Passive Treatment of Nitrate in Groundwater – *A Review of the Piscataqua Permeable Reactive Barrier Pilot Project*

Danna Truslow, PG, CG; Truslow Resource Consulting, LLC,
Vicky Stafford, Assistant District Manager, Rockingham County Conservation District

In association with

Mark Kelley, PE; Haley & Aldrich, Inc.
Pio Lombardo, PE; Lombardo Associates, Inc.
Leonard Lord, PhD, CWS, CSS, District Manager
Rockingham County Conservation District

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Truslow RESOURCE CONSULTING LLC

HALEY ALDRICH

NHDES 319 Grant Project – Great Bay Watershed

Project Purpose

- Begun in 2014
- 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 concludes in 2017

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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. 1712

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

BRENTWOOD, NEW HAMPSHIRE 1742

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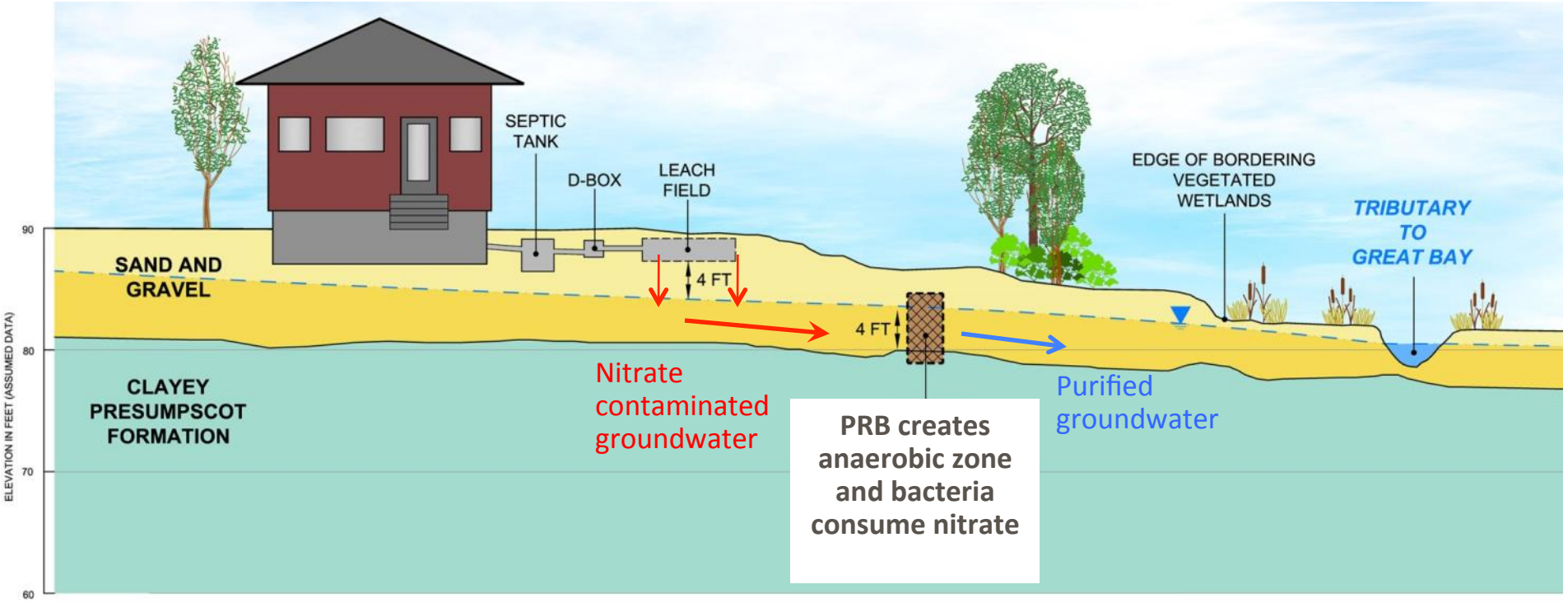
Permeable Reactive Barrier (PRB) : Nitrate Removal Using PRB



SITE DESIGNATION	LENGTH OF NITREX™ PRB	DEPTH OF NITREX™ PRB
RESIDENTIAL SYSTEM (600 GPD ±) DURHAM, NH	50 FT	5 FT
COMMUNITY SYSTEM (8,000 GPD ±) BRENTWOOD, NH	110 FT	8 FT

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.

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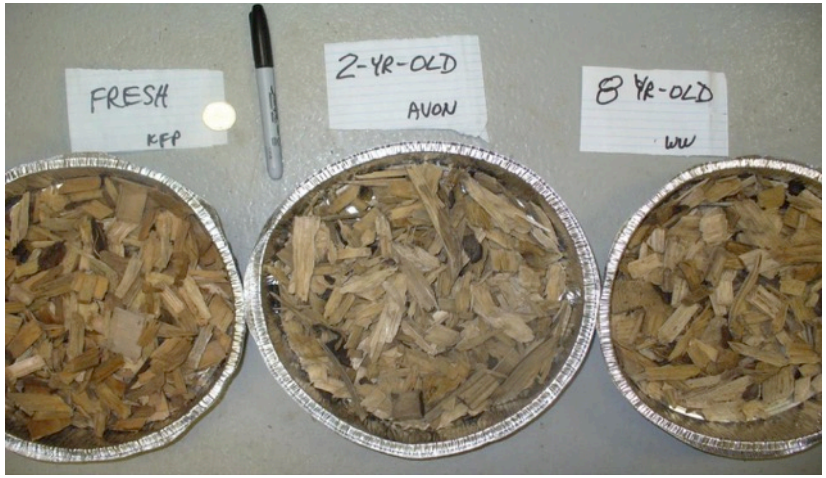
Wood Chip Bioreactor PRBs

- Low-cost carbon source for denitrification (wood chips)
- 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 unless first nitrified



1, 2 and 8-yr-old woodchips
Similar to playground wood chips

Bacteria + C + $N0_3$ ⇨ N^2

(Carbon + nitrate) ⇨ (nitrogen gas)

(Dr. Will Robertson, U. Waterloo, Canada)
wroberts@sciborg.uwaterloo.ca

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PRB Design Parameters – what to know before design

What is the purpose of PRB?

