municipality is authorized to do individually or to allow one municipality to perform a service for another. Unlike districts established under the Clean Waters Act, these statutory options do not require prior approval of DEP (although a municipality must vote to accept the provisions of M.G.L. c. 40N before availing itself of the authority thereunder), and they can be alternative means of accomplishing some of the benefits of a district on a more modest scale.

Regional Health Districts

Finally, M.G.L. c. 111, §27B authorizes two or more municipalities to form a "regional health district," which consists of a regional board of health, a director of health, and his or her staff. A regional health district established thereunder has "all the powers and shall perform all the duties conferred upon, or exercised by, the boards of health and health departments of the constituent municipalities under any law or ordinance pertaining thereto." Unlike a district established pursuant to the MA Clean Waters Act, the primary purpose of a regional health district does not appear to be pollution abatement, but the language of M.G.L. c. 111, §27B is broad enough to encompass the wastewater regulatory powers of a Board of Health and, therefore, may be another general law option worth exploring.

Establishing a district through the enactment of a special act of the Legislature

In practice, districts of regional scope in Massachusetts have been established by special acts of the Legislature. As examples, in 1968 the Legislature enacted separate acts of special legislation establishing two regional water pollution abatement districts - the Greater Lawrence Sanitary District (GLSD), and the Upper Blackstone Water Pollution Abatement District (UBWPAD). *[Chapter 750 of the Acts of 1968, establishing the GLSD, and Chapter 752 of the Acts of 1968, establishing the UBWPAD.]* GLSD's enabling legislation established a district consisting of the Cities of Lawrence and Methuen and the Towns of Andover and North Andover. GLSD, pursuant to statute and contract, also serves the Town of Salem, New Hampshire. In comparison, UBWPAD's special legislation authorized the City of Worcester and several adjoining towns to create a district, the boundaries of which are based on an affirmative vote of each of the member municipalities. In particular, the GLSD enabling legislation, as amended by subsequent special legislation (*Chapter 320, Acts of 1970*), is similar to the framework established for a water pollution abatement district under the MA Clean Waters Act. Both the GLSD and UBWPAD special acts comprehensively address the scope of authority and responsibilities essential to a regional district, such as authority to take land by eminent domain, to issue bonds and notes, and to impose assessments on member municipalities, who in turn may assess user charges.

Special legislation may also be necessary or appropriate when a municipality is seeking to manage wastewater within its boundaries in a manner that goes beyond or is inconsistent with applicable general or special laws. For example, Chapter 157 of the Acts of 2000 provides that notwithstanding the provisions of two sections in a state general law (*M.G.L. c. 83*) that govern a municipality's authority to establish and administer a sewer system, the Town of Provincetown may limit those properties that may connect to the sewer to ones where an on-site septic system cannot be constructed on the property in compliance with 310 CMR 15.000 (*Title 5*). The above referenced provision of state law from which the Legislature exempted Provincetown gives property owners the right to connect to an abutting municipal sewer line with available capacity. This special legislative authority to restrict the scope of properties initially served by the sewer system significantly reduced the cost of the municipal wastewater treatment facility and gives the Town more flexibility to control growth. The Provincetown special legislation also varied the requirements of M.G.L. c. 80, the state general law on betterments, by allowing the Town to defer imposing a betterment assessment on the properties adjoining the sewer system unless and until the property is actually connected to the sewer, rather than upon the completion of the sewer.

The Massachusetts Constitution authorizes municipalities to file home rule petitions with the Legislature, which request enactment of a special law. *[Section 8 of the Home Rule Amendment (Mass Const. Amend., Article 2, as appearing in Amend. Article 89.)]* The municipal legislative body must first approve a home rule petition before it can be acted on by the Legislature. The municipal vote approving a home rule petition may be general in that it requests legislation to accomplish a general purpose, and may or may not include draft legislation. A general vote does not preclude legislative amendments. If the municipality does not approve a draft bill, the legislation may be drafted by the municipal executive (the mayor, manager, or selectmen) or by the state legislator who files it. A municipal vote may also specifically restrict or preclude the Legislature from making substantive amendments to the draft bill approved by the municipality. The downside to this approach is that the municipality may need to vote again on legislative amendments to its proposed bill in order to secure passage of the special legislation, which could delay action for months, particularly if a town meeting vote is required. Another option is to include language in the municipal vote that authorizes the municipal executive (e.g., selectmen) to approve amendments to the bill that are within the scope of the general public objectives of the petition. *[Memorandum to City Solicitors and Town Counsels from the Counsel to the House of Representatives and the Counsel to the Senate, dated March 24, 1998, on the Form of Home Rule Petitions.]*

Because of the Legislature's broad authority to enact laws consistent with the state constitution, including the power to exempt municipalities from otherwise applicable general laws, the enactment of special legislation can be the most effective vehicle for establishing a district encompassing one or more municipalities or an environmentally relevant geographic area and/or to manage wastewater and its related impacts in creative ways. Parties that need to be involved in the special legislation route to establishing a district include the municipality's executive, municipal counsel, and state legislator(s). It is also important to consult with EOEA and DEP in the development and legislative review of special legislation of this nature. Both agencies will typically weigh in the merits of the proposed legislation, and their support can be an important factor in securing passage of the bill.

