FALMOUTH
PERMEABLE REACTIVE BARRIER PLANNING

USING PERMEABLE REACTIVE BARRIERS TO ADDRESS NITROGEN POLLUTION

APRIL 5, 2017

Sia Karplus
Science Wares, Inc.

Jim Begley
MT Environmental Restoration

PRB SITE ASSESSMENT AND DESIGN PROCESS

1. Develop initial Conceptual Site Model (understanding of site conditions)
2. Collect data to confirm the model
3. Design the PRB

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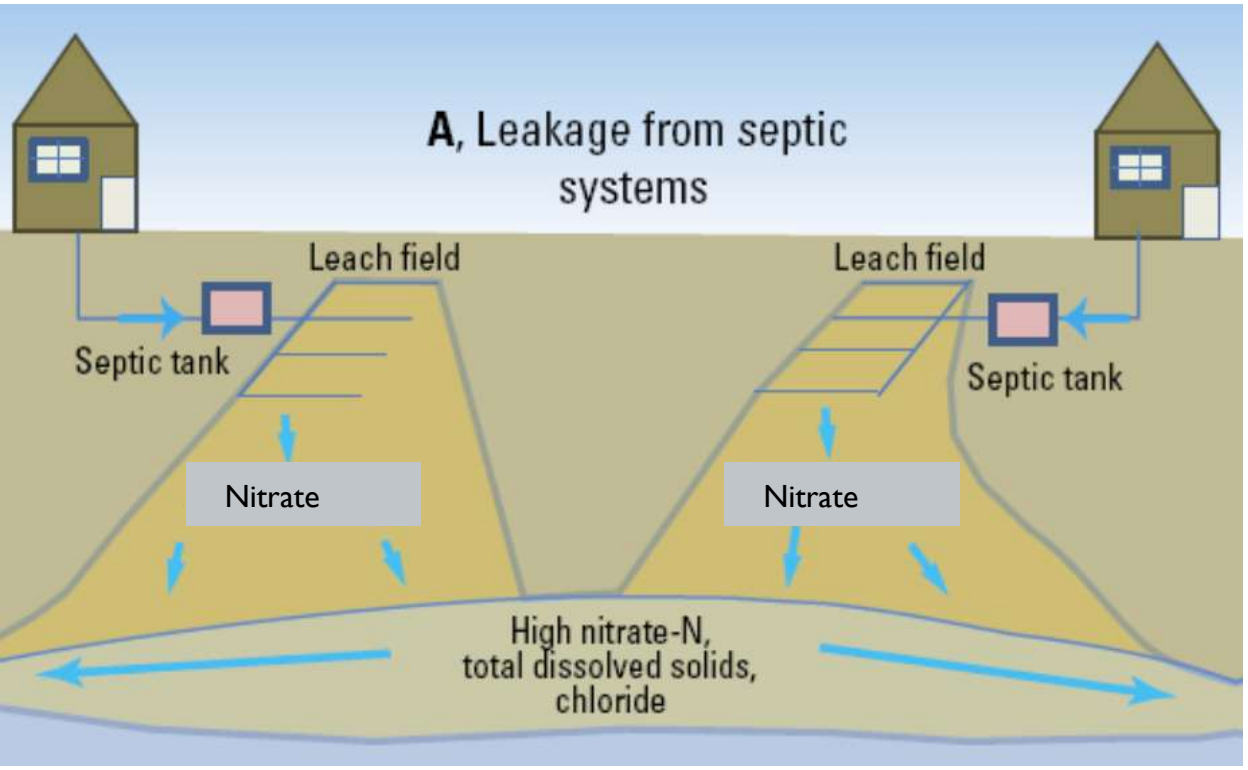
SOURCES AND TRANSPORT OF NITRATE IN GROUNDWATER