Understand Site Hydrogeology:

- What is underlying geology? *Is it permeable enough, depth of impact?*
- What is the direction of groundwater flow from septic?
- How fast does groundwater flow?
- How much does groundwater level change over the year?
- What is the starting nitrate, dissolved oxygen, dissolved metals concentration?

- **Calculate required PRB residence time:** (How long does flowing groundwater need to stay in the 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 – to treat bulk of NO3-impacted groundwater

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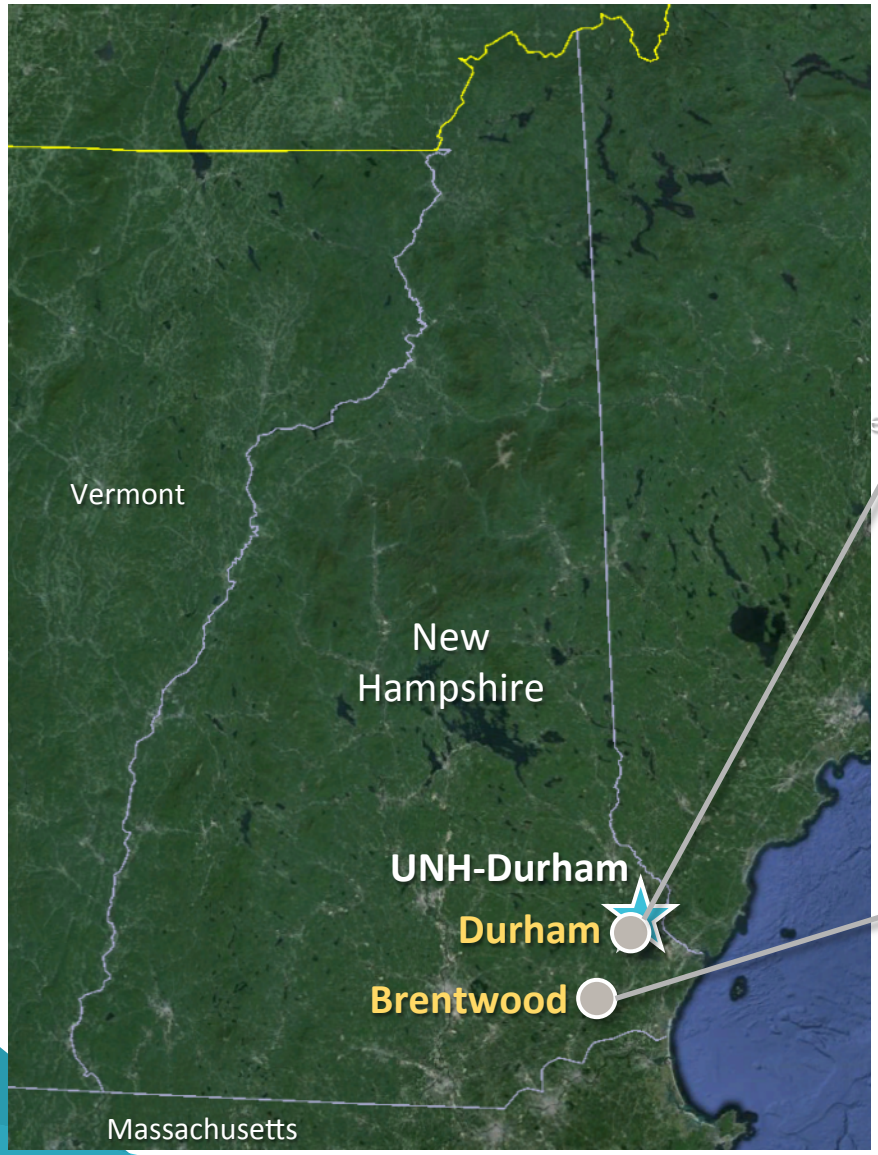
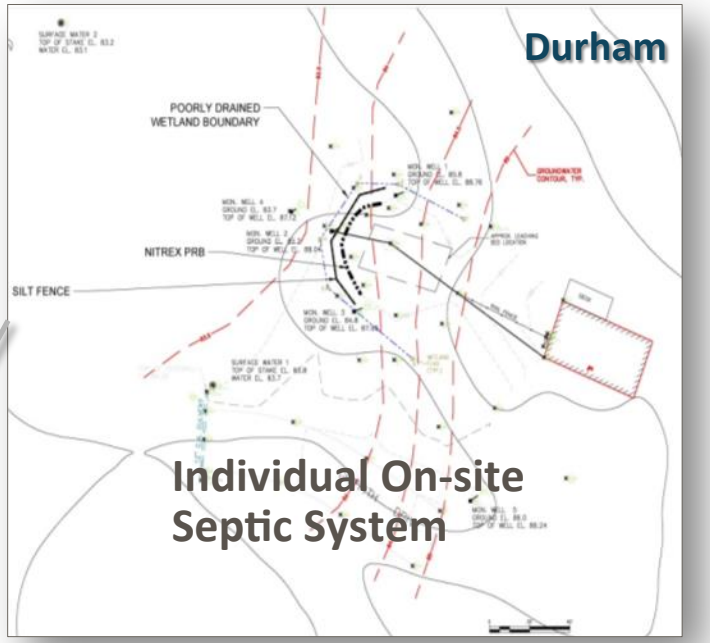
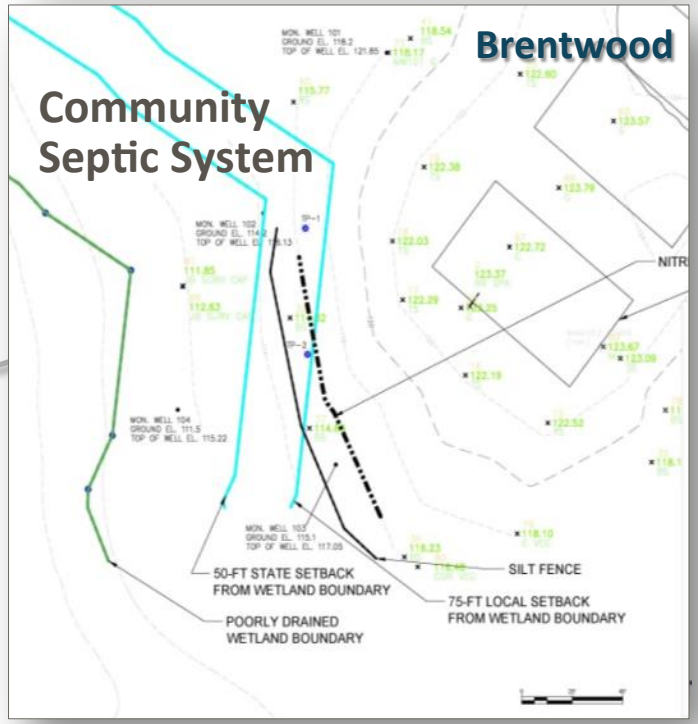
Site Locations