Establishing a district through the enactment of a municipal bylaw

A municipality's home rule powers under the Massachusetts Constitution grant authority to any city or town to exercise any power or function which the Legislature has the power to confer on it, which is not inconsistent with the Constitution or a state law or prohibited by the charter of a city or town. *[Section 6 of the Home Rule Amendment to the Massachusetts Constitution, and M.G.L. c. 43B ("Home Rule Procedures").]* As a result, municipalities may adopt zoning or general bylaws to regulate a wide range of uses and activities within all or a portion of a municipality.

Zoning and general bylaws differ in their approach and procedure for adoption. Both a zoning and general bylaw must be approved by the Attorney General (AG). If the AG fails to act within ninety days, the bylaw is deemed constructively approved by the AG. The AG's narrow standard of review is whether the bylaw is, on its face, consistent with the state constitution and state laws.

Zoning Bylaws

A zoning bylaw typically imposes restrictions on categories of land uses located in a defined geographical area. For example, a zoning bylaw may establish an aquifer protection district that encompasses the boundaries of the Zone II of contribution to a public water supply well. This type of zoning bylaw imposes additional wellhead protection zoning controls that prohibit the siting of certain new land uses within that zone because of their potential adverse impact on the well. *[310 CMR 22.21 of DEP's Drinking Water Program Regulations, which sets forth the scope of wellhead protection zoning and nonzoning controls that must be adopted to* *protect a new public water supply well approved by DEP.]* A building inspector has the authority to withhold a building or occupancy permit if the structure would violate a zoning bylaw. However, a zoning bylaw "grandfathers" (i.e., allows the continuation of) prior nonconforming uses within a zoning district. Procedurally, a zoning bylaw is adopted in accordance with the provisions of M.G.L. c. 40A, §5, and requires a planning board hearing and a two-thirds vote of town meeting.

General Bylaws

In comparison, a general bylaw is adopted pursuant to a municipality's home rule authority and in accordance with the procedures in M.G.L. c. 40, §32, which require only a majority vote of town meeting. Moreover, a general bylaw is not required by state law to grandfather prior nonconforming uses, and typically applies uniformly to all existing and new uses or activities subject to the bylaw. A common example of a general bylaw is a wetlands protection bylaw that implements a local permit program with more stringent requirements than the state Wetlands Protection Act. A number of municipalities have also enacted bylaws that require residents to comply with water conservation measures, such as restrictions on outdoor watering. Violations of a general bylaw are subject to penalties of up to $300 per violation and may be enforced pursuant to the non-criminal disposition provisions of M.G.L. c. 40, §21D, which allow the municipality to issue a "ticket" for the violation.

Accordingly, a municipality has broad home rule authority to enact a general bylaw applicable to existing and new uses in a defined environmentally sensitive or other geographical "district" within the boundaries of the municipality. Such a bylaw may impose more stringent requirements related to wastewater management within the district, including limitations on the use of fertilizers or setbacks on wastewater discharges that have the potential to impact nearby surface water bodies. The bylaw could also establish a related permit program that further regulates nutrient generating activities. Municipalities must be careful, however, that their bylaw permitting scheme does not substantively conflict or interfere with DEP's plenary regulatory and permitting authority over wastewater facilities and discharges under the Massachusetts Clean Waters Act, M.G.L. c. 111, §17 and M.G.L. c. 83. It is also important to consult with municipal legal counsel to assess the issues associated with charging a fee for any such municipal permitting activities. These issues include ensuring that the assessment constitutes a valid fee rather than a tax that has not been authorized by the Legislature, and evaluating whether and under what circumstances fee revenues can be deposited into a dedicated revolving fund rather than the municipality's general fund. *[e.g., M.G.L. c. 44, §53 and §53E½.]*

The cost of a municipality's construction of wastewater treatment facilities or extension of its municipal sewer system to serve uses within the district is typically recovered through the assessment of betterments on the benefited properties pursuant to M.G.L. c. 80.

Board of Health Authority

Finally, it is worth noting that a Board of Health (BoH) has broad authority to regulate wastewater independent of a general bylaw adopted by a municipality. A Board of Health is authorized to promulgate "reasonable" regulations under M.G.L. c. 111, §31, including regulations that exceed the minimum requirements of Title 5, provided the BoH states at the public hearing on the proposed regulation the local conditions that exist and/or reasons that support the more stringent regulation. A BoH may assess a fine of up to $1000 for a violation of its regulations, as compared to a maximum $300 fine that can be assessed for a violation of a general bylaw. Boards of Health also have the authority to enter into betterments associated with the upgrade of failed Title 5 systems pursuant to M.G.L.c. 111, §127B½.

