Reducing Nitrates with Permeable Reactive Barriers

Passive Treatment of Nitrate in Groundwater

National Association of Conservation Districts Webinar
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ROCKINGHAM COUNTY CONSERVATION DISTRICT

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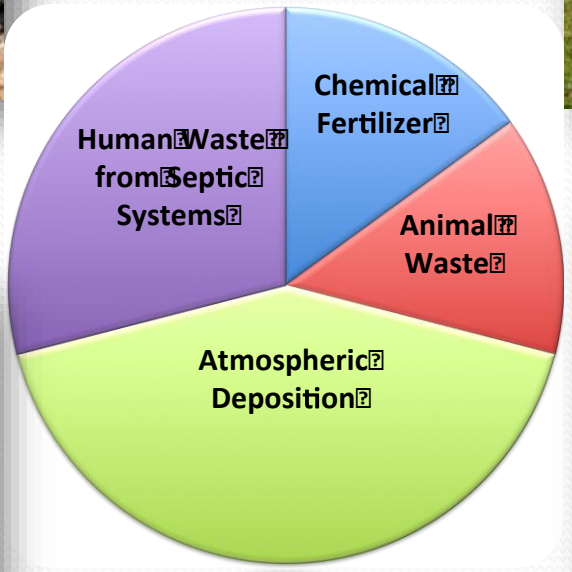
Major sources of nitrate in groundwater



Pie chart data – estimated sources of nitrogen from non-point sources from 2014 Great Bay Nitrogen Non-Point Source Study

Why is excess nitrate a problem?

- Causes degradation of water quality and habitat from Eutrophication of surface waters – coastal environments most vulnerable

- Excessive nitrate/nitrite in drinking water can be harmful to health, especially to infants – 10 mg/L/1 mg/L regulatory limit in drinking water

What is a Permeable Reactive Barrier (PRB)

- Subsurface treatment zone *below the water table* that groundwater passes through under natural flow conditions
- A supplemental carbon source is added in the treatment zone
- Treatment zone slightly more permeable than surrounding areas to promote flow without impacting treatment rate
- Creates nitrate reducing conditions – enhances environment for naturally occurring denitrifying (anaerobic) bacteria
- Sustainable infrastructure with no mechanical infrastructure needed but requires monitoring and maintenance
- Proven technology in agricultural areas and being adopted in coastal areas

Wood Chip Bioreactor PRBs

- Trench or zone with a low cost carbon source (wood chips) for denitrification
- Creates environment for naturally occurring anaerobic bacteria to thrive and transform nitrate to nitrogen gas
- Shallow reactive barriers can be simple to install and maintain

Bioreactor wood chips similar to wood chips used for playgrounds

Emulsified Vegetable Oil PRBs

- Emulsified Vegetable Oil (EVO) that is formulated for the treatment setting is injected into treatment zone
- Utilization of EVO in subsurface is monitored and periodically refreshed
- Can be used in areas of deeper/more extensive areas of contamination.

What information is needed for proper design and installation?

- Subsurface geology
- Concentration of nitrate in groundwater
- Potential/actual depth of nitrate impact
- Basic groundwater geochemistry in treatment area
- Direction of groundwater flow from nitrate source
- Depth to groundwater
- Groundwater flow rate
- Annual groundwater level fluctuation

PRB Pilot Study
NHDES 319 Grant Project – Great Bay Watershed

- A PRB surrounding a domestic septic system in Durham, New Hampshire
- A PRB surrounding a community septic field in Brentwood, New Hampshire
- Funded by USEPA 319 Grant
- Significant in-kind services provided by Towns of Brentwood and Durham, NH, Conservation Districts, and project consultants
- Two willing landowners participated in the project

PILOT STUDY PROJECT TEAM

ROCKINGHAM COUNTY CONSERVATION DISTRICT

STRAFFORD COUNTY CONSERVATION DISTRICT

HALEY ALDRICH

Truslow RESOURCE CONSULTING LLC

Environmental Engineers/ Consultants
LOMBARDO ASSOCIATES, INC.

