

**WATER SYSTEMS, SCIENCE, AND SOCIETY (WSSS) RESEARCH
PRACTICUM UEP 0294-11**

**Cape Cod Green Infrastructure – Alternative Approaches to Ecosystem & Water
Quality 2015**

Syllabus

Instructor: Scott Horsley

Address: 97 Talbot Avenue, Medford

Telephone: 508-364-7818

Email: scott.Horsley@Tufts.edu

Schedule: Fridays 12:30 - 2:30 PM

Practicum Description

This Practicum will examine a broad range of emerging technologies that are designed to restore water quality and ecosystem health using natural (green) processes that incorporate recycling of nutrients and provide attractive alternatives to conventional technologies. It is designed to produce a guidance document for the purpose of informing stakeholders about these technologies with the goal of advancing their implementation.

Examples of green infrastructure that will be explored in the course include constructed wetlands, rain gardens, bioretention systems, green roofs, phytoremediation, permeable reactive barriers, shellfish bed restoration, aquaculture, fertigation systems, and ecotoilets. These technologies show significant promise for water quality and ecosystem restoration, with many co-benefits including resiliency to climate change, low energy costs, low maintenance, and local job creation.

The Practicum is designed to give students an understanding of green infrastructure, the challenges associated with the development and implementation of emerging technologies. It will include a field trip to Cape Cod, Massachusetts to visit sites where these technologies are being pilot tested and to meet with organizations and individuals who are engaged in watershed planning and permitting as part of the Cape Cod 208 Water Quality Plan – an innovative regional planning process conducted by the Cape Cod Commission and authorized by the U.S. Environmental Protection Agency (USEPA) and the Massachusetts Department of Environmental Protection (MADEP).

The Practicum provides an opportunity to learn about green infrastructure – the principles of designing emerging technologies, what the technologies are, how they are being utilized, barriers and hurdles for their adoption, and an adaptive management process that

can enable the integration of these technologies into our society by managing risks and optimizing benefits.

Class Schedule

- January 16 Introduction to Practicum, discuss goals and opportunities, background on Cape Cod 208 project
- January 23 Discuss various options for outreach document (web, app, flyer, etc), 208 progress update
- January 30 Assignments of technologies, organize into four groups of two students (two technologies each), 208 progress update
- February 6 Updates on readings, reports from each group, discussion of video and web technology options
- February 20 Conference Call with Sia Karplus (Green Infrastructure Coordinator, Town of Falmouth, MA)
- February 27 Discuss format for technology descriptions, updates on technology options
- March 6 Share sample technology descriptions, develop pilot project map
- March 13/20 No Meeting - Spring Break
- March 27
- April 3 Plan details for field trip and meeting with Cape Cod Commission
- April 10 Field Trip to Cape Cod, visit technology pilot projects and meeting with Cape Cod Commission
- April 17 Review videos and finalize web site format, review and edit pilot project map and descriptions
- April 24 Final Presentations by students

Required Readings for All Students:

Cape Cod Commission, Water Quality 208 Plan for Cape Cod, March 2015, <http://capecodcommission.org>

Cape Cod Commission Regional Policy Plan, Water Resources Standards, pp. 115-127. http://www.capecodcommission.org/resources/RPP/2012RPP_webJan2013.pdf

Introduction to TMDLs <http://www.epa.gov/owow/tmdl/intro.html>

Reference Materials for Individual Technologies:

Eco-Toilets:

Berndtsson, J.C. “Experiences from the implementation of a urine separation system: Goals,

planning, reality” *Building and Environment* 41 (2006) 427–437.

Boller, M. “Fertilizer from the Library” *Eawag News* 63e March (2007) 17-19.

Eawag. “NoMix: A New Approach to Urban Wastewater Management” Final Report Novaquatis.

Escher, B. and J. Leinert. “Can NoMix Help to Prevent Environmental Problems Caused by Medicines?” *Eawag News* 63e March (2007) 23-25.

Larsen, T.A. and J. Leinert. “Spotlight on NoMix” *Eawag News* 63e March (2007) 4-7.

