

## A Demonstrated Approach for Nitrate Removal From Groundwater

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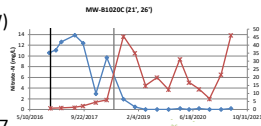
### Introduction

- Denitrification permeable reactive barriers (PRBs) are one of the primary non-traditional technologies for the reduction of nitrate loads to Cape Cod's estuaries, ponds, and water bodies.
- Numerous communities have performed evaluations of denitrification PRBs, including site selection assessments, column studies, and in-situ demonstration pilot tests injecting emulsified vegetable oil (EVO).
- Four demonstration Sites are presented on Cape Cod and Martha's Vineyard illustrating a range of conditions. Two PRB demonstration projects were completed with support of a Southeast New England Program (SNEP) Watershed Grants.
- These projects provide valuable learnings to optimize future installations properly designing for key factors including:
  - geology and hydrogeology
  - groundwater velocity
  - nitrate concentration and flux
  - PRB dimension – length, width, and depth
  - emulsified vegetable oil (EVO) dilution and total injection volume
  - injection point spacing and orientation
- Pilots were conducted with SRS<sup>®</sup>-NR, a specifically formulated EVO from Terra Systems designed with larger droplets and anionic surfactants for better retention on the sandy lithology in high flow aquifers.

### Orleans

- Injection in two phases November 2016 & June 2018 with June 2018 injections to extend the PRB to intercept nitrate flowing from west
- Dimensions: 220 feet long (L) x 20 feet wide (W) x 38 feet deep (D)
- Groundwater flow rate 0.2 – 0.3 feet/day
- Nitrate concentrations: 8.4 – 21.6 mg/L
- Total injection volume 25,500 gallons in 37 points (9-12% pore volume (PV))
- Designed for 3+ years longevity, observing > 5 years so far

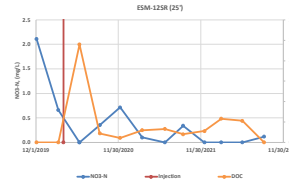
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### Eastham

- Injection April 2020
- Dimensions: 220 feet L x 12 feet W x 43 feet D
- Groundwater flow rate 0.5 feet/day
- Nitrate concentrations: 2.8 mg/L
- Total injection volume 31,300 gallons in 21 points (16% PV)
- PRB works for low nitrate concentrations

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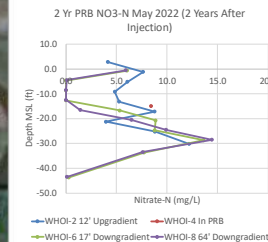


### Falmouth

- Column studies complete 2015-2016 & 2020
- Injections July 2020 – two barriers (1-year and 2-year EVO loadings)
- Dimensions: 120 feet L x 10 feet W x 24 feet D
- Groundwater flow rate 0.13 feet/day
- Nitrate concentrations: 4.2 – 5.8 mg/L
- Total injection volume 12,200 gallons in 12 points (10% PV)
- Barriers designed with limited injection volume to evaluate longevity of substrate
- 1-year PRB loading insufficient. 2-year PRB has lasted 2 years

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SNEP  
Southeast New England Program

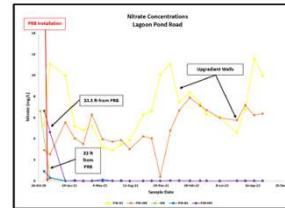


### Martha's Vineyard

- Injections November 2020
- Dimensions: 150 feet L x 12 ½ feet W x 18 feet D
- Groundwater flow rate 0.6 feet/day
- Nitrate concentrations: 2.0 mg/L
- Total injection volume 21,200 gallons in 12 points (27% PV)
- Injections as close as 80 feet from water body had no impact on pond

MARtha's VINEYARD COMMISSION

UMass | Dartmouth



### Takeaways

- Nitrate can be reduced to very low concentrations with the results seen nearly immediately
- PRBs constructed by direct injections can be installed nearly anywhere (few restrictions)
- PRBs have demonstrated effectiveness for 5+ years, with predicted longevity of 10+ years
- PRBs provide a tool for communities to address nitrate impacts both quickly and cost effectively
- PRBs provide an interim measure pending permanent solutions (e.g. sewerage)
- Tools are available to assist:
  - Emulsified Vegetable Oil Loading Calculator for Denitrification Permeable Reactive Barriers using Terra Systems' SRS<sup>®</sup>-NR formulation
  - Accompanying spreadsheet tool to estimating loading

