Reducing Groundwater Nitrate with Permeable Reactive Barriers

A passive groundwater treatment approach

Granite State Rural Water Association Field Day – September 11, 2018

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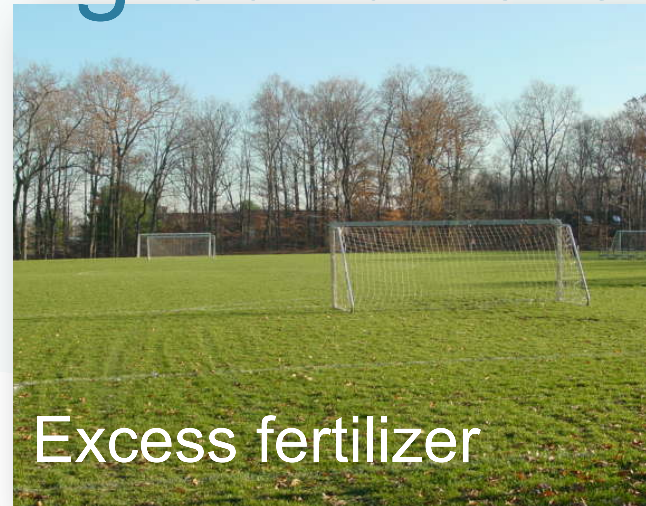
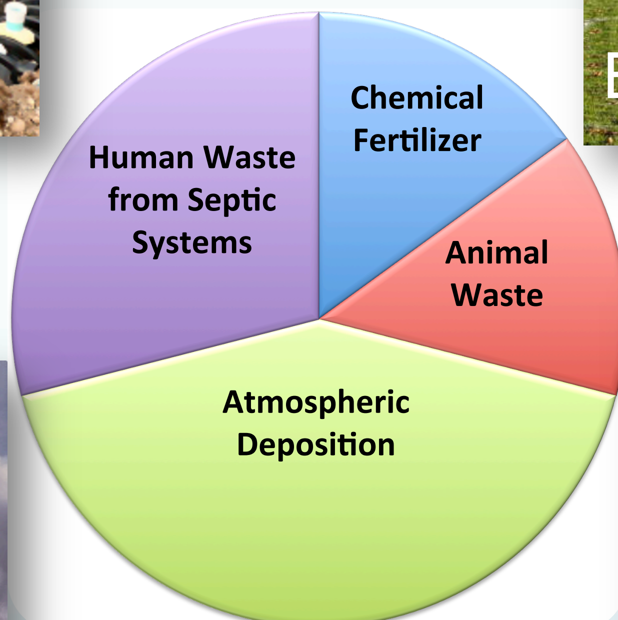
Major sources of nitrate in groundwater