Compared to a general bylaw, a BoH regulation can be an effective vehicle for managing wastewater within all or a portion of a municipality in view of a board of health's existing jurisdiction in this area (under Title 5) and attendant experience, and its greater penalty authority. As discussed above, two or more municipalities have the authority under M.G.L. c. 111, §27B to form a regional health district that would allow the uniform application and enforcement of more comprehensive local wastewater management regulations across a broader geographic area.

Legal Framework for Management Districts
Legal and Regulatory Citations

Massachusetts General Laws and Constitutional Amendments

Massachusetts Clean Waters Act: M.G.L. c. 21, § 26-53.
Water Pollution Abatement Districts: M.G.L. c. 21, § 28-30, 32, 35 and 36.

DEP Authority to Establish and Approve Wastewater Facilities: M.G.L. c. 83, § 6 and M.G.L. c. 111, § 17.

Independent Water and Sewer Commissions: M.G.L. c. 40N.

Intermunicipal Agreements: M.G.L. c. 40, § 4A.

Regional Health Districts: M.G.L. c. 111, § 27B.

Home Rule Petitions for Special Acts of the Legislature: Section 8 of the Home Rule Amendment to the Massachusetts Constitution, Article 2, as appearing in Amendment Article 89.

General State Law on Betterments: M.G.L. c. 80.

Municipal Authority for General and Zoning Bylaws: Section 6 of the Home Rule Amendment to the Massachusetts Constitution, and M.G.L. c. 43B.

Authority and Procedures for Adopting and Enforcing Municipal General Bylaws: M.G.L. c. 40, § 21, 32, and 21D respectively.

Authority and Procedures for Adopting Zoning Bylaws: M.G.L. c. 40A.

Board of Health Authority: M.G.L. c. 111, § 31 and 127B ½.

Municipal Finance: M.G.L. c. 44, § 53 and 53E½ .

Massachusetts Special Legislation

Greater Lawrence Sanitary District Enabling Legislation: Statutes of 1986, c. 750, and Statutes of 1970, c. 320.

Upper Blackstone Water Pollution Abatement District Enabling Legislation: Statutes of 1968, c. 752.

Town of Provincetown Special Legislation: Statues of 2000, c. 157.

DEP Regulations and Other Citations

DEP On-Site Sewage Treatment and Disposal (Title 5): 310 CMR 15.000: http://www.state.ma.us/dep/brp/files/310cmr15.pdf.

DEP Drinking Water Program Regulations: 310 CMR 22.21: http://www.state.ma.us/dep/brp/dws/files/310cmr22.pdf

Memorandum to City Solicitors and Town Counsels on the Form of Home Rule Petitions, from the Counsel to the House of Representatives and the Counsel to the Senate, dated March 24, 1998.

Document Availability

Massachusetts General Laws and Constitutional Amendments are available through the internet: Massachusetts General Laws (MGL): http://www.state.ma.us/legis/laws/mgl/mgllink.htm

Massachusetts Constitution and Amendments: http://www.state.ma.us/legis/const.htm

For copies of special legislation or legislative memoranda, readers can contact the districts, municipalities, or the State Library of Massachusetts: http://www.state.ma.us/lib/homepage.htm

This table summarizes districts and programs established by some Massachusetts municipalities to provide wastewaster management for sources other than traditional sewers and treatment works. This is not a complete listing for Massachusetts. Information is correct as of January 2003.

Town/Coverage	Purpose	Legal Authority	Contact
Tri-Town Septage District Townwide program in Orleans, Brewster, Eastham	Initially there was an on-site inspection and testing program, as well as operation of a septage treatment plant. This was paid by discharge fees to property owners. On-site program was terminated once all systems were inspected. BoH sends out reminder letters to pump every 3 years.	Special legislation	James Burgess, Chief Operator 508/255-4190
Tisbury Townwide program	Operation of a conventional sewer system in downtown area, and inspection and monitoring of on-site systems throughout rest of town.	Town Meeting	Tom Pachico, Health Agent 508/696-4290 Tpachico @ci.tisbury.ma.us
Wayland Town-wide district; services currently provided only to central business district	Treatment plant operation and connection of on-site systems near the plant.	Special legislation	Jeff Ritter, Executive Secretary 508/358-3620
Chicopee Townwide program	Comprehensive stormwater management utility: capital improvements, inspection, and operation and maintenance of stormwater BMPs. Stormwater management fee.	State law governing water/ sewer utilities. City ordinance used to establish fees	Stan Kulig, Public Works Supt 413/594-3557 Skulig@chicopee.ma.us
Cohasset Townwide program	Voluntary inspection, monitoring, maintenance and repair of on-site systems; approximately 1500 on-site systems are located in the Town, or 60% of properties.	Board of Health	Joe Godzik, Health Agent781/383-4116 Cohassetboardofhealth @hotmail.com
Concord Townwide program	Wastewater mgmt services to all facilities, either by sewer or on-sites. On-site services include tech assistance / education / revolving fund. Environmentally sensitive areas will have inspections, loading criteria, and potentially failure criteria.	Board of Health	Mike Moore, Health Agent 978/318-3275 mmoore @concordnet.org