Larsen, T.A. “Applying Traditional Chinese Knowledge” *Eawag News* 63e March (2007)

26-28. Larsen, T.A. and W. Gujer. “Separate Management of Anthropogenic Nutrient Solutions (Human Urine).” *Wat. Sci. Tech.* Vol. 34. No. 3-4. (1996): 87-94.

Leinert, J. “A Good Idea, but Surely No Takers!” *Eawag News* 63e March (2007) 8-10.

Leinert, J and T.A. Larsen. “Pilot Projects in Bathrooms: A New Challenge for Wastewater

Professionals” *Water Practice & Technology* Vol. 2 No. 3. IWA Publishing (2007) doi:

10.2166/WPT.2007057 Pronk, W. “Urine Treatment: from Laboratory to Practice” *Eawag News* 63e March (2007) 20

Ridley & Associates, Inc.; Joel Russell Associates. “Sewers and Smarth Growth: Challenges, Opportunities, and Strategies” (2009) Prepared for The Cape Cod Water Protection Collaborative.

Rossi, L. J. Leinert, and T.A. Larsen. "Real-life efficiency of urine source separation" J. Environ. Management 90. (2009) 1090-1917.

Shi Yingying. "The Smell of Success" China Daily. 2012-0712.
http://www.chinadaily.com.cn/china/2012-07/12/content_15571981.htm.

Town of Falmouth. "A Description of Eco-Toilets" (2012) Retrieved

from: <http://www.falmouthmass.us/waterq/web%20site/pdfs/a%20description%20of%20ecotoilets.pdf>

Udert, K.M. "NoMix Begins in the Bathroom" Eawag News 63e March (2007) 11-13.
Udert, K.M.; M. Wachter "Complete nutrient recovery from source-separated urine by nitrification and distillation" Water Research 46. (2012) 453-464.

Phytoremediation:

Fort Worth, T. X. "Phytoremediation at Naval Air Station–Joint Reserve Base Fort Worth." Technology (2005).

Harkin, T., et al. (2013). 2012 CCC Phyto Technology Demonstration Project. Barnstable, MA:
Cape Cod Commission

Landmeyer, James E. Introduction to phytoremediation of contaminated groundwater: Historical foundation, hydrologic control, and contaminant remediation. Springer, 2011.

Mukerji, Krishna Gopal, Chakravarthula Manoharachary, and Jagjit Singh. Microbial activity in the rhizosphere. Vol. 7. Springer, 2006

Pulford, I. D., and C. Watson. "Phytoremediation of heavy metal-contaminated land by trees—a review." Environment international 29, no. 4 (2003): 529-540.

Tsao, David, and Margaret Katherine Banks, eds. Phytoremediation. Vol. 78. Springer, 2003.

Permeable Reactive Barriers:

Cape Cod Commission. "Technology Matrix." Vol. v22. February 13, 2014.

CDM Smith. "Falmouth, MA PRB Demonstration Project." Status Report, Falmouth, MA, 2013.

CDM Smith. Technical Memorandum No.1: Evaluation Criteria for the Permeable Reactive Barrier (PRB) Pilot Project -Final. Technical Memo, CDM Smith, 2013.

CDM Smith. Technical Memorandum No.2: Preliminary Site Selection for the Permeable Reactive Barrier (PRB) Pilot Project -DRAFT. Technical Memo, CDM Smith, 2013.

Dutta, L., H. Nuttall, A. Cunningham, G. James, and R. Hiebert. "In Situ Biofilm Barriers: Case Study of a Nitrate Groundwater Plume, Albuquerque, New Mexico." *Remediation* 15 (2005): 101-111.

Garrett, K.E., and A.M. Hudson. "Large-scale application of in situ remediation to remove nitrate from groundwater." *Federal Facilities Environmental Journal* 16, no. 1 (April 2005): 97-108.

Khan, I., and R. Spalding. "Enhanced In Situ Denitrification for a Municipal Well." *Water Research (Elsevier)* 38 (April 2004): 3382-3388.