TOWN OF DURHAM, NH 1712

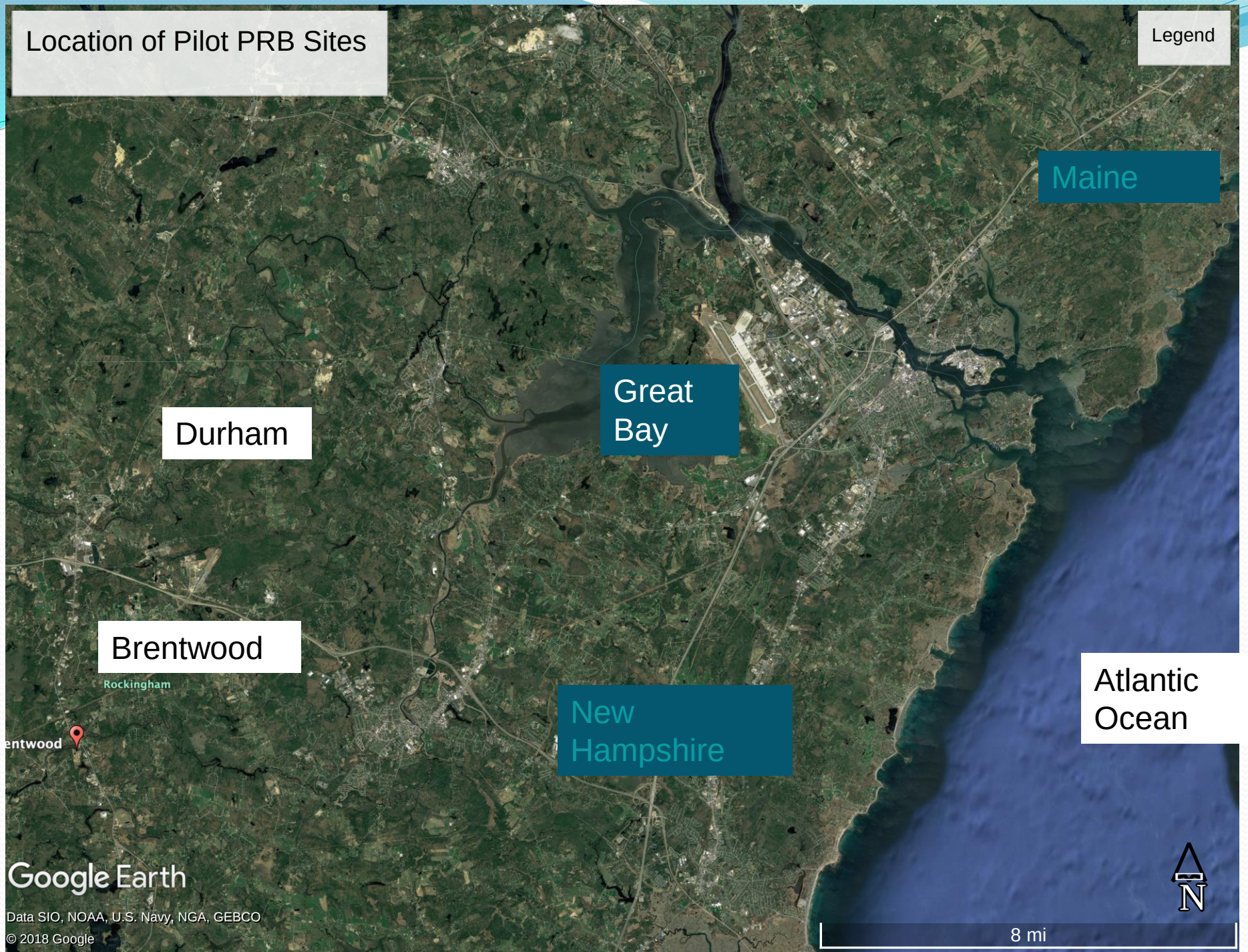
NEW HAMPSHIRE DEPARTMENT OF Environmental Services