Town/Coverage	Purpose	Legal Authority	Contact
Tritown Health District Townwide program in Lenox, Lee, Stockbridge	Outreach/education to on-site owners: I/A information, technical assistance, tax credit information, and information on proper maintenance.	Board of Health	Peter Kolodziej, 413/243-5540 TriTownHealth @aol.com
Gloucester	Tracking and inspection of on-site systems. Private inspectors do inspections and any repairs, under Health Dept oversight; property owners pay all costs. 155 I/A systems are tracked, as well as any upgrades or new construction.More rigorous testing is done in 7 priority areas, including deep pits to check on ground water. Depending on results, full inspections can be required more frequently than every 3.5 years.	Department of Health	Dave Sargent, Health Department 978/291-9771 dsargent @ci.gloucester.ma.us
Hingham	Tracking of on-site systems through local permits: Town fee for installation of any on-site system, and annual permit fee for I/A systems.	Board of Health	Bruce Capman, BOH Director, 781/741-1466 capmanb @hth.ssec.org
Buttermilk Bay Watershed within the Towns of Plymouth, Wareham, Bourne Townwide, tri-town nitrogen management strategy (Plymouth, Wareham, Bourne)	Three towns adopted nitrogen loading goals and limits on growth recommended by the Buzzards Bay Project, in order to limit future nitrogen inputs to Buttermilk Bay. Bourne and Plymouth adopted zoning bylaw changes to increase minimum lot size to reduce future growth potential, and also adopted water protection overlay districts that included nitrogen loading goals. Wareham zoning was deemed adequate. Wareham and Bourne also extended sewering around the bay. (Dr. Joseph Costa. Personal communication 1/23/03).	Intermunicipal agreement. Local zoning and other bylaws	Dr. Joseph Costa, Executive Director, Buzzards Bay Project National Estuary Program 508/291-3625 x.19 jcosta @buzzardsbay.org

How Nutrient Trading Works

Nutrient trading allows pollution sources (e.g., wastewater treatment facilities) to fund nitrogen reductions elsewhere in a watershed or trading area, thus reducing the overall release of nitrogen while not being required to meet more stringent permit requirements themselves. Sources that can implement low-cost pollution reduction efforts also have an incentive to reduce their nutrient loadings below the required level, if there is a system in place allowing them to sell credits for their reductions to facilities with higher control costs. A fundamental principle of nutrient trading is that total discharges in the watershed or trading area will be reduced. As noted in the body of the Guidance, the concepts and issues identified here apply to nitrogen, phosphorus, and other water quality pollutants. In the following discussion, the terms “nutrient” and “nitrogen” are used interchangeably; however, nitrogen is the pollutant of concern in this document.

Nutrient trading has evolved nationally to include a variety of mechanisms depending on geographic area, source of pollutant, and type of discharger. The most common are as follows:

- Cap and trade: includes a mandatory cap on a discharge and is more common in situations where regulatory limits are not being met. The cap is established (for example, in a TMDL) on the amount of total nutrients that can enter waters in the trading area, and the total quantity of allowable discharges is divided among sources taking part in the trading program. Sources responsible for the nitrogen loading then trade with each other or use a bank of credits to make the most cost-effective pollution reductions to meet the TMDL requirements.

A cap may be increased without resulting in an increase in nutrients to the watershed if pollution sources not already subject to the cap reduce their loadings by the same amount or more than the cap is increased.

- Open systems: typically a voluntary system and used where effluent standards are already being met. The total amount of discharge may be a percentage reduction goal. Reductions below a baseline are made to generate credits that in the future can be used to meet future nutrient reduction requirements or sold to other dischargers.
- Offsets: a facility applying for a new or increased discharge reduces discharges from other sources. This tool has been used in a few Massachusetts communities, where permits for wastewater treatment facilities included the connection of on-site systems to their facility, thereby reducing the total nutrient discharge to the watershed. *(See Case Studies at the end of this Appendix.)*

Trading can take place among a variety of point and nonpoint sources of nitrogen:

- Point-to-Point Trading: between point sources such as wastewater treatment plants.
- Intra-facility Trading: between different discharges in the same facility (usually an industrial plant).
- Pretreatment Trading: between a wastewater treatment plant and one of its industrial or commercial customers. Typically, the POTW pays for pretreatment upgrades for its customers rather than for upgrades to its own plant.
- Point Source to Nonpoint Source Trading: between a point source and a nonpoint source. For nitrogen control, this type of trade can have a significant impact, since there are many opportunities for nonpoint source controls that are less costly than those from point sources. Examples would be an increase in the discharge from a POTW, in return for reductions in loadings from on-site treatment systems.