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

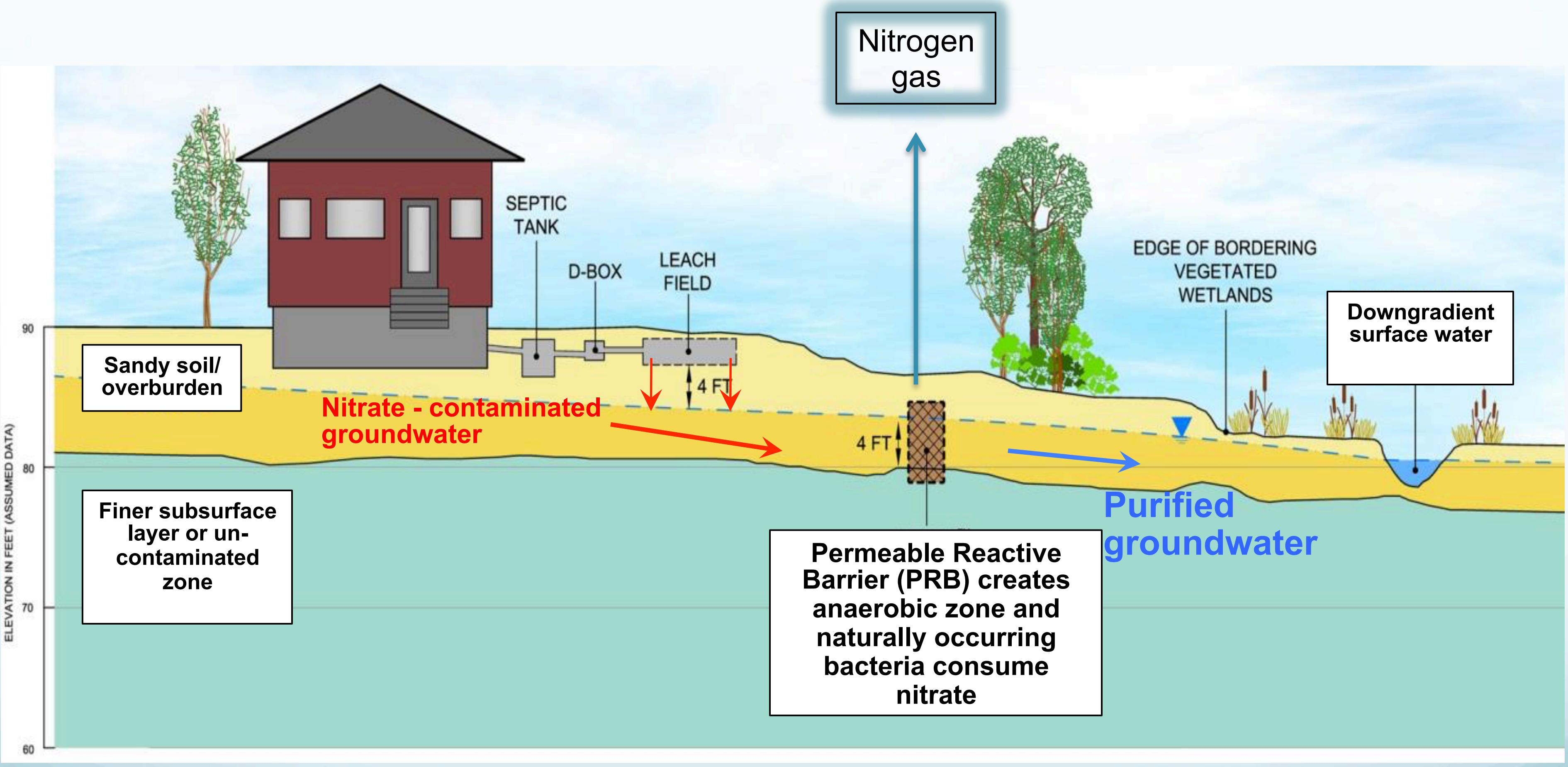
Why is excess nitrate a problem?

- Causes degradation of water quality and habitat and may result in harmful algal blooms and turbidity 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 conditions
- Supplemental carbon source added in treatment zone
- Treatment zone more permeable than surrounding areas to promote flow/treatment rate
- Creates reducing conditions – enhances environment for naturally occurring denitrifying bacteria
- Sustainable infrastructure with little/no mechanical infrastructure needed but requires monitoring and maintenance
- Proven technology in agricultural areas and being adopted in coastal areas

How does a PRB reduce nitrate?



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

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) designed for the treatment setting is injected into treatment zone through small diameter wells
- Utilization of EVO in subsurface monitored and periodically refreshed
- Can be used in areas of deeper/more extensive contamination
- This approach being piloted on Cape Cod and Long Island

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
- Groundwater flow rate
- Annual groundwater level fluctuation

Optimal settings for PRB use in New England

- Developments near sensitive areas – can treat combined septic system/ stormwater discharges
- Supplement a traditional septic system to treat nitrate to 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 near a source area
- Shallow groundwater depth and nitrate plume
- Site where hydrogeologic study already completed or required

Pilot Study – Brentwood, NH – Community Septic Field

Project Purpose

- To install and pilot 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
- *To implement effective nitrogen removal solutions in the Great Bay Watershed as part of the Great Bay watershed management plan.*
- Project started in 2014 and concluded in 2017

PROJECT TEAM

ROCKINGHAM COUNTY CONSERVATION DISTRICT

STRAFFORD COUNTY CONSERVATION DISTRICT

HALEY ALDRICH

Truslow RESOURCE CONSULTING LLC

Environmental Engineers/ Consultants
LOMBARDO ASSOCIATES, INC.