Modified from USGS 2013

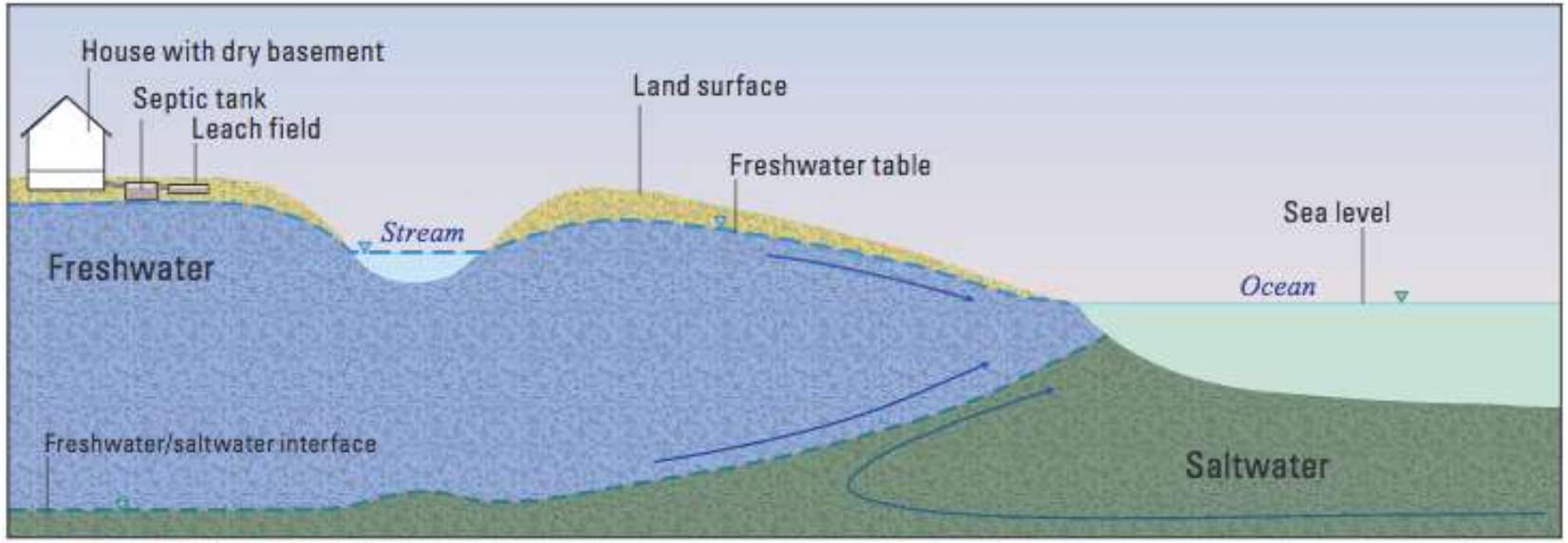
widely distributed - multiple sources –groundwater transport to coastal waters

MANY SOURCES FORM LARGE DILUTE NITROGEN PLUMES

- Relatively low concentration extending over a large area
- Permeable aquifer with high flow
- Potential mass transfer between high and low permeability zones
- Minimal attenuation of nitrogen
  - Significant dissolved oxygen levels
  - Low organic carbon and biomass