Morrison, S., C. Carpenter, D. Metzler, T. Bartlett, and S. Morris. "Design and Performance of a Permeable Reactive Barrier for Containment of Uranium, Arsenic, Selenium, Vanadium, Molybdenum, and Nitrate at Monticello, Utah." In *Handbook of Groundwater Remediation Using Permeable Reactive Barriers -Applications to Radionuclides, Trace Metals, and Nutrients*, by D. Naftz, S. Morrison, J. Davis and C. Fuller. San Diego, CA: Elsevier Science, 2002.

Remediation Technologies Development Forum. Permeable Reactive Barrier Installation Profiles. June 11, 2001. <http://www.rtdf.org/public/permbarr/prbsumms/profile.cfm?mid=87> (accessed March 11, 2014).

Schipper, L., and M Vojvodic-Vukovic. "Five Years of Nitrate Removal, Denitrification and Carbon Dynamics in a Denitrification Wall." *Water Research (Elsevier Science Ltd.)* 35, no. 14 (2001): 3473-3477.

The Interstate Technology & Regulatory Council PRB: Technology Update Team. *Permeable Reactive Barrier: Technology Update. Technical/Regulatory Guidance*, Washington, DC: Interstate Technology & Regulatory Council, 2011.

U.S. Department of Energy. *Innovative Technology Summary Report: In Situ Redox*

Manipulation. Technology Report, Office of Environmental Management and Office of Science and Technology, Richland: U.S. DOE, 2000.

U.S. Environmental Protection Agency. Permeable Reactive Barriers. November 26, 2012. <http://www.epa.gov/ada/gw/prb.html> (accessed February 12, 2013).

U.S. Environmental Protection Agency. "Evaluation of Reactive Barrier Technology for Remediation of Nutrient-Contaminated Ground Water from a Swine CAFO." National Risk Management Research Laboratory. http://www.epa.gov/ada/gw/pdfs/research_35.pdf (accessed February 13, 2013).

Vallino, Joseph, and Ken Foreman. Effectiveness of Reactive Barriers for Reducing N-Loading to the Coastal Zone. Final Report, NOAA/UNH Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET), Woods Hole: Ecosystems Center, Marine Biological Laboratory, 2008.

Wilkin, R., S. Hutchings, T. Lee, and B. Scroggins. Performance Evaluation of a Carbon-based Reactive Barrier for Nitrate Remediation. U.S. EPA, Ground Water and Ecosystems Restoration Division, U.S. Environmental Protection Agency, EPA, 2006.

Young, D., E. Sanderson, and C. Silver. Falmouth, MA PRB Demonstration Project Final Report. Presentation, CDM Smith, 2014.

Constructed Wetlands:

Agudelo, Ruth Marina, Carolina Machado, Néstor Jaime Aguirre, Jordi Morato, and Gustavo Penuela. "Optimal conditions for chlorpyrifos and dissolved organic carbon removal in subsurface flow constructed wetlands." *International Journal of Environmental and Analytical Chemistry* 91, no. 7-8 (2011): 668-679.

Campbell, Craig S., and Michael H. Ogden. *Constructed wetlands in the sustainable landscape*. Vol. 3. John Wiley & Sons, 1999.

Hammer, Donald A., ed. *Constructed wetlands for wastewater treatment: municipal, industrial and agricultural*. CRC Press, 1989.

Huang, J., R. B. Reneau Jr, and C. Hagedorn. "Nitrogen removal in constructed wetlands employed to treat domestic wastewater." *Water Research* 34, no. 9 (2000): 2582-2588.

Kadlec, Robert H., Robert L. Knight, J. Vymazal, H. Brix, P. Cooper, and R. Haberl. "Constructed wetlands for pollution control." Published by International Water Association (2000).

Matamoros, Víctor, Carlos Arias, Hans Brix, and Josep M. Bayona. "Removal of

pharmaceuticals and personal care products (PPCPs) from urban wastewater in a pilot vertical flow constructed wetland and a sand filter.” *Environmental science & technology* 41, no. 23 (2007): 8171-8177.

Nassauer, Joan Iverson. “Monitoring the success of metropolitan wetland restorations: cultural sustainability and ecological function.” *Wetlands* 24, no. 4 (2004): 756-765.