Absolute Resource associates

SEAL OF THE TOWN OF DURHAM N.H. 1732

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

BRENTWOOD, NEW HAMPSHIRE 1742

PRB Installation – Community Septic Field

Erosion control installed to protect wetland

PRB Placement and Site Restoration

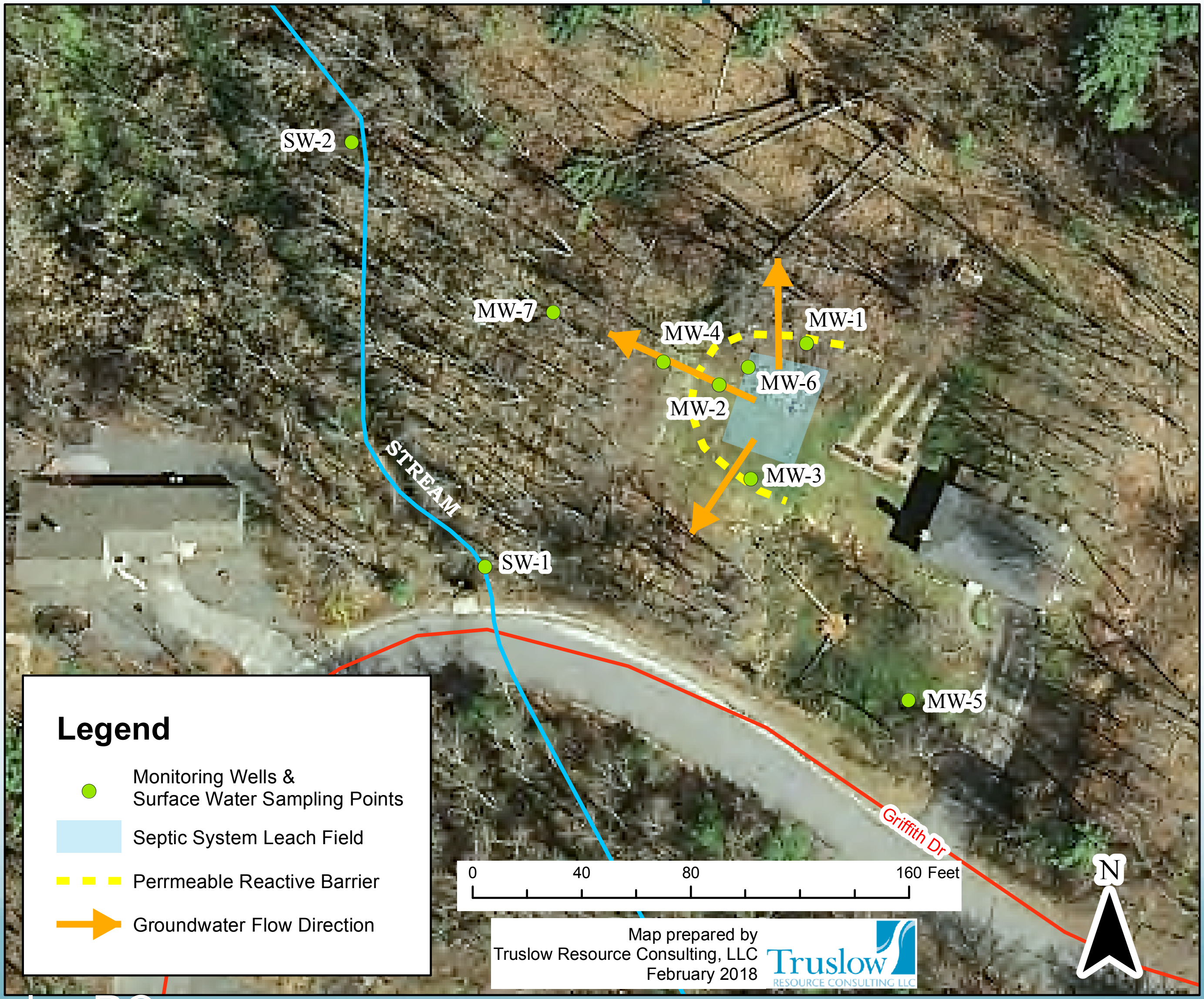
Filling trench with chips as trench is excavated