Brentwood Site – Windsor Meadows Condos

- Failed septic area in community septic field – five beds in field
- Two new beds installed in 2012
- Silty sand with underlying silt
- Groundwater (GW) flow southwest towards Dudley Brook, tributary of Exeter River, and radially from septic field; 0.03 ft./ft. gradient
- GW velocity – 0.2 ft../day average
- Nitrate 12 to 46 mg/L at wells
- 1.9 mg/L in nearby SW measured in past
- ***Installed October 2015***

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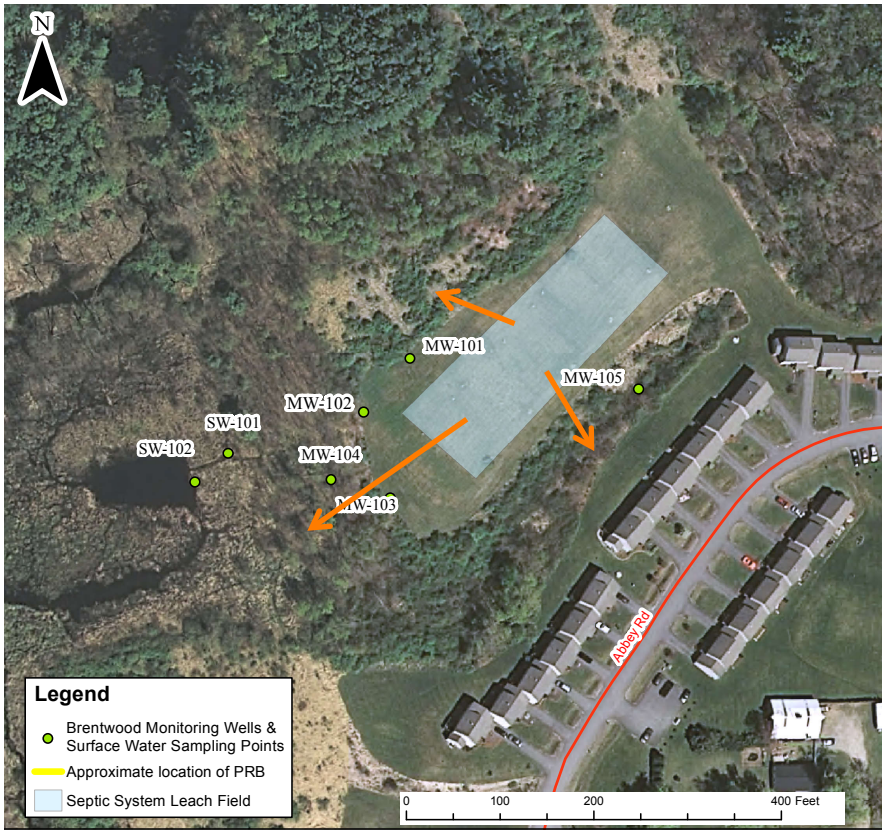
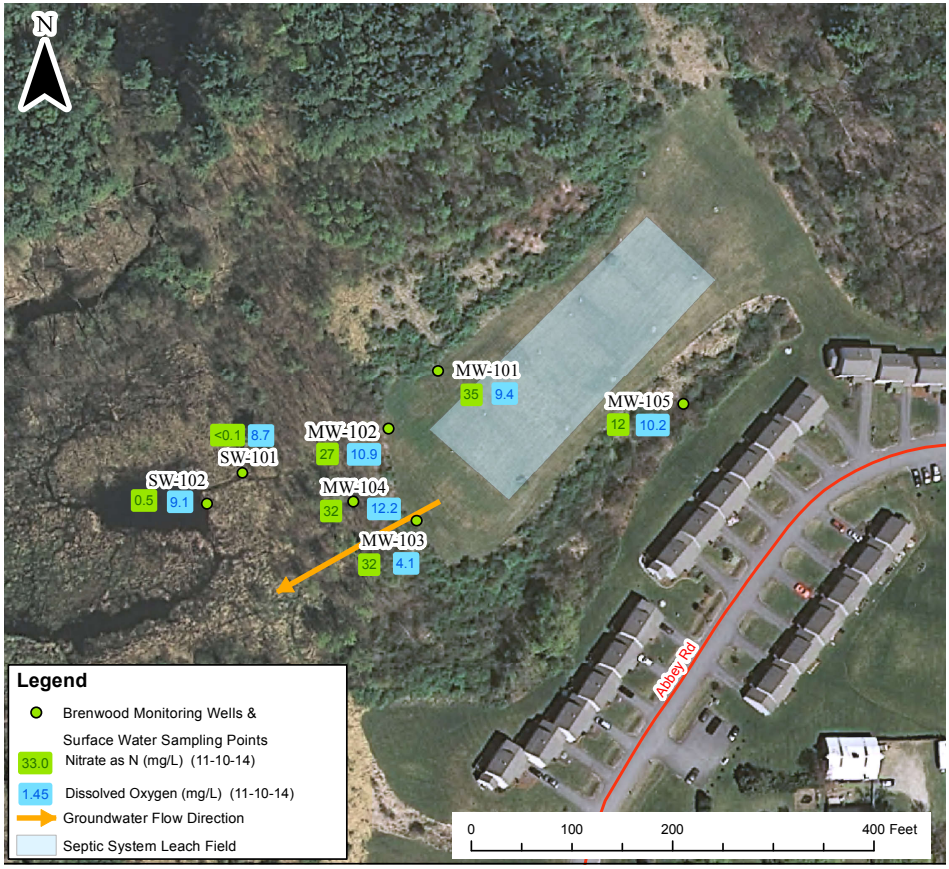
Brentwood – Groundwater Flow Direction and Initial Water Quality