GROUNDWATER SYSTEM

Migration controlled by contaminant characteristics and hydrogeology

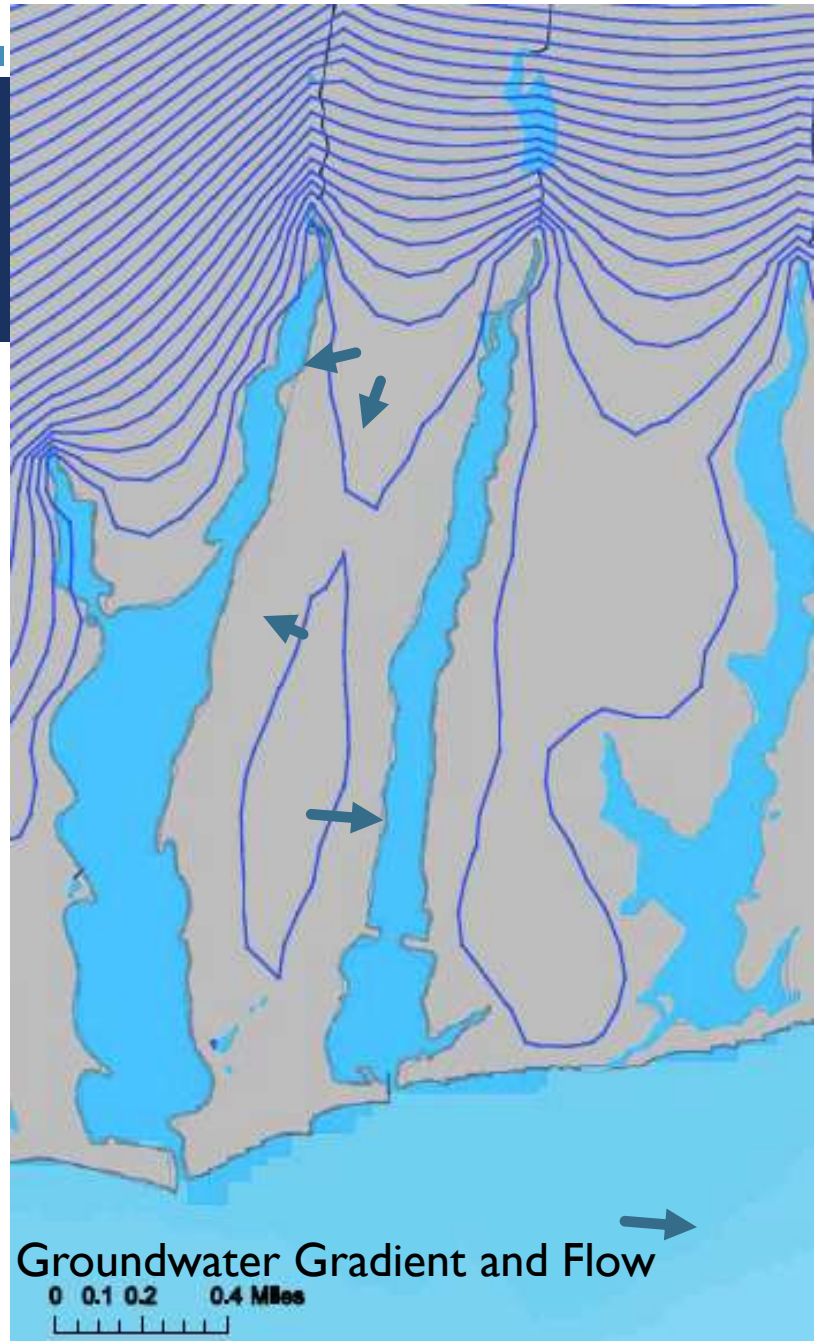


NOT TO SCALE; VERTICALLY GREATLY EXAGGERATED

EXPLANATION

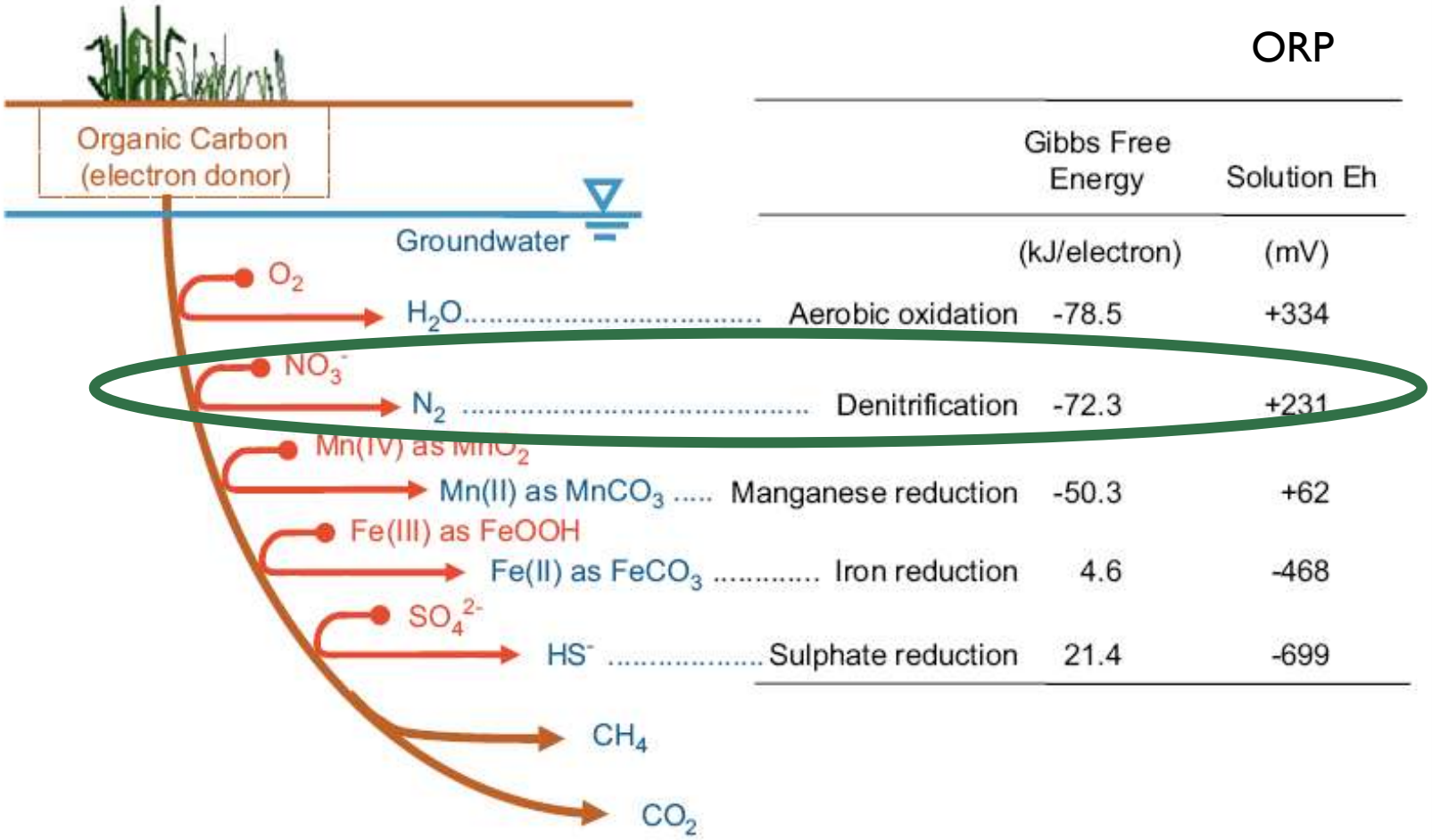
- Freshwater-level indicator
- Saltwater-level indicator

Credit USGS



Credit USGS

GROUNDWATER CHEMISTRY -SIGNIFICANCE OF OXIDATION-REDUCTION POTENTIAL (REDOX CONDITIONS)



ORP

	Gibbs Free Energy (kJ/electron)	Solution Eh (mV)
Aerobic oxidation	-78.5	+334
Denitrification	-72.3	+231
Manganese reduction	-50.3	+62
Iron reduction	4.6	-468
Sulphate reduction	21.4	-699