Nonpoint Source to Nonpoint Source: between nonpoint sources, depending on where controls will be more effective and less costly. For communities without large point sources of nitrogen, this type of trading is an important implementation tool.

Implementation Issues

Because it is a new and complex tool, nitrogen trading presents challenges to communities seeking to use it appropriately. A comprehensive trading program must involve the public and regulatory agencies, consider the size of the watershed and location of trading partners, and be able to enforce controls and quantify results. Notable challenges for trading programs include the following:

Credibility of nonpoint pollutant reductions, given the cost and difficulty of monitoring and enforcing nonpoint source controls.

Trading may allow wealthy communities to put more of the pollution burden on poorer communities. One way to avert this situation is to ensure that the public is informed and involved in any trade decisions.

The formation of “hot spots,” or locally degraded areas in the watershed due to an increased discharge. Although the discharger may have provided nitrogen management elsewhere in the watershed that will improve overall water quality, the area just downstream of the discharge may be degraded.

Transaction costs. If the cost of making and tracking trades is too high, there will be no incentive to pursue it as a means of pollution abatement. It is therefore necessary to create an easy way for potential traders to find each other and to determine the needs of individual participants.

Public knowledge and acceptance of proposed or actual trades. A simple trail of transactions needs to be recorded so that government and the general public can review any part of a trading agreement.

To address these issues, EPA has developed a framework of eight principles for stakeholders to consider in determining the applicability of this approach:

Participating facilities should meet applicable technology-based requirements.

Trades should be consistent with the water quality standards set in local, state, and federal laws.

Trades should be based on a TMDL or an equivalent regulatory framework such as a NPDES permit.

Trades should take place within existing regulations and enforcement systems.

Trading should take place within manageable trading areas, usually a watershed or sub-watershed.

Participating facilities and communities should expect to do increased monitoring to verify results of trading.

The localized impact of trading should be considered, so that water quality is not degraded in any one part of the trading area.

Trading systems should involve all stakeholders and the public.

Nutrient Trading Case Studies

Edgartown, Massachusetts
Falmouth, Massachusetts
Wayland, Massachusetts
Neuse River, North Carolina
Tar-Pamlico Basin, North Carolina

The format for the following Case Studies is adapted from the following report prepared for the EPA: *A Summary of U.S. Effluent Trading and Offset Projects*, November 1999. http://www.environomics.com/Effluent-Trading-Summaries_Environomics.pdf.

Information for the Wayland, Neuse River, and Tar-Pamlico Basin is taken from the above document, with updates as of January 2003. Information is reprinted with permission.

Town of Edgartown Wastewater Treatment Facility Upgrade/Edgartown Great Pond Nutrient Management

Nature of Activity: Upgrade of a wastewater treatment facility, additional sewerage and nutrient management in the Edgartown Great Pond watershed.
Environmental Problem: Cultural eutrophication due to increased nitrogen inputs to Edgartown Great Pond.
Pollutant(s)/Pollution Type(s): Nitrogen
Trade Types: Point/nonpoint offset between advanced tertiary treatment, additional sewering, use of on-site denitrifying systems, use of agricultural fertilizers, and purchase of conservation easements.
Stage of Implementation: As part of a comprehensive wastewater management plan, the current Edgartown wastewater treatment facility was upgraded in 1996 to meet Class I Ground Water Discharge Standards, with a goal of limiting the annual nitrogen loading to 2200 kilograms. Although the facility is designed for 750,000 gpd, the ground water discharge permit limits the flow initially to 500,000 gpd until actual performance data is available. To date, the facility has exceeded expectations with an average total nitrogen discharge below 5 mg/L. Approximately 300 additional residences in the recharge area will be connected to the facility, but there is no current timetable for this phase of the project. Dentrifying on-site treatment systems will be encouraged elsewhere within the watershed.
Relation to TMDL: On the initial list of 20 estuaries for detailed analysis by the Massachusetts Estuaries Project.
Number of Potential Participants: 300 homes are to be sewered and a number of facilities (as yet to be determined) are to install denitrifying on-site treatment systems.
Trading Ratios: The target ambient nitrogen concentration in Edgartown Great Pond was used to back calculate the reductions in mass loading and allocations throughout the watershed necessary to achieve the target range, particularly the treatment facility annual limit of 2200 kilograms of total nitrogen. The provision of sewer service to 300 homes and denitrifying on-site systems for approximately 900 new homes will produce a yearly saving of 1130 and 1135 kilograms of total nitrogen, respectively.
Estimated Cost Savings: Undetermined at this time.
Available Written Information: *Edgartown Great Pond: Nutrient Loading and Recommended Management Program* – November 1998 prepared by the Martha's Vineyard Commission.
Innovative Aspects: Conservation easements
Obstacles: Funding for sewer extensions and conservation easements.
Contact: Bill Wilcox, Martha's Vineyard Commission 508/693-3453.

