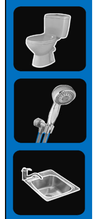
Infrastructure Evaluation Matrix: PRECEDENT STUDY

Nitrogen Source	Scale	Strategy	Short Description	Type of Infrastructure	Mechanism for Nitrogen Management	Spatial/Siting Considerations	Land Area Requirements	Contaminant Removal Rates (all approx. averages*)	Contaminant Cycle: Sources/Sinks	Potential Regulatory Barriers	Calculation for Cost of Removal	Cost of Removal per lb.	Approximate Capital Cost	Approximate Annual O&M Cost	Readiness for Immediate Application	Applicability for TMDL Compliance	Community Benefits	Potential Detriments	Targeted Source	Average Treatment Capacity (GPD/CF)	Annual Energy Usage	Annual Greenhouse Gas Emmissions
	Site	**Urine Diverting Toilets**	Urine diversion systems divert the urine to be utilized as fertilizer.	Non Discharing On Site Systems	Capture of nitrogen before entering groundwater (captured nitrogen must be subsequently removed from nitrogen sensitive watersheds)	In private homes in impaired watersheds; in municipal buildings	N/A	**None**		Town - BOH. State - DEP			$600-$2000 for system only										
		Composting Toilets	Non-water discharging systems which process human wastewith zero or minimal use of water. Allows for biological and physical decomposition to turn excrement into compost.	Non Discharing On Site Systems	Capture of nitrogen before entering groundwater (captured nitrogen must be subsequently removed from nitrogen sensitive watersheds)	In private homes in impaired watersheds; in municipal buildings	N/A	**None**		Town - BOH. State - DEP. Revisions to Title 5 (1994) allow composting toilets for remedial use and for new construction where a conventional Title 5 system could be installed, but appropriate waste disposal must be followed.			$600-$2000 for system only									
		Packaging Toilets	A packaging function of the toilet encapsulates the waste in durable material and stores it away from the user. A seal at the base of the toilet is opened and the durable material covering the inside of the toilet bowl is fed into the waste repository located beneath the toilet.	Non Discharing On Site Systems	Capture of nitrogen before entering groundwater (captured nitrogen must be subsequently removed from nitrogen sensitive watersheds)	In private homes in impaired watersheds; in municipal buildings	N/A	**None**					$600-$2000 for system only									
		Constructed Wetlands: Single Family Subsurface Flow Wetlands (SFW)	Wastewater is treated by pumping water slowly through subsurface gravel beds where it is filtered through macrophyte root zones (anoxic zones). Water flows 3-8" under the surface to prevent public exposure to wastewater and mosquito breeding.	Green Infrastructure	Nitrogen reduction before entering groundwater	Disturbed sites; Heavy soils; highland topography; outside wetland, vernal pool, road, residential, H2O supply buffers; outside zone II's (An underlining is necessary when the system is sited on permeable soils or in an area that receives runoff)		**60-65%**		ConsCom			$87,000/ac; $0.62/gal									
		Permeable Reactive Barriers: Site Scale	Utilized for tertiary treatment or as a reactive barrier, the media is primarily woodchips in a casing which filters out N in the groundwater (heterotrophic denitrification, NITREX as carbon filter)	Innovative Technology and Resource Management	Removal of nitrogen from groundwater	In buffer areas of impaired embayment shorelines		**85-99%**														
		Phytoremediation: Phytobuffer around Septic System	The direct use of green plants and their associated microorganisms to stabilize or reduce contamination in soils, sludges, sediments, surface water, or ground water	Innovative Technology and Resource Management	Removal of nitrogen from groundwater																	
		Eco Machines: Single Family	Eco machines refine the concept of SAS systems by replicating tidal aeration processes without the active sludge and clarification aspects. In a Eco Machine, solids removal is onsite, after which water is pumped through the gravel filled cells (similar to subsurface wetlands) which fill and empty like the tide, only more often. This process transfers more oxygen to the wastewater.	Green Infrastructure	Nitrogen reduction before entering groundwater	Disturbed sites; Heavy soils; highland topography; outside wetland, vernal pool, road, residential, H2O supply buffers; outside zone II's (An underlining is necessary when the system is sited on permeable soils or in an area that receives runoff)	Depending on treatment capacity; approx SF per GPD?	**52-65%**		MA DEP, CCC, EPA. May only be permitted as pilot project?			$1,077,777/40K GPD (with greenhouse); $10,457,542/1mil. GPD (w grnhouse)									
