Permeable Reactive Barriers for Reduction of Nitrate Discharge from Septic Systems – Great Bay Pilot Project

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strafford county
conservation district

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Project Purpose

• To install pilot systems and test effectiveness of Permeable Reactive Barriers (PRBs) in the Great Bay Watershed for nitrogen removal

• To gather shallow groundwater quality data adjacent to existing septic systems to determine septic system nitrate contribution to groundwater

• To implement effective nitrogen removal solutions in the Great Bay Watershed as part of the watershed management plan.
Site Locations

- Maine
- Vermont
- Massachusetts
- New Hampshire
- UNH-Durham
- Durham
- Brentwood
Permeable Reactive Barrier (PRB) Demonstration: Showing Nitrate Removal Using PRB

**Diagram Description:**
- **Permeable Reactive Barrier (PRB):** Demonstrated for nitrate-contaminated groundwater purification.
- **Clayey Presumpscot Formation:** Groundwater contaminated area.
- **Sand and Gravel:** Aquifer layer.
- **Septic Tank:** Source of nitrate contamination.
- **Leach Field:** Aeration area.
- **Permeable Reactive Barrier:** Treatment area.
- **Purified Groundwater:** Water after treatment.
- **TRIBUTARY TO GREAT BAY:** Discharge area.

**Table: Site Designation and PRB Specifications:****

<table>
<thead>
<tr>
<th>Site Designation</th>
<th>Length of Nitrex® PRB</th>
<th>Depth of Nitrex® PRB</th>
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</thead>
<tbody>
<tr>
<td>Residential System (600 GPD ±)</td>
<td>50 FT</td>
<td>5 FT</td>
</tr>
<tr>
<td>Durham, NH</td>
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<td></td>
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<tr>
<td>Community System (8,000 GPD ±)</td>
<td>110 FT</td>
<td>8 FT</td>
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<tr>
<td>Brentwood, NH</td>
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**Notes:**
1. Assume depth is 1 FT into clay and 1 FT above typical groundwater depth.
2. Typical Nitrex PRB width to be 6 FT.
Wood Chip Bioreactor PRBs

- Low-cost carbon source for denitrification
- Shallow barriers are simple to install and maintain
- PRB creates the right chemical environment for the naturally occurring bacteria (anaerobic) to thrive
- Ammonia not treated by PRBs

\[ \text{Bacteria} + C + \text{NO}_3 \rightarrow \text{N}_2 \]

(Carbon + nitrate) \rightarrow (nitrogen gas)

(Dr. Will Robertson, U. Waterloo, Canada)

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PRB Design Parameters

- **Understanding of Site Hydrogeology:** How fast does groundwater flow, how permeable is subsurface material, what is the direction of groundwater flow, how do groundwater levels change, what is the concentration of nitrate in groundwater?

- **PRB Residence time:** (How long does groundwater stay in PRB for treatment?) Function of removal goal: Published values range from 0.7 to 32 mg/L of N per day over the area of the PRB.

- **Width and Depth of PRB:** Width is determined by estimated PRB residence time, and depth determined by site specific geology.
Conceptual Great Bay PRB Designs

• **Design Parameter:** 2 mg/L N/day Removal

• **Residence time of 10 to 20 days:** Groundwater travel time or groundwater velocity is about 0.1 ft/day at Durham and Brentwood Sites

• **Design Width of PRB** = 2.0 ft wide for a 10 to 20 days residence time

• **Depth:** Durham = 5 ft.
  Brentwood = 8 ft.

• **Length:** Durham = 50 ft.
  Brentwood = 110 ft.
Durham Site

• Near Chesley Brook tributary of Oyster River
• Failed septic close to house, new septic field installed 2008
• Silty sand underlain by silt
• Initial nitrate 6.2 mg/L at one field-side monitoring well,
• Installation May 2016
Great Bay PRB Pilot Study

Legend
- **Groundwater Elevation 0.5' Contours**
- **Hydrography**
- **Septic System Leach Fields**

Rockingham County Conservation District
Strafford County Conservation District
Permeable Reactive Barrier Demonstration Project
Durham, NH

Groundwater Elevations (December 2014)

GREEN DOTS ARE MONITORING WELLS
Construction of Durham, NH PRB
19 May 2016

- Wetland protection for access,
- trench stayed open
- Less than 1 day to complete
Construction of Durham, NH PRB
19 May 2016

- Areas seeded
- Silt fence will stay up until full re-growth
- Additional well installation and monitoring through 2017
Nitrate-Nitrogen at Durham PRB Well and Chesley Brook

PRB Installed May 2016

MW-1
MW-2
MW-3
SW-2

MW-1
MW-2
MW-3
SW-2

Date of Sampling
08/11/14 11/19/14 02/27/15 06/07/15 09/15/15 12/24/15 04/02/16 07/11/16 10/19/16 01/27/17 05/07/17
Brentwood Site

• Near Dudley Brook, tributary of Exeter River

• Failed septic area in community septic field

• New area installed in 2012
  – Silty sand with underlying silt

• Nitrate 12 to 46 mg/L at wells

• 1.9 mg/L in nearby SW measured in past

• Installed October 2015
Pond flows to Dudley Brook.

Groundwater Elevations (December 2014)

Legend

- Groundwater Elevation 2' Contours
- Hydrography
- Septic System Leach Fields
- Roads
- Monitoring Wells (MW)

ROCKINGHAM COUNTY
CONSERVATION DISTRICT

Rockingham County Conservation District
Strafford County Conservation District
Permeable Reactive Barrier Demonstration Project
Brentwood, NH
Great Bay PRB Pilot Study

Lines of equal concentration of Nitrate-N
December 2014

Permeable Reactive Barrier
Construction of Brentwood, NH PRB – 13 October 2015
PRB Placement and Site Restoration
Permeable Reactive Barrier (PRB) Demonstration: Showing Nitrate Removal Using PRB
Monitoring Results

• New monitoring wells installed in and just downgradient of trench

• Nitrate-Nitrogen decline in and near trench
  – 20 to 30 mg/L pre installation
  – Less than 2 to 12 mg/l in and adjacent to trench – four months after installation

• Dissolved Oxygen (very low oxygen needed for bacterial growth)
  – 4 mg/L pre-installation to < 1.0 mg/L post installation at /near trench
Installation of PRB – October 2015

Increase at MW-107 may be due to low groundwater levels in 2016
Nitrate Concentrations in Wells February 2017

MW-101: 54 mg/L
MW-102: 32 mg/L
MW-107: 12 mg/L
MW-106: 0.4 mg/L
MW-104: 13 mg/L
MW-103: 2.7 mg/L

Apparent Extent of Nitrate Treatment February 2017
Specific Conductance at PRB Downgradient Wells

- MW-103
- MW-104
- MW-106
- MW-107

Increase in SC may be due to PRB, now dropping in most wells

PRB Installation
Funding for this project was provided in part by a Watershed Assistance Grant from the NH Department of Environmental Services with Clean Water Act Section 319 funds from the US Environmental Protection Agency.
Questions for practitioners

• How could you see this technology applied for your projects?

• How could this be used with a traditional septic system or as an added treatment tool?

• What obstacles/problems would you see in installing PRBs?