Town of Falmouth Wastewater Treatment Facility Upgrade/West Falmouth Harbor Nutrient Management

Nature of Activity: Upgrade of a wastewater treatment facility, additional sewerage and nutrient management in the West Falmouth Harbor watershed.
Environmental Problem: Cultural eutrophication due to increased nitrogen inputs to West Falmouth Harbor.
Pollutant(s)/Pollution Type(s): Nitrogen.
Trade Types: Point/nonpoint offset between advanced tertiary treatment, additional sewering, and use of on-site denitrifying systems.
Stage of Implementation: As part of a comprehensive wastewater management plan initiated in 1998, the current Falmouth wastewater treatment facility is being upgraded from a Class III to a Class I ground water discharge. Construction of the new facility is expected to begin in the Spring of 2003. More than 400 additional connections will be made to the treatment plant from homes and businesses in the watershed west of Route 28; there is no current timetable for this phase of the project. Dentrifying on-site treatment systems will be installed at sites east of Route 28, and will be centrally managed. A management plan still needs to be implemented to oversee this work. The treatment plant will be designed at 1.2 mgd and to meet a 3 mg/L total nitrogen discharge at a maximum rate of 1 mgd within the watershed. Any additional discharge will have to occur outside the watershed.
Relation to TMDL: On the 1998 list for pathogens and mentioned in Appendix C of the 2002 list for the Massachusetts Estuaries Project.
Number of Potential Participants: 400+ homes are to be sewered and a number of facilities (as yet to be determined) are to install denitrifying on-site treatment systems.
Trading Ratios: The target ambient nitrogen concentration was used to back calculate the reductions in mass loading and allocations throughout the watershed necessary to achieve the target range. An allowance was factored in for a 20% attenuation of nitrogen through the Masapaquit Creek salt marsh and 45% attenuation of nitrogen through spray irrigation in woodlands at the wastewater treatment facility.
Estimated Cost Savings: Undetermined at this time, but without the 20% attenuation credit, the discharge within the watershed would have been decreased from the current 800,000 gpd to 700,000 gpd rather than be able to increase to 1 mgd.
Available Written Information: Falmouth's Comprehensive Wastewater Management Plan.
Innovative Aspects: Providing credit for natural attenuation.
Obstacles: Funding for sewer extensions.
Contacts: Dr. Brian Howes, SMAST, 508/910-6310; bhowes@capecod.net. Brian Dudley, DEP, 508/946-2753, brian.dudley@state.ma.us

Wayland, Massachusetts Business Center Treatment Plant Permit

Nature of Activity: The Wayland Business Center, an office building complex under new ownership, sought to discharge effluents from its wastewater treatment plant into the Sudbury River. The facility had been operated by the Raytheon Corporation, and the new owners originally sought to renew and transfer the existing permit. DEP and the U.S. EPA ruled that the Raytheon permit could not be transferred to the new owners of the Wayland Business Center, and hence the facility's discharge was to be construed as a new discharge. As a condition for allowing the discharge, the NPDES permit specified that the facility needed to obtain an offset of phosphorus. The facility is obtaining offsets by connecting to the plant septic systems on neighboring properties which are in a high water table area and/or are failing.
Environmental Problem: General water quality and eutrophication of Sudbury River.
Pollutant(s)/Pollution Type(s): Phosphorus.
Trade Types: Point/nonpoint.
Stage of Implementation: The process began in early 1998; the permit was issued in September 1998. The municipality decided to take ownership of the facility and conducted a negotiated eminent domain taking of the facility. The small scale, pressure sewer was designed and installed. Each property owner connecting to the sewer will pay for the cost of its hookup to the stub provided in the street in front of each property. As of January 2003, 25 properties had been connected The additional properties are being charged as though they were hooked up.
Relation to TMDL: Parts of the Sudbury River are on the state's list of waters not meeting water quality standards and for which TMDLs must be developed (the 303(d) list) for metals, and parts of neighboring rivers are 303(d)-listed for nutrients. The offset does not have a direct relation to a TMDL, but the actions will result in an 80% decrease in phosphorus loadings to the Sudbury from the participating point source and nonpoint sources. The wastewater from the septic systems would have flowed, via the high water table, into the Sudbury River without any appreciable removal of phosphorus if it had not been routed through the treatment plant.
Number of Potential Participants: The Wayland Business Center, two municipal buildings of the Town of Wayland, and 32-34 property owners with septic tanks.
Trading Ratios: The facility is permitted to discharge 0.125 pounds per day (ppd) of phosphorus, and must reduce loadings via septic tank connections by at least 0.375 ppd, thus the trading ratio is 3:1. The plant's flow is permitted at 45,000 gpd.
Estimated Cost Savings: The users paid the entire cost of the plant, approximately $500,000. The plant may have been less expensive for individual users than installing very costly on-site systems. Some property owners also felt that sewering was a more aesthetically pleasing option than the raised leach fields that would have been necessary in some cases.
Available Information: The NPDES permit, including the trading clauses.
Innovative Aspects: A clause in the NPDES permit specifying the offset provision and the septic tank sewerage is believed to be the first of its kind. The municipality has assumed responsibility for the business center's WWTP, effectively making it a POTW. A contingency plan was specified if the sewer connection option could not be implemented, including the possibility of harvesting excess algal growth in the river.