From Rivett, 2008

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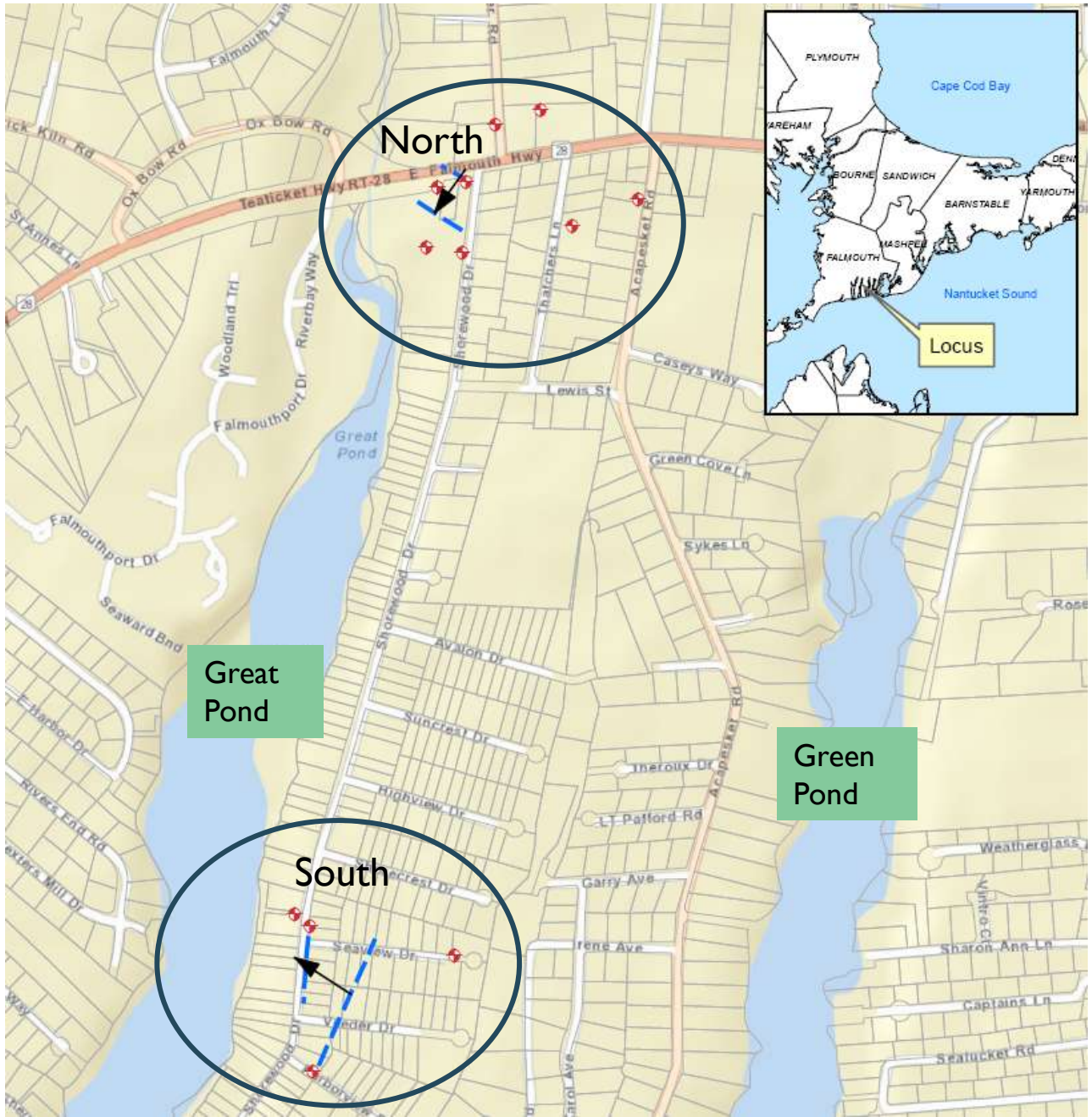
Falmouth Assessment Case Study