Geotextile cover at surface of trench

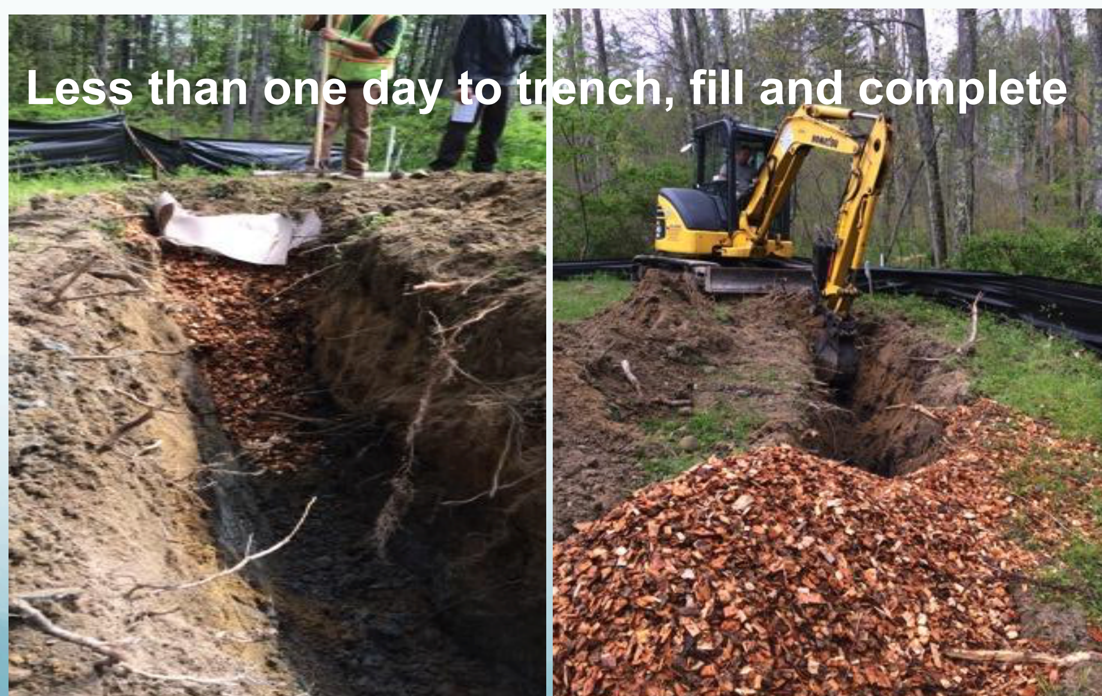
Filled Trench

Completed PRB

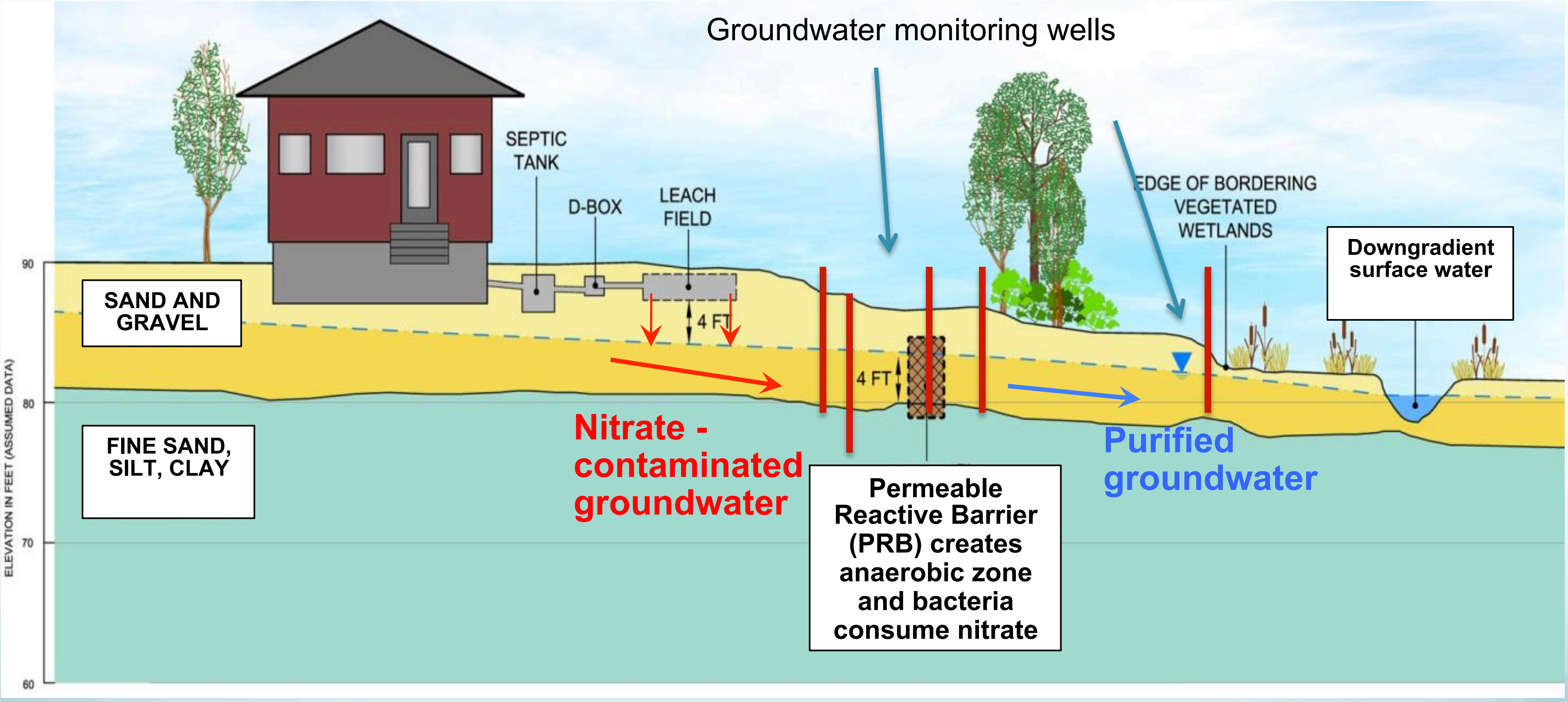
Pilot PRB