Design flow = 9,000 gpd

Serves 30 units - 60 bedrooms



Durham Site - Griffith Drive Neighborhood

- Failed septic close to house, new septic field installed 2008 away from house and closer to brook
- Silty sand underlain by silt
- GW flows northwest towards Chesley Brook tributary of Oyster River; 0.01 ft./ft. GW gradient
- Average GW flow rate 0.06 ft../day
- Initial nitrate 6.2 mg/L at one field-side monitoring well
- Wetland/shoreland local permit required
- *Installation May 2016*

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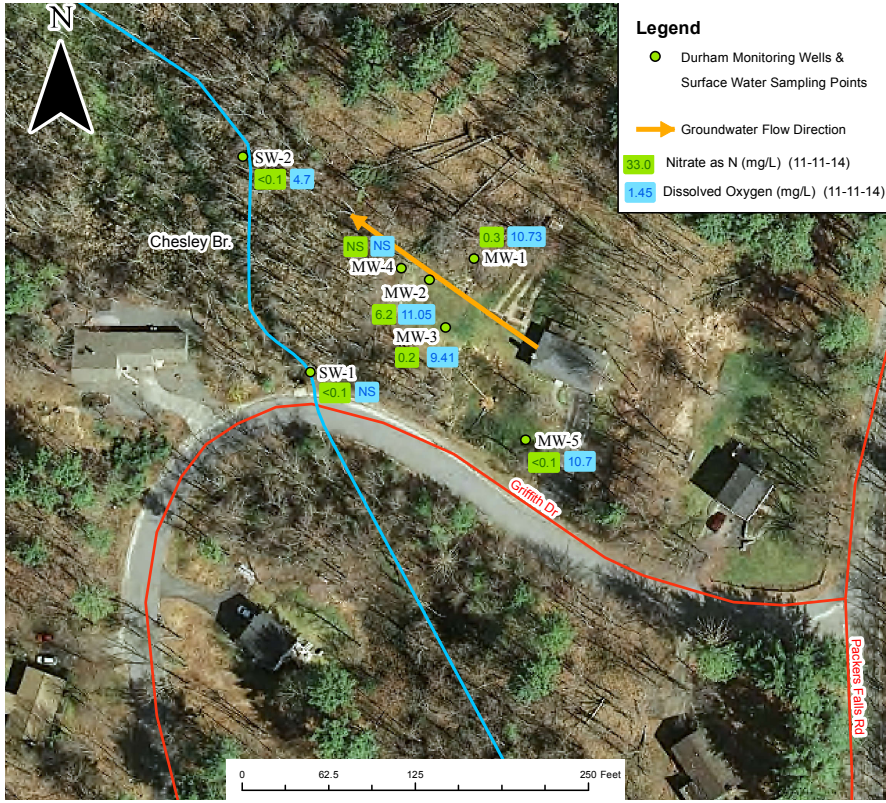
Durham – Groundwater Flow Direction and Initial Water Quality



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 based groundwater flow rates
- **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..
- Established *surface and groundwater monitoring points*, measured water quality and water levels regularly to evaluate effectiveness

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Brentwood PRB

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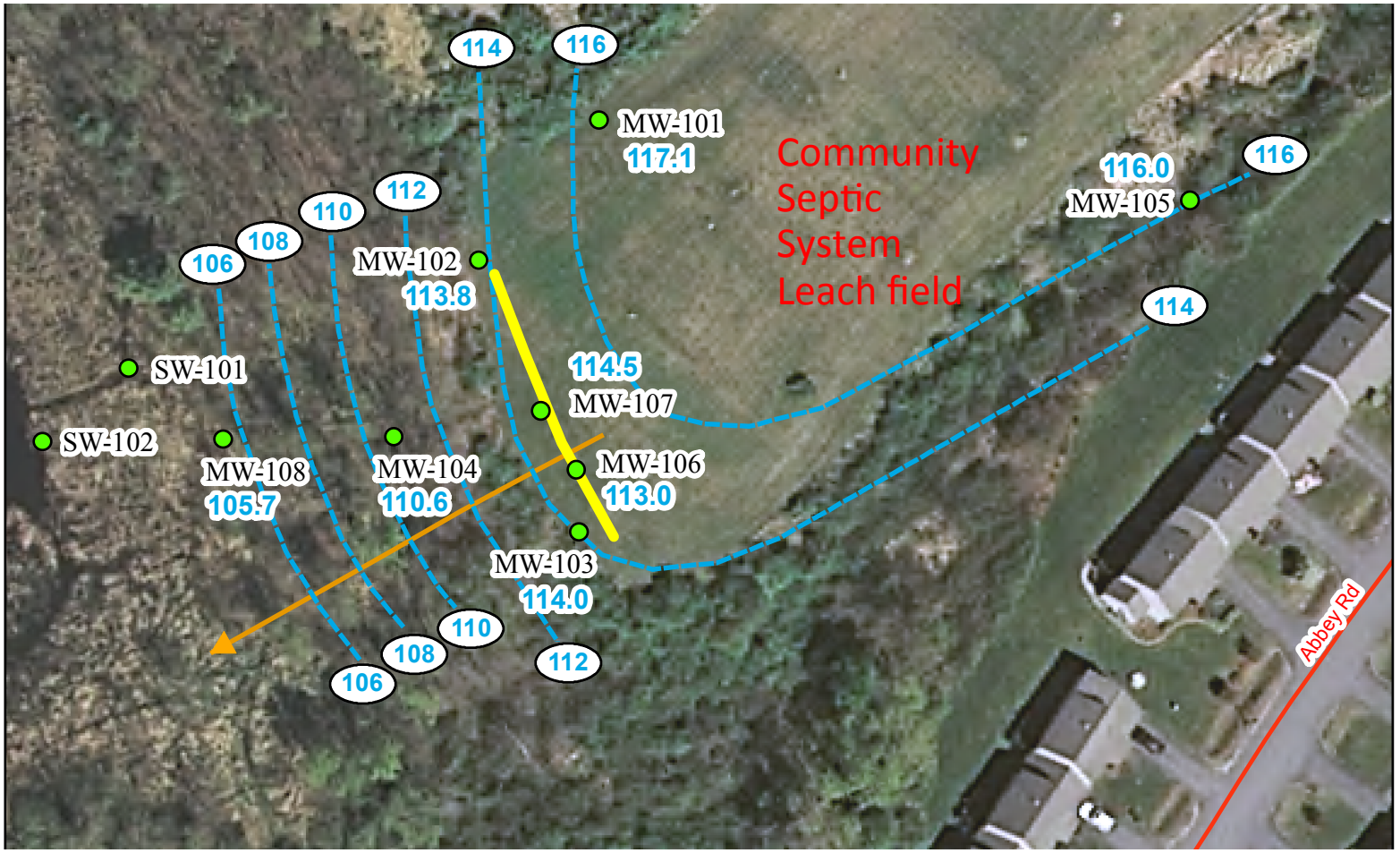
Brentwood - Groundwater Elevations and Flow