2 nearby locations on South Coast

Funding provided by Cape Cod Water Protection Collaborative

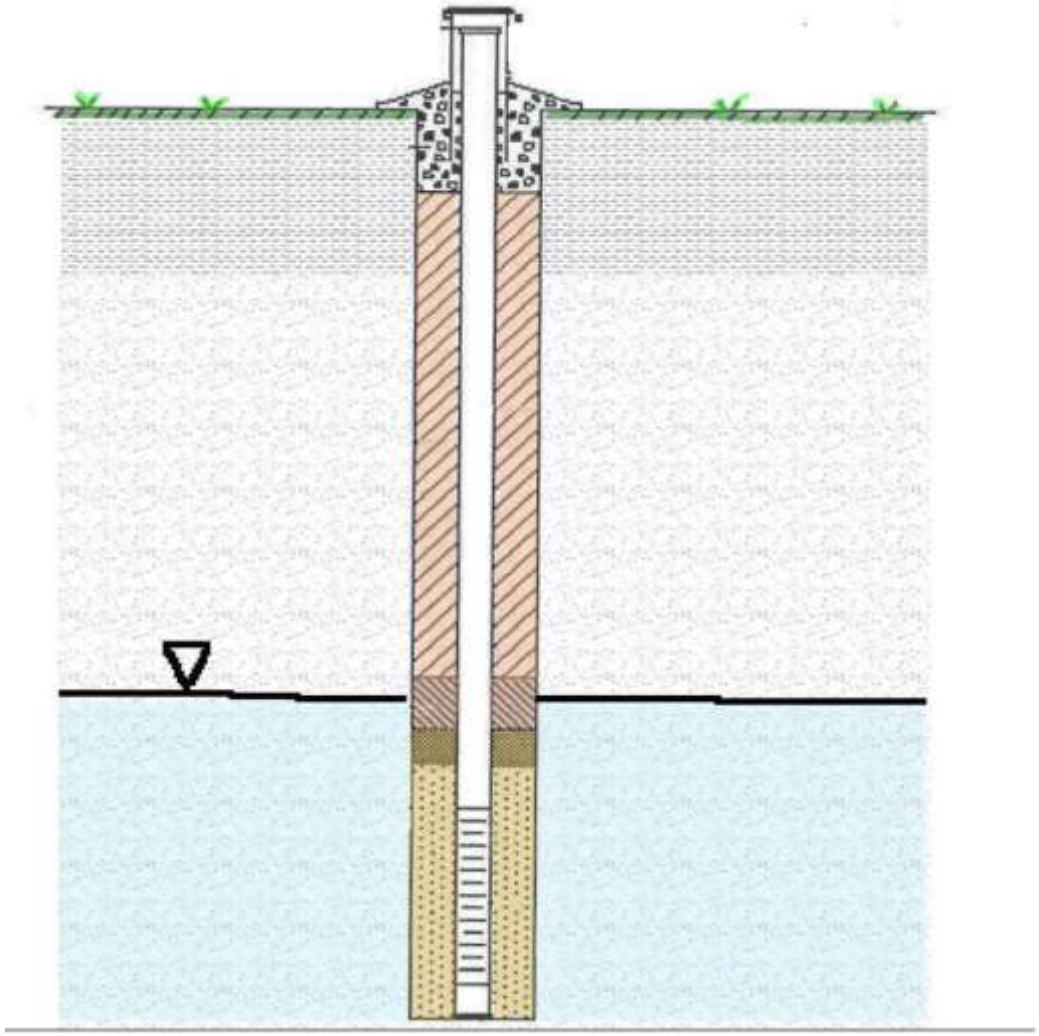


PRB SITE DATA

- Hydrogeology (groundwater flow direction and velocity)
- Groundwater chemistry/nitrogen concentration (effect on biological activity)
- Vertical dimension (low permeability boundary at depth, saltwater interface, or vertical limit of significant nitrogen concentration)
- Flux of nitrogen compounds in groundwater (concentration and flow)