BRENTWOOD, NEW HAMPSHIRE 1742

Absolute Resource associates

PRB Pilot Study
NHDES 319 Grant Project – Great Bay Watershed - Project Background

- Project began in 2014
- Purpose - to install and pilot two (2) shallow wood chips Permeable Reactive Barriers (PRBs) to reduce nitrate in groundwater and test their effectiveness
- To gather shallow groundwater quality data adjacent to existing septic systems to determine septic system nitrate contribution to groundwater before and after PRB installation
- *To implement effective nitrogen removal solutions in the Great Bay Watershed as part of the Great Bay watershed management plan*
- Project completed in 2017


Location of Pilot PRB Sites
Legend
Maine
Great Bay
Durham
Brentwood
Rockingham
New Hampshire
Atlantic Ocean
Google Earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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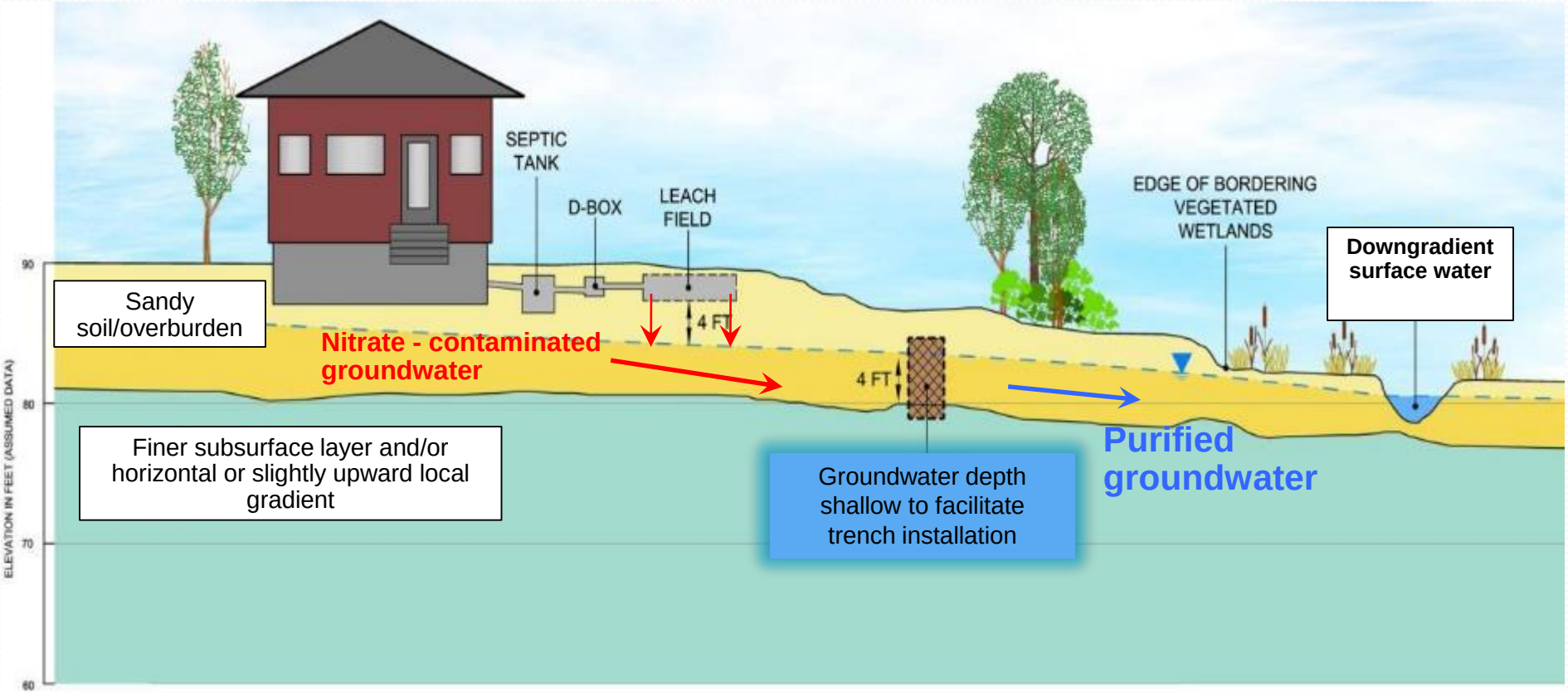
Selecting the optimal pilot site