Line of equal groundwater elevation

MW-103 (114.0) Measured groundwater elevation at well (ft.. above mean sea level)

Overall groundwater flow direction

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Construction of Brentwood, NH PRB – 13 October 2015

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Brentwood - PRB Placement and Site Restoration

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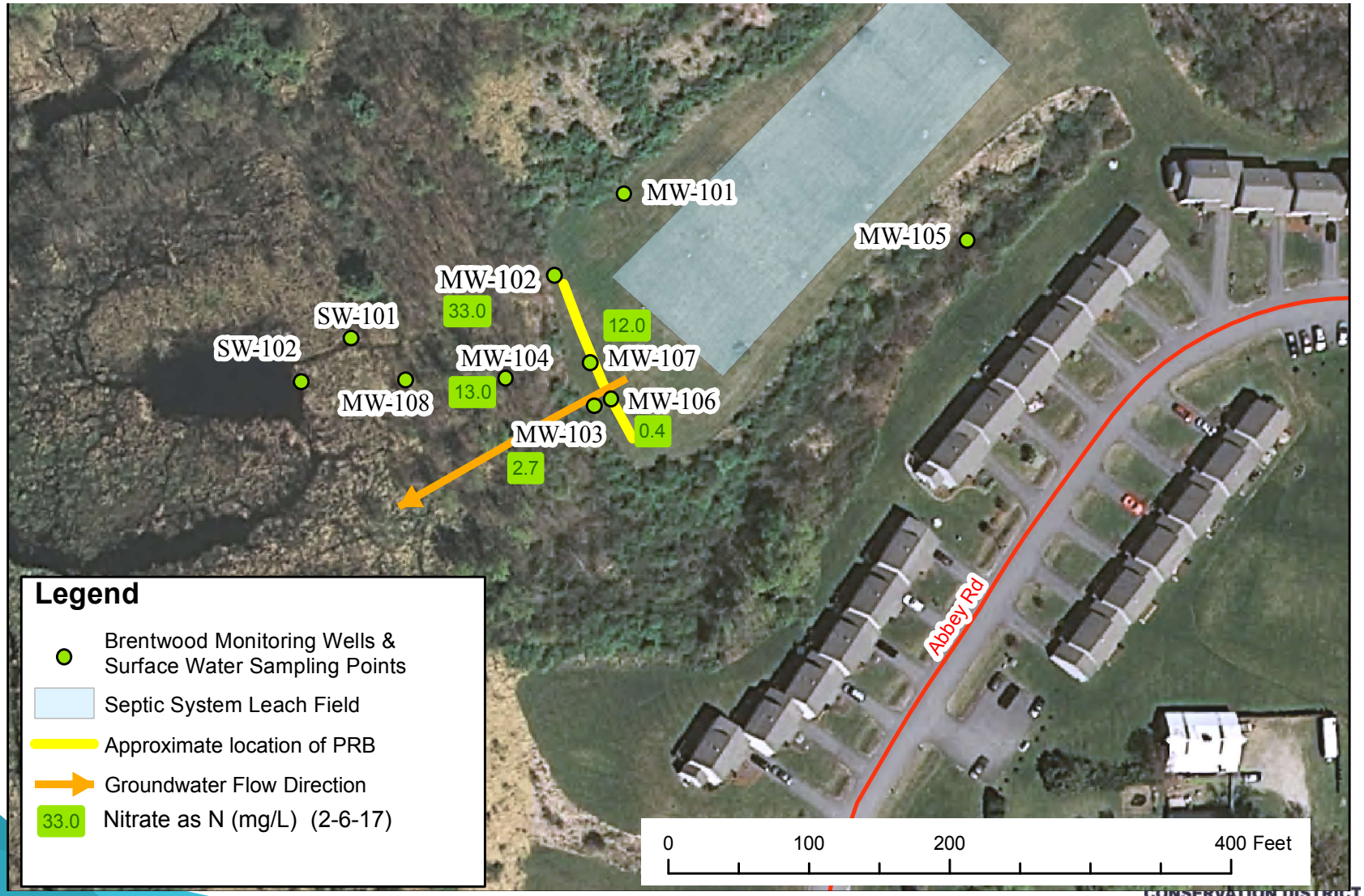
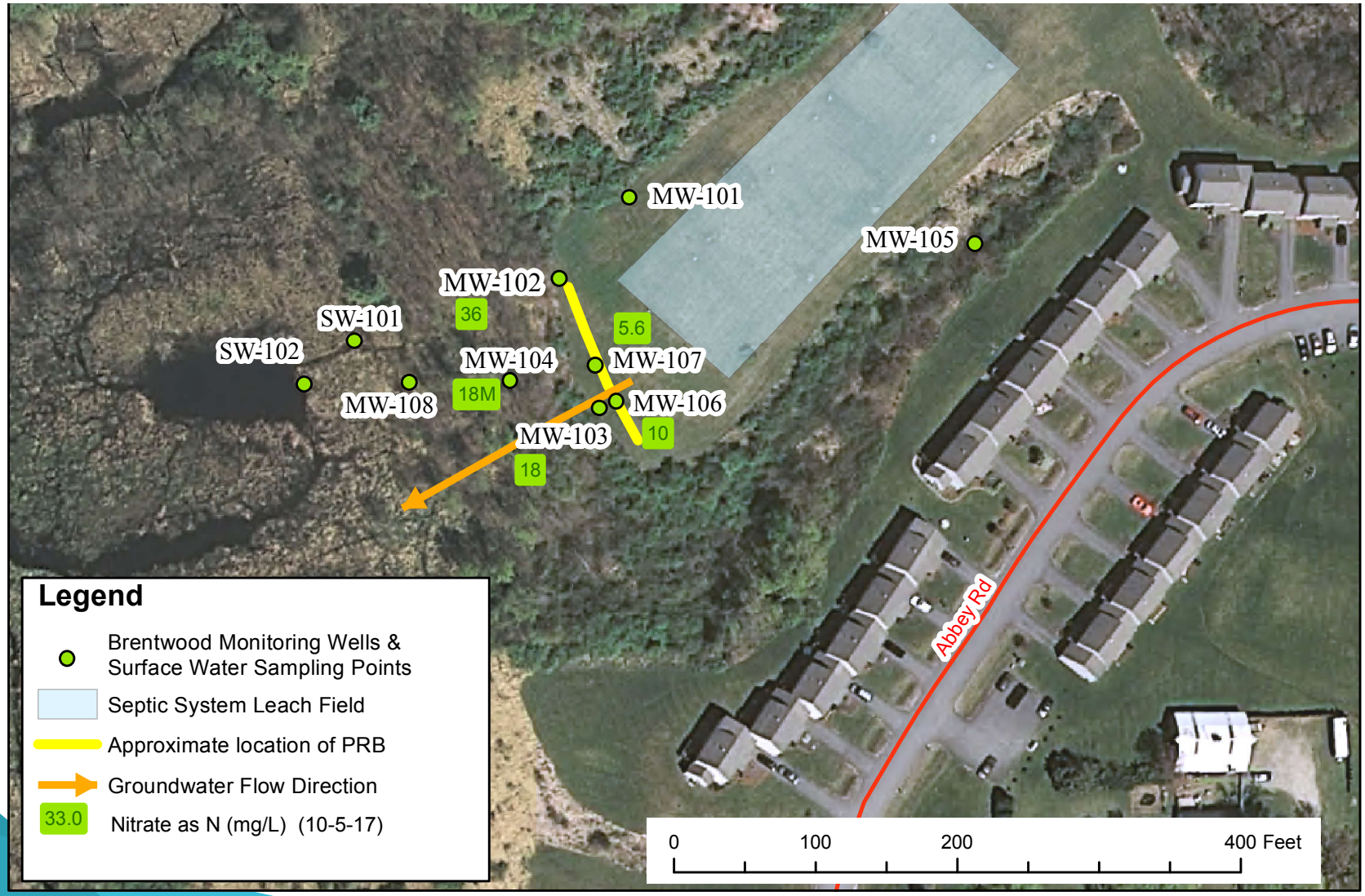
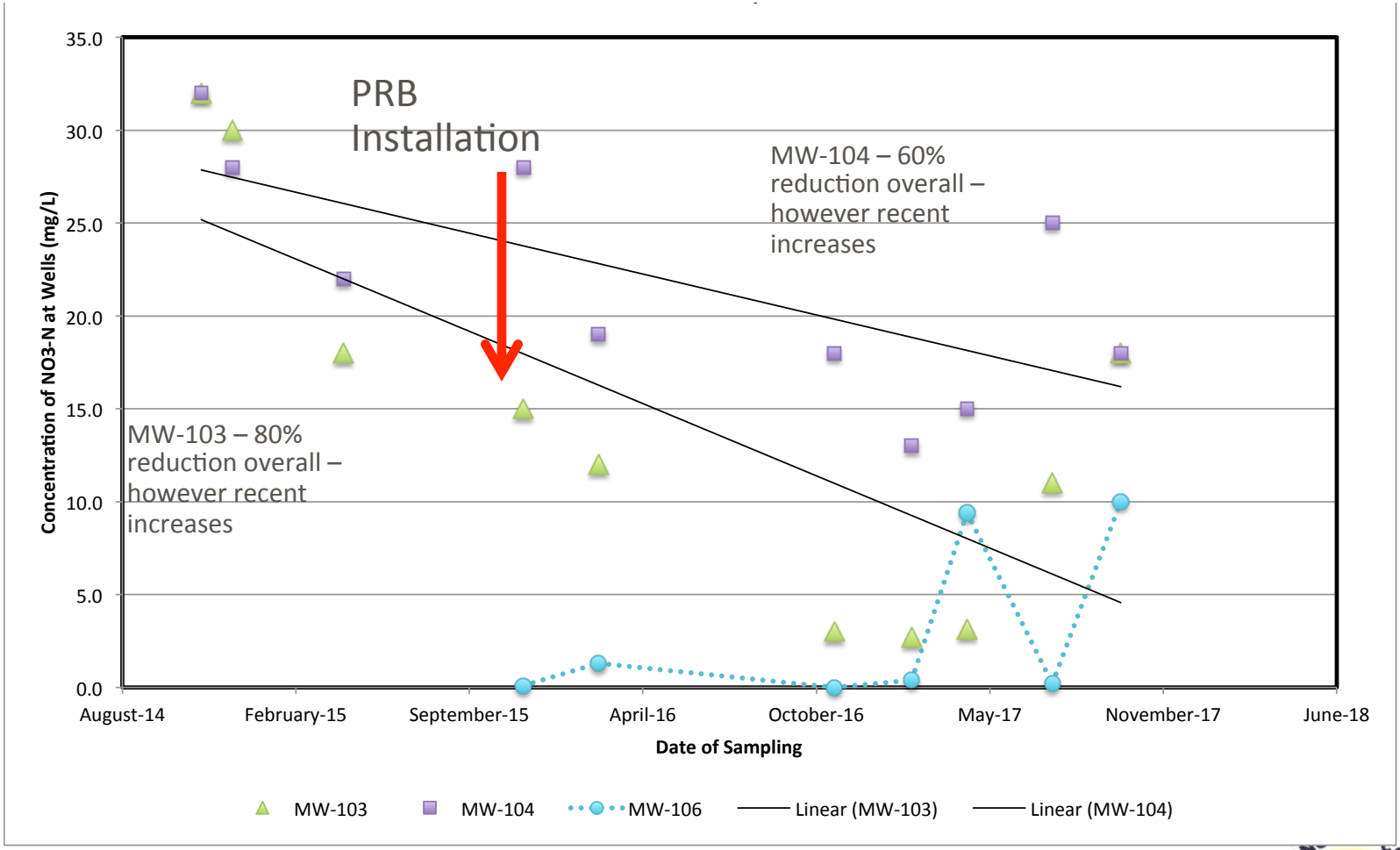
Brentwood - nitrate and DO concentrations – February 2017