Obstacles: The corporate owners of the Wayland Business Center did not have legal authority to perform sewerage work. From a public health standpoint, it was preferable to have the town own the plant so that users would not be dependent on a private entity.
Contact: Jeff Ritter, Executive Secretary, 508/358-6360.

Neuse River, North Carolina Nutrient Sensitive Water Management Strategy

Nature of Activity: North Carolina established a nutrient management strategy for the Neuse River Basin to reduce the total nitrogen load to the Neuse estuary from all sources. The strategy sets annual nitrogen allocations for existing point source dischargers over 0.5 mgd, and also provides the option of joining a basin-wide association of point sources. The association's allocation will equal the sum of its members' allocations. If the association or any non-association discharger exceeds its allocation in any year, it must make an offset payment to the state's Wetlands Restoration Fund. The association's members have also made trades among themselves. Any new or expanding discharger must either purchase its allocation from an existing discharger at a negotiated price, or make a payment to the Wetlands Restoration Fund. The Fund restores wetlands and riparian areas.
The program also addresses nonpoint sources of nitrogen from urban stormwater. New residential and commercial developments are required to meet nitrogen discharge limits of 3.6 pounds/acre/year. If projects cannot reduce their loadings below certain levels (6 pounds for residential, 9 pounds for commercial), they can purchase discharge credits by paying funds to the Wetlands Restoration Fund. As of 2003, about $1.5 million has been collected, but no restoration projects have been carried out. To be eligible for funding, restoration projects must be able to remove 5,000 pounds of nitrogen for 30 years.
Environmental Problem: Nutrient enrichment-driven eutrophication, fish kills in the Neuse estuary.
Pollutant(s) / Pollution Type(s): Nitrogen and phosphorus (though only nitrogen will be traded).
Trade Types: Point/point, point/nonpoint, nonpoint/nonpoint.
Stage of Implementation: The state classified the upper portion of the basin as Nutrient Sensitive Waters in 1983 and declared the entire basin Nutrient Sensitive in 1988. The state began developing basin-wide nutrient rules in 1995, and most rules were effective in August 1998. Dischargers will have to meet their allocations by 2003 or pay for offsets.
Relation to TMDL: Several waters in the basin are on the 303(d) list. A TMDL for total nitrogen in the Neuse estuary was approved by EPA in July 1999. The basis for the TMDL was the study used to implement the trading program.
Number of Potential Participants: Forty point sources submitted letters of interest in joining the association before a March 1998 deadline, when enrollment was closed for 5 years. This number includes about 90% of point source flows and 70-80% of the point source dischargers in the watershed.
Trading Ratios: There is no ratio established by the rule for trading among the point sources, nor is the offset rate (the amount per pound to be paid to the Wetland's Restoration Fund by a discharger exceeding its allocation)formally

a trading ratio. However, the amount of the payment ($11/lb/year) is based on calculations done by the state for the Tar-Pamlico Basin trading program and represents roughly twice the cost of the least cost-effective nutrient BMPs that the state has been supporting farmers in implementing throughout the state. The state's charge of $11/lb per year when a point source exceeds its allocation is two or more times higher than the cost at which the state has been obtaining reductions from nonpoint sources. Thus, if we were to assume that a payment into the Wetlands Fund has the effect of increasing the state's spending on nonpoint source BMPs by a similar amount, the offset rate would have a 2:1 trading ratio embedded in it. Moreover, new or expanding point sources that do not purchase allocations from the association must buy offsets from the Wetlands Fund at price 200% of the base offset rate.

Estimated Cost Savings: The offset rate is $11/lb nitrogen for each pound over the association's allocation. For comparison, costs for at-the-plant controls elsewhere in North Carolina (in the Tar-Pamlico Basin) were estimated at roughly $25-30/lb.