Nitrate contaminated groundwater passes through the PRB and nitrate is converted to nitrogen gas

Pilot Study – Brentwood, NH – Community Septic Field

PRB Installation–Community Septic Field


Flagged PRB alignment


Wood chips for PRB


Erosion control installed


to protect wetland

PRB Placement and Site Restoration

Filling trench with chips as trench is excavated

Geotextile cover at surface of trench

Filled Trench

Completed PRB

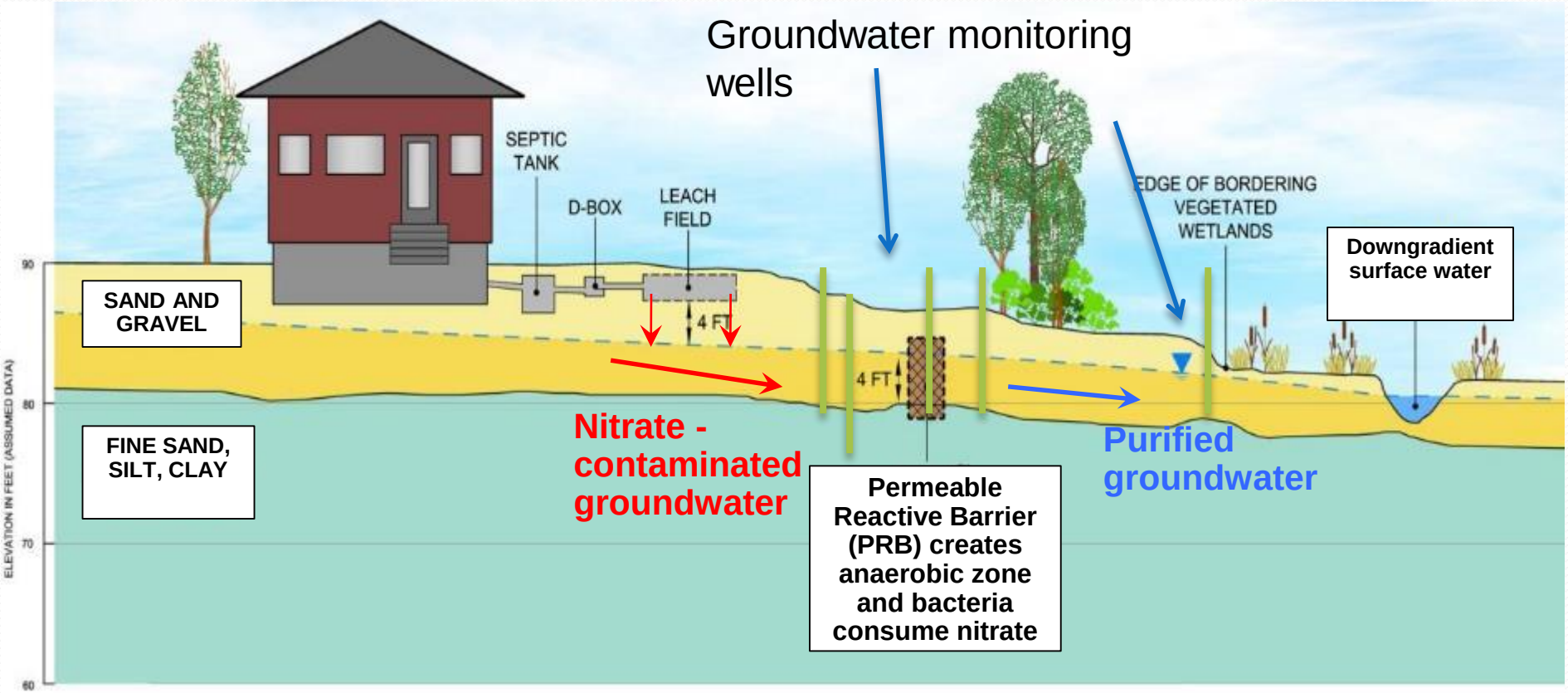
Typical PRB Layout – Domestic Septic Field