Domestic Septic Field



PRB at Single Residence Septic Field

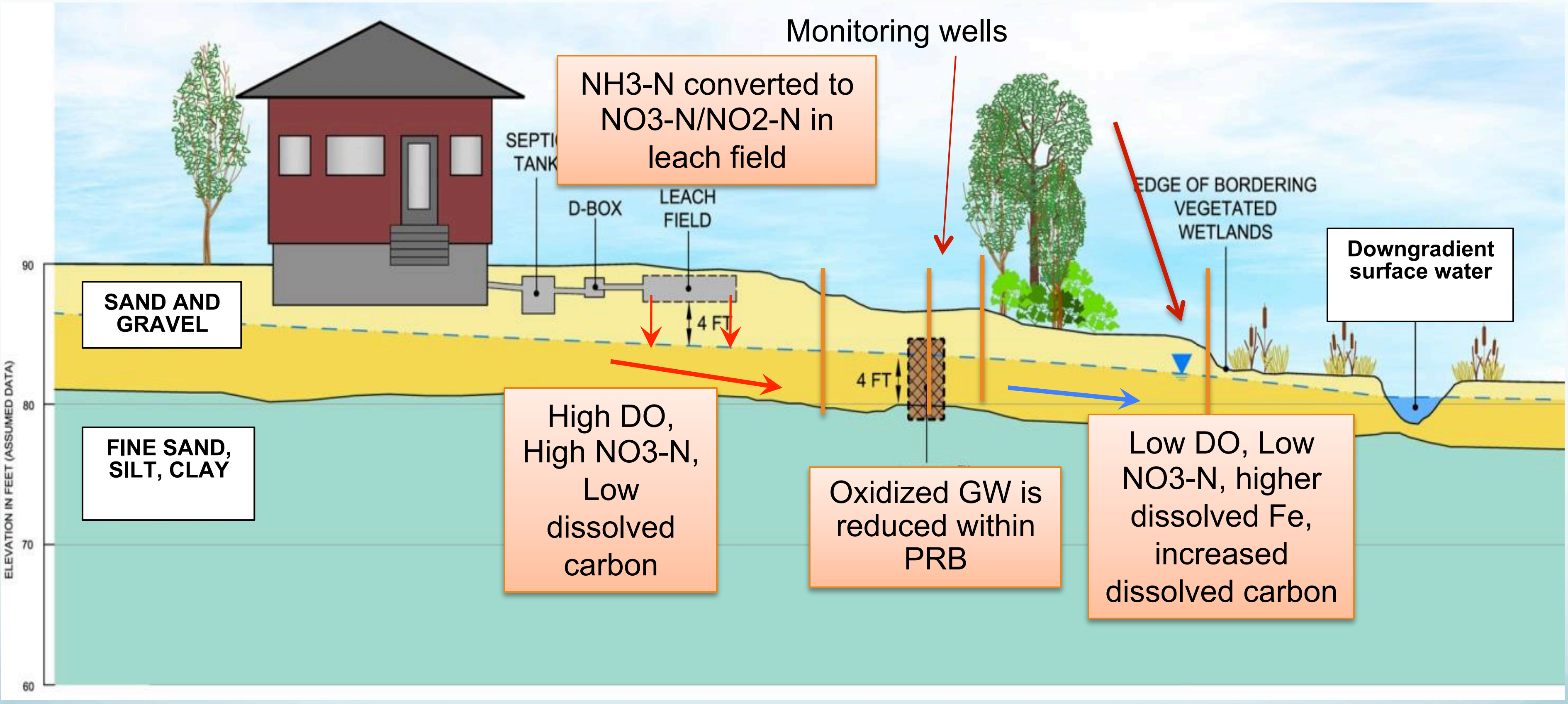


Monitoring PRB Effectiveness - Where is water tested?