Available Information: Two 1997 reports from the North Carolina Department of Environment, Health and Natural Resources (now DENR), several fact sheets. Web site: http://h2o.enr.state.nc.us/nps/Neuse_NSW_Rules.htm

Innovative Aspects: By instigating nonpoint source controls and collecting payments from point sources that do not meet their allocations, the state assumes much of the burden of trading transactions. Under the strategy's rules for agriculture, farmers can participate in their county plans or implement BMPs individually; however, they will not trade directly with point sources.

Obstacles: Trading between point sources and agriculture was not authorized, in part over concern that farmers would be challenged to meet their own 30% loading reduction goals and thus might have difficulty generating tradable "excess" reductions. Farmers were also concerned about having full responsibility for reducing nitrogen loadings. Because the state provides significant funding for wetlands restoration in addition to federal funds, farmers may have less incentive to sell credits to other dischargers.

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Tar – Pamlico Basin, North Carolina Nutrient Reduction Trading Program

Nature of Activity: North Carolina established a basin-wide nutrient trading program to reduce nitrogen and phosphorus loads to the Pamlico estuary. There are two main components: The Tar-Pamlico Basin Association (point sources) and a trading mechanism. The Association works cooperatively to meet nutrient caps set by the state. If the Association does not meet its goals it must purchase offsets by paying a pre-set price per pound to the state's Agriculture Cost-Share Program for Nonpoint Source Pollution Control. This is a statewide program that pays farmers up to 75 % of the average cost of implementing approved BMPs. Monies paid by the Association to the cost-share program are earmarked to finance nutrient offsets from agricultural nonpoint sources in the Tar-Pamlico basin. Association members pay annual dues, but no exceedance taxes have been paid yet. Since the state cost-share program contracts with the

farmers, the state rather than the point sources is responsible for finding trading partners and ensuring the validity of the offsets.
Environmental Problem: Eutrophication of Pamlico River Estuary.
Pollutant(s) / Pollution Type(s): Nitrogen and phosphorus.
Trade Types: Point/point cooperation and point/nonpoint trading in the form of a cap exceedence offset fee.
Stage of Implementation: The Basin was designated a Nutrient Sensitive Water in 1989, and program development began in 1990. In 1991, the Association hired an engineering firm to investigate measures and costs for nutrient reduction at the Association's facilities. Trading rules were fully developed in 1992. The point sources have met their collective cap each year since 1990 via the operational measures and minor capital improvements recommended by the engineering analysis, and through the addition of nutrient removal processes at a total of seven member facilities. The Association purchased and banked credits for future use, but has not yet needed to use them. The current membership in the Association and price for offsets will continue through 2004. Phase I: 1990-1994. Phase II: 1995-2004, to be followed by Phase III.
Relation to TMDL: A TMDL is in place, having been developed during Phase I. An estuarine response model that was developed under Phase I was used to develop the TMDL.
Number of Potential Participants: The Association began with 14 members and opened enrollment to additional facilities after 1999. It has since added one member and another is in process. Fourteen of the current members are municipal treatment works, and one is in industry. The Agricultural Cost Share Program works with farmers throughout the basin.
Trading Ratios: The current cost of offsets includes a 2:1 ratio. The offset rate of $29/kg/yr is based on the estimated cost of the least cost-effective agricultural BMP typically implemented in the Tar-Pamlico Basin: $13/kg/yr, plus an additional $13 (a 2:1 ratio) and a 10% fee for administrative costs.
Estimated Cost Savings: The offset rate is currently set at $29/kg for each kg over the Association's allocation. For comparison, the sum of all individual members meeting technology limits of 6 mg/L N and 2 mg/L P was projected to cost $50-100 million in 1998, or a cost of $250 to $500 per kg. Additionally, a Great Lakes Trading Network report cites Malcolm Green (President of the Association) to the effect that the reductions achievable for $1 million from nonpoint sources would have cost $7 million from point sources.
Available Information: Two North Carolina Department of Environment, Health and Natural Resources (now DENR) reports from 1995, and one each from 1997 and 1998. Web site: http://h2o.enr.state.nc.us/nps/tarpam.htm
Innovative Aspects: The state takes on the burden of arranging for and vouching for the nonpoint source load reductions via the Agriculture Cost-Share Program. From the point of view of point sources, this sharply reduces the transaction costs and uncertainties of trading. Members of the Association jointly paid for the engineering study. New dischargers or non-members wishing to expand must pay offsets for agricultural BMPs as well as meet technology limits from 1995 of 6 mg/L N and 1 mg/L P.

Obstacles: It was very complex to quantify the impacts of runoff from animal feeding operations. Imprecise language in the Phase II agreement resulted in a disagreement over the duration of the offset rate and credits that have been purchased. This will be resolved in Phase III discussions. Other issues for Phase III will be to revisit the caps, establish an offset rate for phophorus (the $29 is for Nitrogen), and replace the gross assumptions on in-stream losses from end-of-pipe to estuary which were used in the Phase II cap-setting process with actual fate and transport modeling for all dischargers.
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