PRB at Single Residence Septic Field

Wetland protection for site access

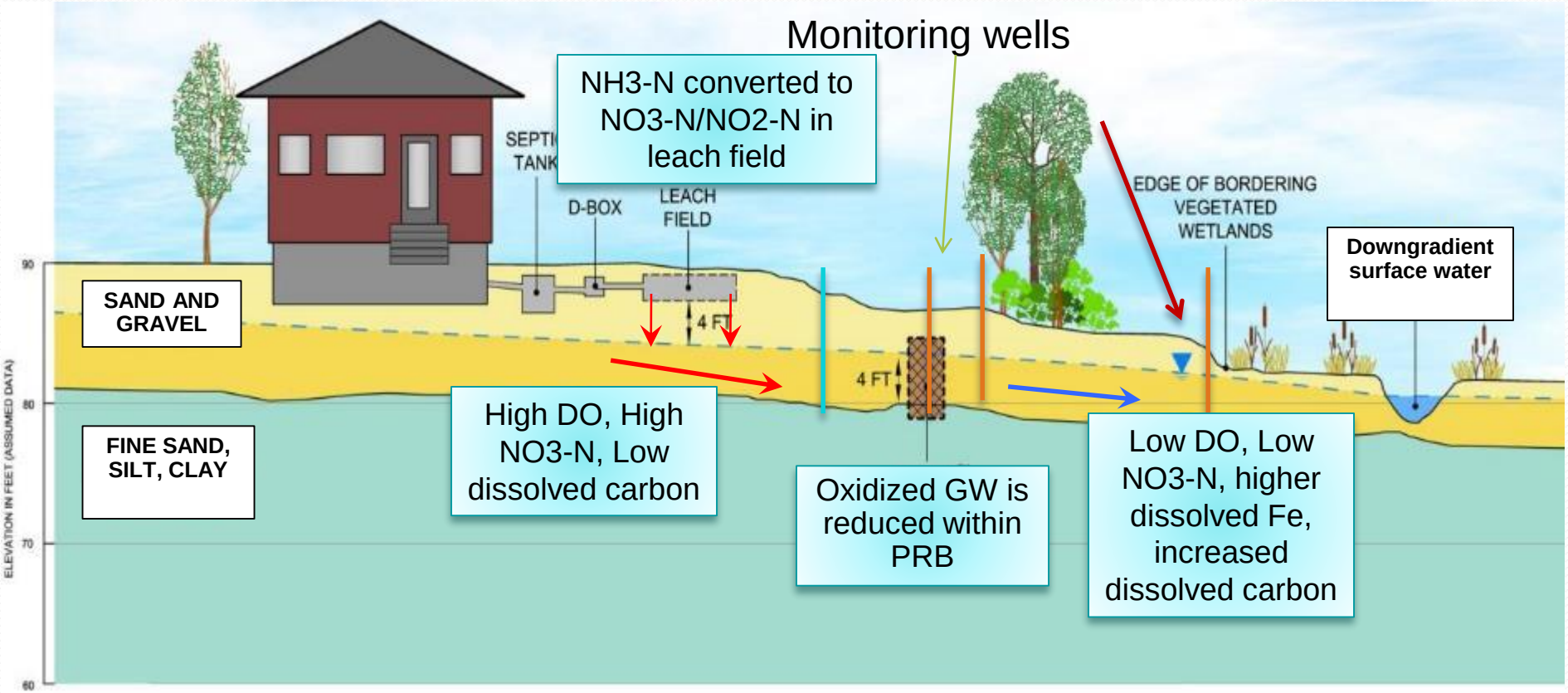
Less than one day to trench, fill and complete

Monitoring PRB Effectiveness -Where is water tested?