Monitoring network of wells and surface water

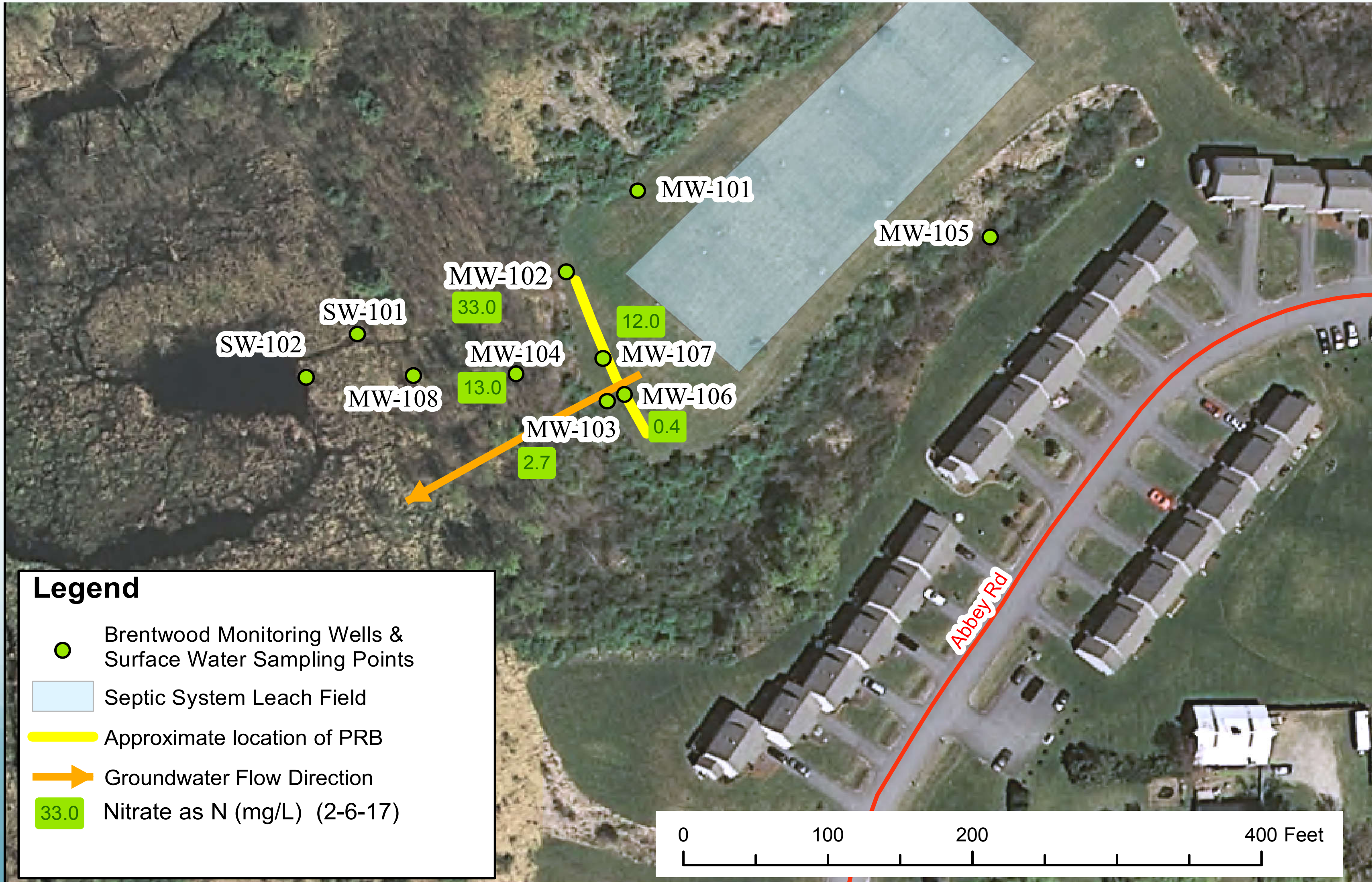
What Water Chemistry Changes are Expected?