Brentwood -nitrate and DO concentrations – October 2017



Nitrate at wells treated by PRB



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Summary - Brentwood

- Nitrate reduction near PRB apparent in year 1 – 12 to 3 mg/L at MW-103 and MW-104 (28-13 mg/L)
- 2016 drought followed by heavy precip (Nov 2016 - May 2017)
- Large septic field surface recharge area
- Rapid recharge increased DO in PRB impacting anaerobic conditions – incomplete treatment, greater PRB residence time needed?
- Geotextile barrier to surface infiltration compromised by vegetation, burrowing?
- *Needed* - geotextile/berm upgrades

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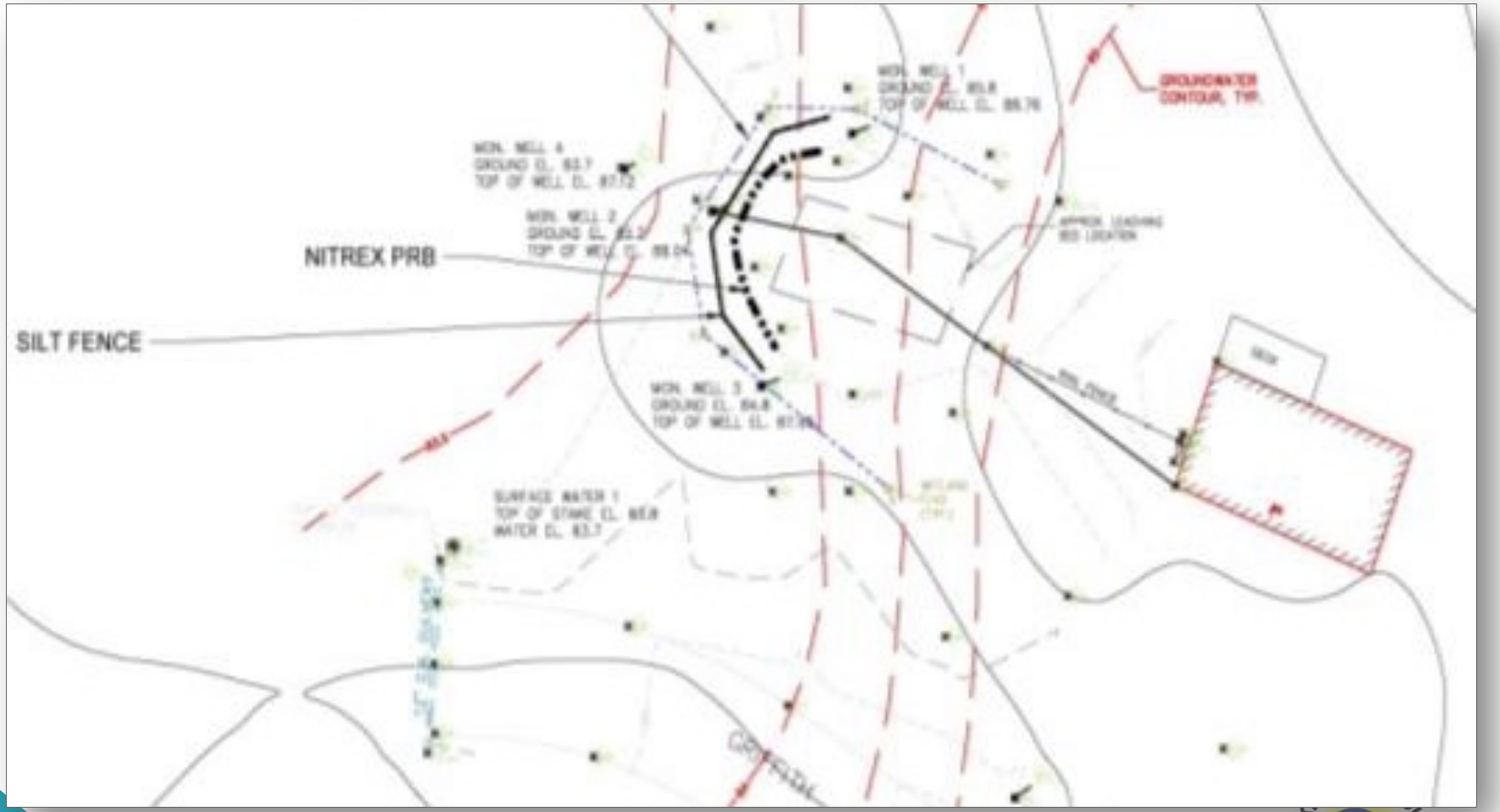
Durham PRB