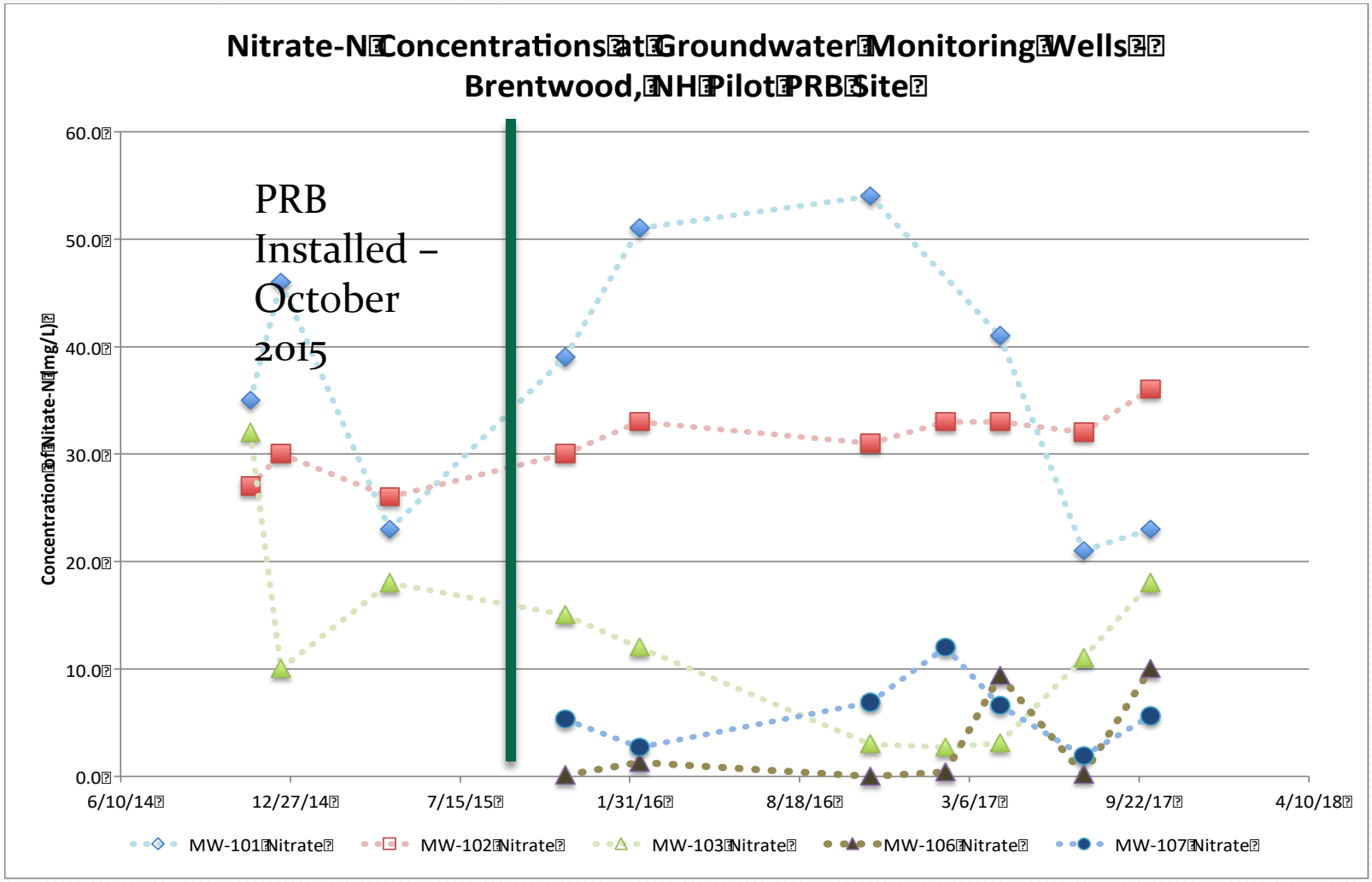
Monitoring network of wells and surface water