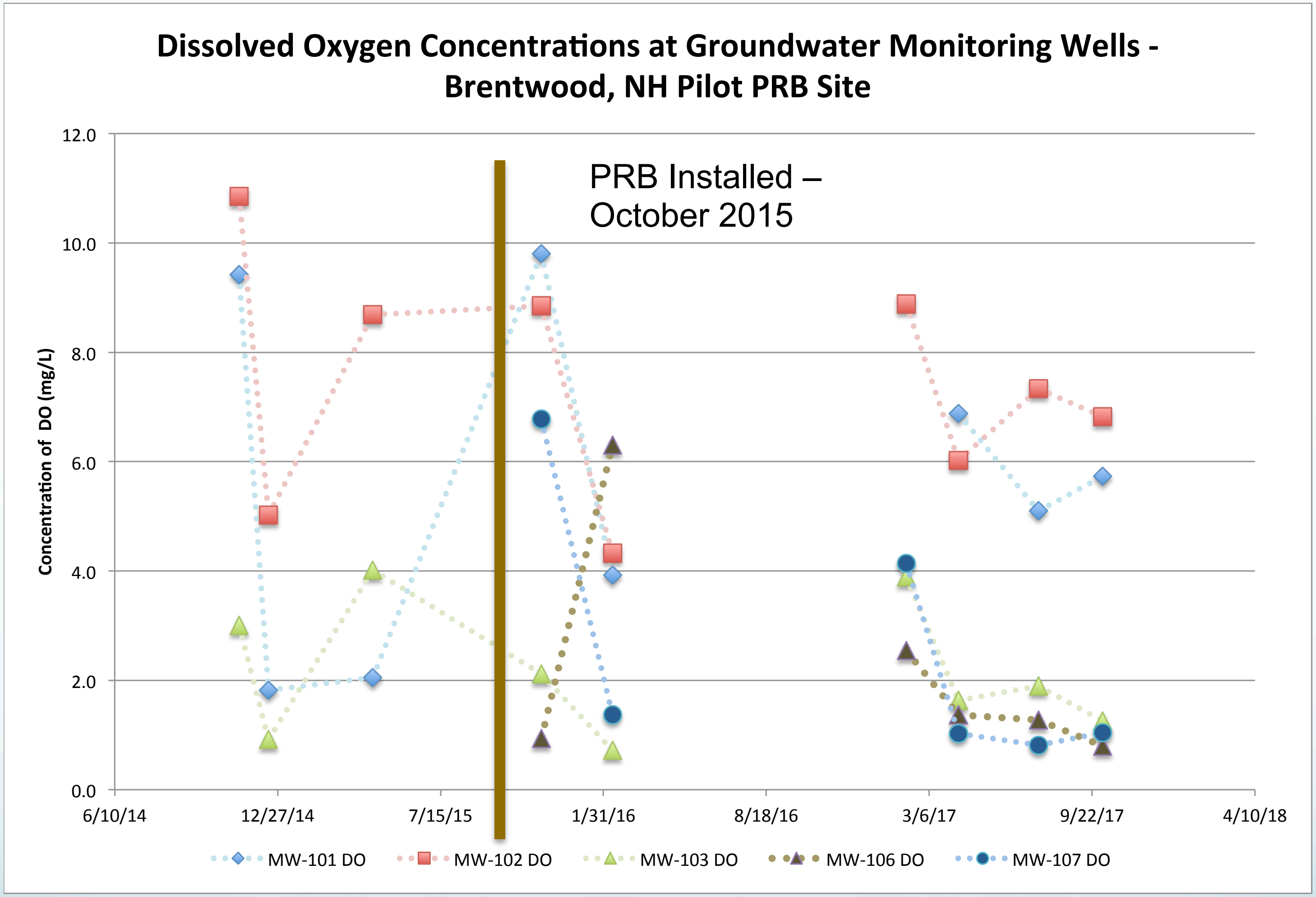


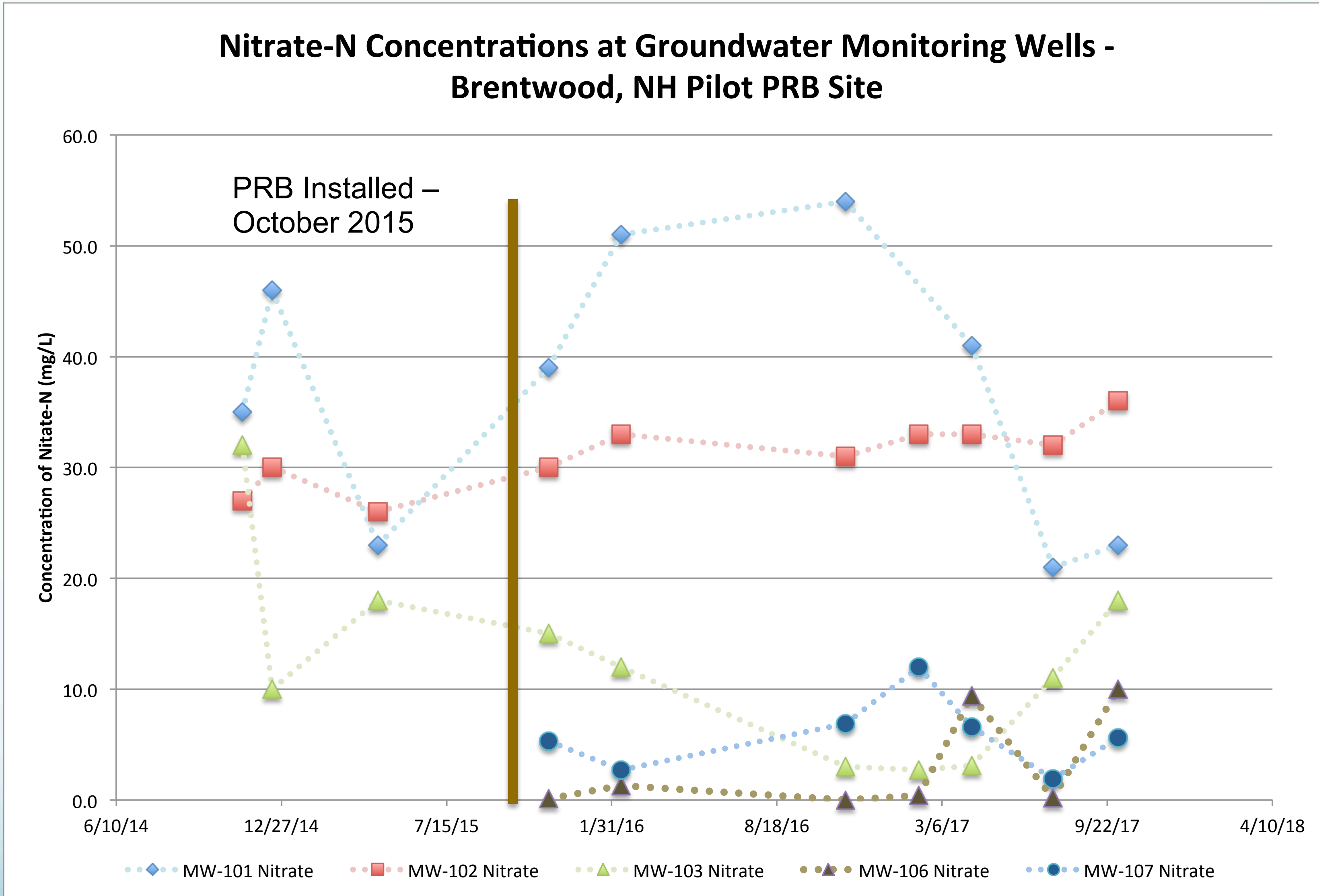
Regular monitoring under various weather conditions to test effectiveness of PRB

DO- dissolved oxygen; NH3-N – Ammonia; NO3-N/NO2-N – nitrate and nitrite; GW- groundwater; Fe - Iron

Brentwood, NH – nitrate concentrations in expanded monitoring network – February 2017




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



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

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

Recommended Operation and Maintenance

- Check integrity of geotextile to prevent surface infiltration of precipitation/snowmelt or runoff. Replace or repair as needed.

- Keep area around PRB mowed and remove woody shrub/trees from immediate PRB area