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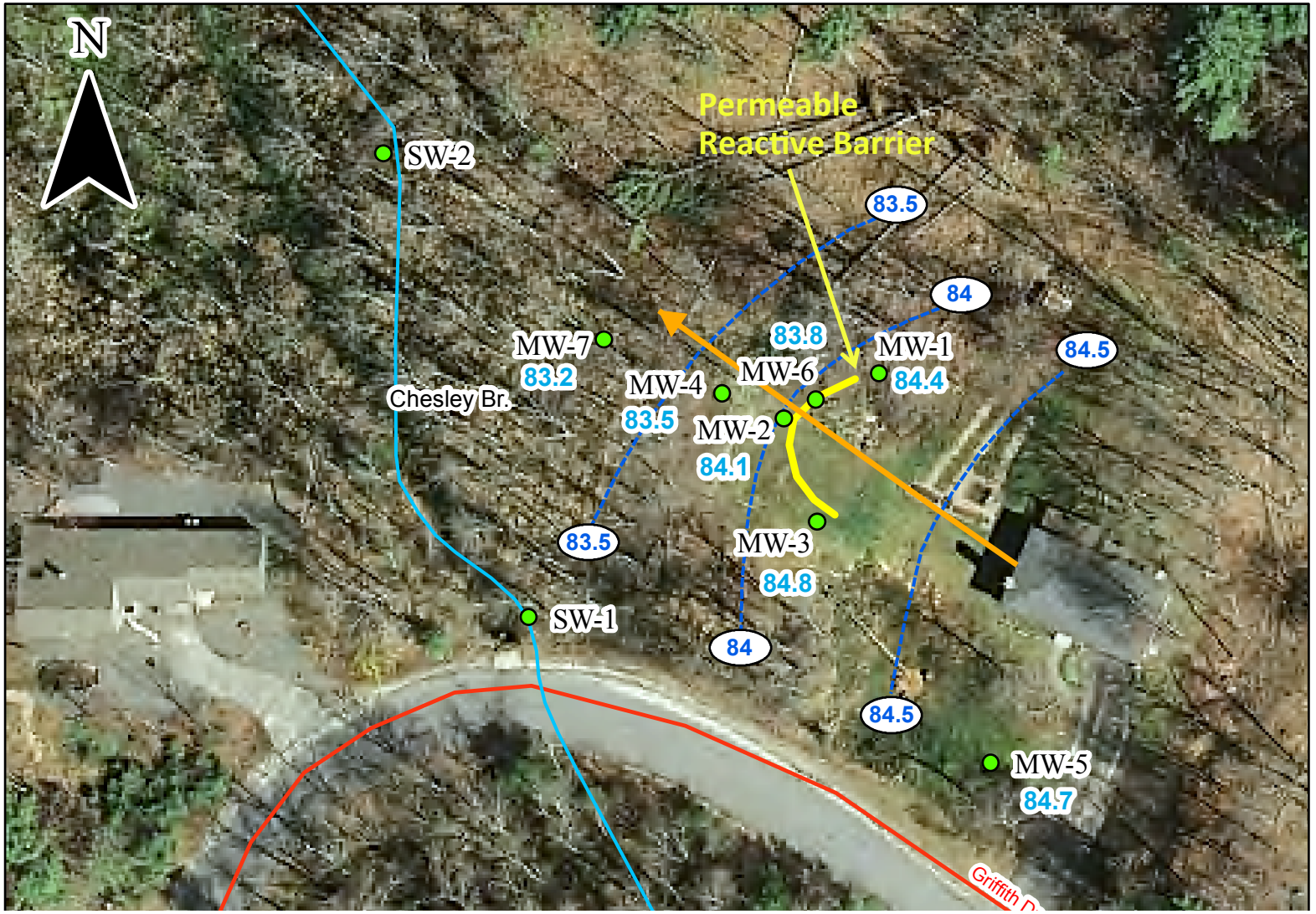

Line of equal groundwater elevation

MW-1 (84.4) Measured groundwater elevation at well (ft.. above mean sea level)

Overall groundwater flow direction

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Construction of Durham, NH PRB
19 May 2016

- Wetland protection for access,
- trench stayed open
- Less than 1 day to complete

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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

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All downgradient wells treated – upgradient well still has elevated nitrate-N

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PRB Cost Estimates

PRB Pilot – Brentwood – design, monitoring, installation

- 110’ long, 2’ wide, 8’ deep
- $35,990
- $21/ cubic foot of trench

PRB Pilot – Durham - design, monitoring, installation, local permits

- 50’ long, 2’ wide, 5’ deep
- $26,303
- $53/cubic foot of trench

Proposed Durham PRBs (modified pilot)

- 50’ long x 8’ deep x 3’wide - No permits, one year post installation monitoring
- $17, 574
- $15/cubic foot of trench

Simplified PRB approach – site dependent (test pit background evaluation, reduced cost)

- 50’ long x 8’ deep x 3’wide - No permits, no post installation monitoring
- $8,275
- $7/ cubic foot of trench

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Summary and Lessons Learned – Pilot PRB project

Design/Operation

- Increased flux of groundwater/DO after heavy rain may decrease denitrification effectiveness at trench
  - Widen trench on larger systems to increase residence time - accommodate **these fluxes**
- Pilot at community septic 110’ long – remedial trench installation should be longer to treat all discharge
- **PRB siting limitations** based on soil type, depth to groundwater, water chemistry
- Simple **operation and maintenance** important! – mowing, removal of woody plants and burrowing animals to prevent increased recharge at PRB through geotextile

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Summary and Lessons Learned – Pilot PRB project

Installation/Monitoring

- Location **near stream** may be superior hydrologic setting for treatment
- However, **wetland/shoreland permitting** can be costly and time consuming
- Larger trench for multiple properties or community system most **cost effective**
- **System monitoring** - rig installed wells allow larger diameter, deeper for more cost-effective sampling
- Long term **monitoring** may be optional for some PRBs depending on application
- Soil/saturation conditions that require **trench box** use could add costs

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Application of PRBs in Seacoast Area?

- Sandy saturated soil/overburden underlain by lower permeability material - adjacent to surface water
- Areas of dense existing development – treat combined septic system discharges
- Septic close to property line - may not meet nitrate standard at boundary with standard system
- More cost effective than denitrification in certain settings
- Surrounding a community septic system for protection of sensitive receptor
- Near a drinking water well – to remediate elevated nitrate
- Site where hydrogeologic study already required – reduces data collection costs

Other Planned or Ongoing Pilot PRB Projects

- New pilot project proposed – Strafford County Conservation District
- Pilot study on Cape Cod - density of systems much greater, large sand and gravel aquifers – carbon source injected emulsified vegetable oil

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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. In addition supplies, services and equipment were donated by the project team and the Towns of Brentwood and Durham, NH

Questions?

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