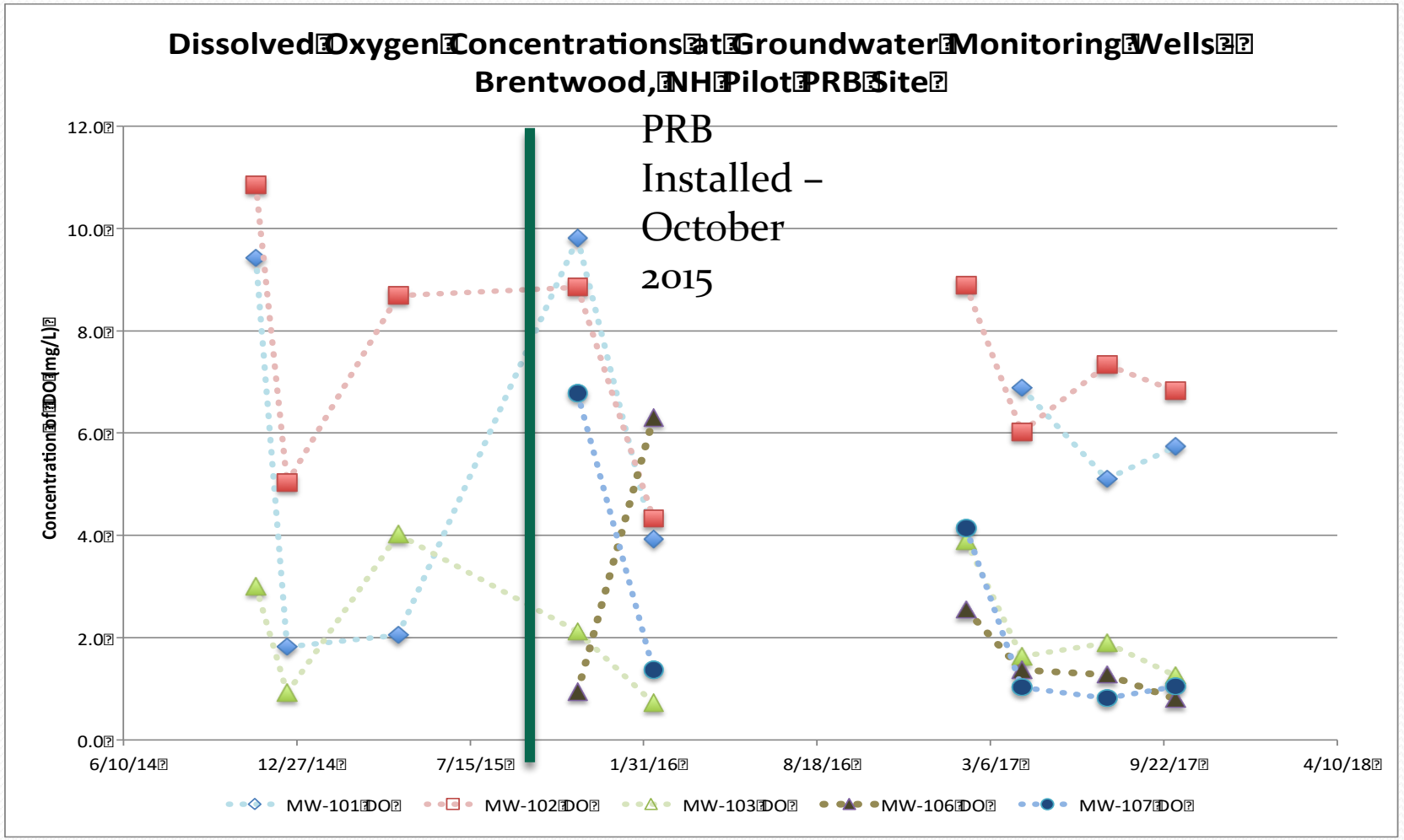
Water Chemistry Changes



Regular monitoring under various weather conditions to test effectiveness of PRB

Brentwood – nitrate concentrations in expanded monitoring network – February 2017