- Continue groundwater/surface water monitoring to assure continued effectiveness and to prevent negative impacts on nearby surface water.

- Replace or refresh wood chips as needed. (Ongoing pilot study in Canada suggests 20+ year lifespan).

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

Optimal settings for PRB use in New England

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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?

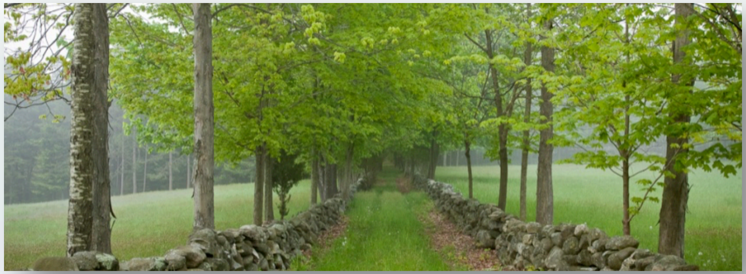
Truslow Resource Consulting LLC

providing land & water resource solutions

Truslow Resource Consulting LLC

Hydrology, Geomorphology & Restoration

Source Water Protection



Land Conservation Assistance, Federal & State Grant Writing

Groundwater & Surface Water Quality Sampling & Monitoring

GIS Mapping & Analysis

Resource Planning & Management