	Neighborhood/ Regional	**Solar Aquatic Systems: Community Sized**	As the predecessors to Living Machines, Solar Aquatic Systems (SAS) combine aeration and clarification chambers with constructed wetlands (a system of chambers allows for the microbial communities to engage with the wastewater while plants are suspended on racks with their roots systems doing all the work). Sludge settles to the bottom, where it is collected and fed back into the system for additional treatment.	Green Infrastructure	Nitrogen reduction before entering groundwater	Disturbed sites; Heavy soils; highland topography; outside wetland, vernal pool, road, residential, H2O supply buffers; outside zone II's (An underlining is necessary when the system is sited on permeable soils or in an area that receives runoff)		**Up to 99%**		MA DEP, CCC, EPA. May only be permitted as pilot project?			$750,000/12k GPD (with greenhouse									
		Eco Machines: Community Sized	Eco machines refine the concept of SAS systems by replicating tidal aeration processes without the active sludge and clarification aspects. In a Eco Machine, solids removal is onsite, after which water is pumped through the gravel filled cells (similar to subsurface wetlands) which fill and empty like the tide, only more often. This process transfers more oxygen to the wastewater.	Green Infrastructure	Nitrogen reduction before entering groundwater	Disturbed sites; Heavy soils; highland topography; outside wetland, vernal pool, road, residential, H2O supply buffers; outside zone II's (An underlining is necessary when the system is sited on permeable soils or in an area that receives runoff)	Depending on treatment capacity; approx SF per GPD?	**52-65%**		MA DEP, CCC, EPA. May only be permitted as pilot project?			$1,077,777/40K GPD (with greenhouse); $10,457,542/1mil. GPD (w grnhouse)									
		Constructed Wetlands: Freewater Wetland Systems (FWS)	water is gravity fed into freewater (FW) constructed wetlands, which are systems where open water is exposed much like in a natural marsh. Freewater constructed wetlands closely mimic the ecosystem of a natural wetland by utilizing water loving plants (Macrophytes) to filter wastewater and debris through their root zone in a planted medium.	Green Infrastructure: FOR TERTIARY TREATMENT	Nitrogen reduction before entering groundwater	Disturbed sites; Heavy soils; highland topography; outside wetland, vernal pool, road, residential, H2O supply buffers; outside zone II's (An underlining is necessary when the system is sited on permeable soils or in an area that receives runoff)		**Difficult to measure N attenuation in open water systems.**		Conscom			$22,000/ac; ($0.78/gal)									
		Constructed Wetlands: Disposal Subsurface Flow Wetlands (SFW)	Wastewater is treated by pumping water slowly through subsurface gravel beds where it is filtered through macrophyte root zones (anoxic zones). Water flows 3-8" under the surface to prevent public exposure to wastewater and mosquito breeding.	Green Infrastructure	Nitrogen reduction before entering groundwater	Disturbed sites; Heavy soils; highland topography; outside wetland, vernal pool, road, residential, H2O supply buffers; outside zone II's (An underlining is necessary when the system is sited on permeable soils or in an area that receives runoff)		**60-65%**		ConsCom			$87,000/ac; $0.62/gal									
		Phytoremediation: Phytoirrigation of Effluent	The direct use of green plants and their associated microorganisms to stabilize or reduce contamination in soils, sludges, sediments, surface water, or ground water	Innovative Technology and Resource Management	Removal of nitrogen from groundwater																	
	Estuary	**Constructed Wetlands: Floating Wetlands**	Bioengineered floating structures planted with Macrophytes, anchored in place in degraded waterbodies for on-site treatment.	Green Infrastructure: FOR TERTIARY TREATMENT	Nitrogen reduction before entering groundwater	Within impaired freshwater sites and degraded embayments																
		Shellfish Seeding/Aquaculture	Seeding of aquaculture beds (Oysters, clams) which attenuate Nitrogen through natural filtration in their body mass.	Innovative Technology and Resource Management	Uptake of nitrogen from water column (must be subsequently removed from water column)	Impaired embayments.	In waterbody	**0.5 g N per oyster; 15 – 20 lbs of nitrogen per acre per month**		Town - Shellfish Dept., Harbormaster, ConsCom, Selectmen. State - DEP, DFG (DMF, NHESP), CZM, BLIAR. Fed - ACOE. May also be public acceptance and/or use conflict concerns for large scale operations (competing uses, aesthetics).											