Nitrate-N Concentrations at Groundwater Monitoring Wells
Brentwood, NH Pilot PRB Site
PRB Installed – October 2015
Concentration of Nitate-N (mg/L)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
6/10/14
12/27/14
7/15/15
1/31/16
8/18/16
3/6/17
9/22/17
4/10/18
MW-101 Nitrate
MW-102 Nitrate
MW-103 Nitrate
MW-106 Nitrate
MW-107 Nitrate


Dissolved Oxygen Concentrations at Groundwater Monitoring Wells
Brentwood, NH Pilot PRB Site
PRB Installed – October 2015
Concentration of DO (mg/L)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
6/10/14
12/27/14
7/15/15
1/31/16
8/18/16
3/6/17
9/22/17
4/10/18
MW-101 DO
MW-102 DO
MW-103 DO
MW-106 DO
MW-107 DO

Data summary

Measuring Point	Measurement Period	Nitrate-N – Mean (mg/L)	Dissolved Oxygen – Mean (mg/L)	Dissolved Iron – pre-post (mg/L)
Well MW-101 Untreated by PRB	All dates	37.0	5.6	BDL – 0.23
Well MW-102 Untreated by PRB	All dates	31.1	7.3	BDL – 0.35
Well MW-106 In PRB	Post installation	3.1	2.2	NM – 10.0
Well MW-107 5' DG of PRB	Post installation	5.9	2.5	NM – 5.6
Well MW-103 10' DG of PRB	Post Installation	9.3	1.9	BDL – 40.0
Well MW-104 70' DG of PRB	Post Installation	19.4	9.3	BDL – 2.4
Change in NO3-N concentration with PRB treatment	**MW-102 – MW-107**	**31 to 6 ppb**	**81% reduction**	**10 mg/L regulatory requirement**

DG – downgradient;
PRB – permeable reactive barrier
BDL – below detection limit;
NM – not measured

Optimal settings for PRB use

- Developments near sensitive areas – can treat combined septic system/stormwater discharges
- To supplement a traditional septic system that will treat nitrate to WQ standard at property line
- Surrounding a community septic field for protection of sensitive area (water supply, stream, etc..)
- Near a water supply well – to remediate or prevent elevated nitrate migration from a source area
- Site where hydrogeologic study already completed or required

Advantages of using wood chip Permeable Reactive Barriers (PRBs)

- Passive treatment of nitrate in groundwater – no mechanical systems to maintain
- Wood chips for trench are locally available and low cost
- Wood chips are safe, plant based materials
- Can provide significant nitrate reduction
- Can be sited to treat multiple source areas
- Minor maintenance required once trench installed
- Expected lifetime – 20+ years

Examples of successful PRB installations

- Midwest and Canada – Agricultural applications – woodchip bioreactors
  - https://jbioleng.biomedcentral.com/articles/10.1186/s13036-017-0057-4
  - *www.tidescanada.org/.../D-1-9LauraChristiansonD-enitrificationWooD-chipBioreactor*..
  - https://engineering.purdue.edu/watersheds/conservationdrainage/bioreactors.html

- Brentwood, NH and Durham, NH – Pilot woodchip bioreactor trenches
  - http://www.rockinghamccd.org/presentations/nitrogen-septic-systems-great-bay-and-why-it-matters/

- Orleans, MA – Injected Emulsified Oil PRB – ongoing pilot study
  - https://www.town.orleans.ma.us/sites/orleansma/files/file/file/owqap_prb_breakout_group_presentation_final_0.pdf

Questions?

Rockingham County Conservation District
&
Truslow Resource Consulting LLC
providing land & water resource solutions