U.S. Department of Agriculture, Small Cranberry, National Resources Conservation Service (NRCS) National Plant Data Team, Greensboro, NC: USDA, (2011)
U.S. Environmental Protection Agency, Constructed Wetlands Treatment of Municipal Wastewaters, Office of Research and Development, EPA/625/R-99/010. Cincinnati, Ohio: EPA, (2000)

Vymazal, Jan. “Horizontal sub-surface flow and hybrid constructed wetlands systems for wastewater treatment.” *Ecological Engineering* 25, no. 5 (2005): 478-490.

Vymazal, Jan. “Removal of nutrients in various types of constructed wetlands.” *Science of the total environment* 380, no. 1 (2007): 48-65.

Wallace, Scott D., and Robert Lee Knight. *Small-scale constructed wetland treatment systems: feasibility, design criteria, and O&M requirements*. WERF, 2006.

Zipper, C., Reneau, R.B. Jr., Jantrania, A. *On-Site Sewage Treatment Alternatives*. Virginia Cooperative Extension. <http://pubs.ext.vt.edu/448/448-407/448-407.html> (accessed May 9, 2014)

Oysters and Aquaculture Restoration:

Beck, M. et al. “Oyster Reefs at Risk and Recommendations for Conservation, Restoration, and Management.” *American Institute of Biological Sciences* (2011): 61(2). 107-116

Coen, L. et al. “Ecosystem Services Related to Oyster Restoration.” *Marine Ecology Progress Series* (2007): 341. 303-307

Golden, R. “Coupling Oyster and SAV Restoration in South River, Maryland.” Report prepared for the National Oceanic and Atmospheric Administration. Chesapeake Bay Office (2011)

Maryland Interagency Oyster Restoration Workgroup “Harris Creek Oyster Restoration Tributary Plan: A Blueprint to restore the oyster population in Harris Creek” Report prepared by participants from Oyster Recovery Partnership, US Army Corps of Engineers, Maryland Dept. of Natural Resources and NOAA (2013)

Newell, R. "Ecosystem Influences of Natural and Cultivated Populations of Suspension-feeding bivalve mollusks." *Journal of Shellfish Research* (2004) 1: 51-61

Newell, R. & Mann, R. "Shellfish Aquaculture: Ecosystem Effects, Benthic-Pelagic Coupling and Potential for Nutrient Trading." Report prepared for the Secretary of Natural Resources, Commonwealth of Virginia (2012)

NOAA PMEL Carbon Program "Ocean Acidification's Impact on Oysters and Other Shellfish." Accessed April 8, 2014.
<http://www.pmel.noaa.gov/co2/story/Ocean+Acidification%27s+impact+on+oysters+and+other+shellfish>

Oyster Metrics Workgroup "Restoration Goals, Quantitative Metrics and Assessment Protocols for Evaluating Success on Restored Oyster Reef Sanctuaries." Report prepared for the Sustainable Fisheries Goal Implementation Team of the Chesapeake Bay Program (2011)

Piehl, M. & Smyth, A. "Habitat-specific Distinctions in Estuarine Denitrification Affect Both Ecosystem Function and Services." The University of North Carolina at Chapel Hill, Institute of Marine Sciences (2011)

Rose, J. et al. "A Role for Shellfish Aquaculture in Coastal Nitrogen Management." *Environmental Science and Technology* (2014): 48. 2519-2525

Sisson, M. & Kellogg, L. et al. "Assessment of Oyster Reefs in Lynnhaven River as a Chesapeake Bay TMDL Best Management Practice." Report prepared for the US Army Corps of Engineers, Norfolk District and the City of Virginia Beach, (2011) publication 429 Scientific and Technical Advisory Committee "Evaluation of the Use of Shellfish as a Method of Nutrient Reduction in the Chesapeake Bay." Report prepared for the Management Board of the Chesapeake Bay Program (2013a) publication 13-005

Scientific and Technical Advisory Committee "Nutrient Removal by Oysters: Evaluating the Potential of Oyster Aquaculture and Oyster Restoration as a BMP for Nutrient Reduction." NCBO Sponsored Workshop (2013b)

Yan, L. "Oysters and Climate Change." *Global Aquaculture Advocate* (2009): 12 (4): 61-63