		Phytoremediation: Phytobuffer Groundwater	The direct use of green plants and their associated microorganisms to stabilize or reduce contamination in soils, sludges, sediments, surface water, or ground water	Innovative Technology and Resource Management	Removal of nitrogen from groundwater																	
		Permeable Reactive Barriers: Large Scale	Utilized for tertiary treatment or as a reactive barrier, the media is primarily woodchips in a casing which filters out N in the groundwater (heterotrophic denitrification, NITREX as carbon filter)	Innovative Technology and Resource Management	Removal of nitrogen from groundwater	In buffer areas of impaired embayment shorelines		**85-99%**														
		Seaweed Farming	Aquaculture of specialty seweed that mitigates Nitrogen through natural uptake.	Innovative Technology and Resource Management	Uptake of nitrogen from water column (must be subsequently removed from water column)	Impaired embayments.	In waterbody															

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Fertilizer & Impervious Surfaces	Site	**Surface flow Biofiltration Strips**	LID treatments to capture and treat stormwater at the source. Plantings filter out sediments, debris and major pollutants before sending water downstream.	Green Infrastructure	Nitrogen reduction before entering groundwater	In buffer areas of impaired embayment shorelines; in buffer areas of pond shorelines down grade of lawns; private lawns on pondshores		**40-60%**														
	Neighborhood/ Regional	**Stormwater Treatment Wetlands**	Stormdrain retrofits/LID treatments to capture and treat stormwater at the source. Plantings filter out sediments, debris and major pollutants before sending water downstream.	Green Infrastructure	Nitrogen reduction before entering groundwater	In roadway Right of Way; Disturbed sites; lowland topography upstream of receiving waters; outside wetland, vernal pool, residential, H2O supply buffers; outside zone II's		**40-60%**		MA DEP, Conscom			$4-5/SF									
	Aquifer	**Fertilizer Reduction Policies**	Policy/Outreach campaign to reduce fertilizer/pesticide use and educate on sustainable maintenance practices.	Non Structural Options	Prevention of nitrogen entering groundwater		N/A	**Actual nitrogen reduction may vary by project.**		None? Make local regulations re: using alternatives / organics stronger? (esp. for large-scale operations, e.g., golf courses) Incentivize?												
		Landscape Design Guidelines	Design Standards for Infiltration trenches; biofilters; riparian buffer restoration; tree buffers; rain gardens to utilize plants which uptake nitrogen in key areas.	Non Structural Options	Prevention of nitrogen entering groundwater		N/A	**Actual nitrogen reduction may vary by project.**		None? Make regulations re: bio-infiltration / appropriate plantings stronger? Incentivize?												
		Municipal Maintenance Policies	Implementation of maintenance policies such as street sweeping, de-icing, and landscaping which minimize the release of Nitrogen into the atmosphere and ground.	Non Structural Options	Prevention of nitrogen entering groundwater		N/A	**Actual nitrogen reduction may vary by project.**		None? Make regulations re: municipal maintenance policies stronger? Incentivize?												
Water Body	Estuary	**Culvert Widening**	Wetland areas attenuate nitrogen in the groundwater as it moves through the watershed. At locations where culverts are restricting natural flushing, widening projects increase volume of water entering and exiting the embayment, providing dilution of the groundwater that reaches the embayment.	System Alteration	Improving ability of water bodies to assimilate nitrogen	Marshes with restricted culverts in impaired watersheds	Dependent upon engineering study of area required for flushing restoration	**Actual nitrogen reduction will vary by project.**		EPA? NEPA? MEPA? (DEP, CZM, ACOE, DFG (DMF, NHESP), MHC, MassDOT) CCC? ConsCom, Generally these entities look favorably upon wetland restoration projects, as they achieve habitat restoration goals, too. However, practical considerations, such as flooding low-lying properties, may preclude full restoration to achieve a TMDL.												
		Dredging	The process of removing sand, silt, mud, etc from the bottom of a water body as a means of increasing water circulation, allowing for improved flushing.	System Alteration	Improving ability of water bodies to assimilate nitrogen			**Actual nitrogen reduction will vary by project.**														
		Wetland Restoration/Bogworks/ Stream/ Pond Restoration	Restoring natural hydrology through the excavation and construction of ponds and/or freshwater impoundments; rerouting surface water flow controls to control the depth and flow;encourage groundwater flow through the series of ponds where nitrogen attenuation would occur as it flows through the alternating aerobic and anoxic zones.	System Alteration	Natural processes that improve groundwater quality	Impaired sites in impaired watersheds; cranberry bogs; underground streams; constricted culverts	Dependent upon engineering study of area required for hydrologic restoration	**18%**		ConsCom, DEP, ACOE?												