DIRECT PUSH RIG FOR SOIL BORINGS AND WELL CONSTRUCTION

Soil core samples collected to assess aquifer material



2-inch diameter PVC wells - single and multi-level cluster wells installed

Groundwater field testing/sampling for laboratory analyses

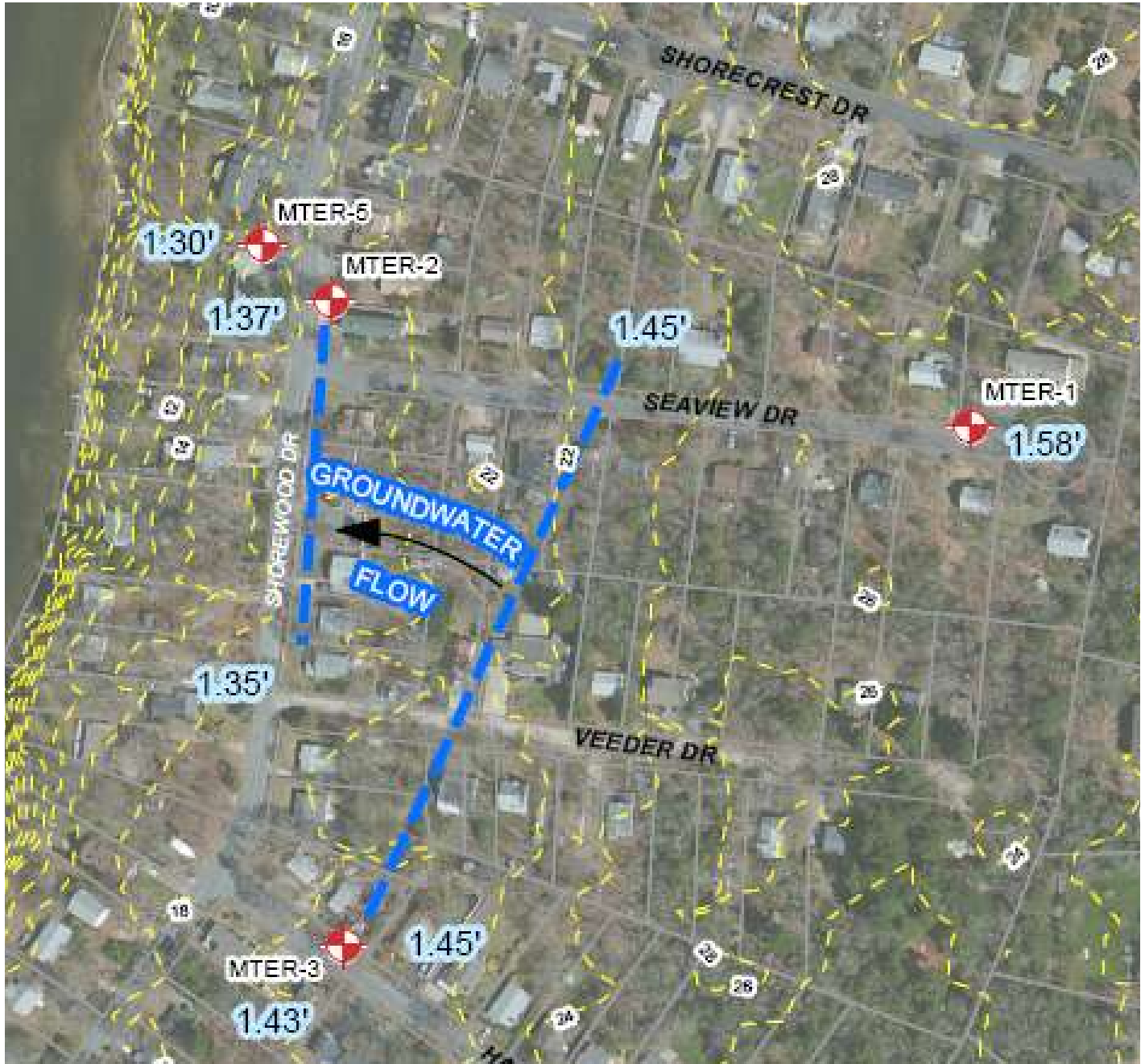
ASSESSMENT: FIELD PARAMETERS MEASURED

- Water temperature
- pH
- Dissolved oxygen (DO)
- Specific conductance (SC)
- Oxidation/reduction potential (ORP)

ASSESSMENT: TYPICAL LABORATORY ANALYSES

- Nitrogen and general chemistry
  - Total nitrogen, ammonia, nitrate, chloride, sulfate
- Dissolved metals and minor elements
  - Iron, manganese, boron
- Dissolved organic carbon

SOUTH SITE ASSESSMENT



SOUTH SITE RESULTS

- The freshwater aquifer is ~ 50 ft. thick in center of the peninsula – saltwater below
- "Island aquifer" with limited upgradient sources of nitrogen
- Aerobic redox conditions
- High hydraulic conductivity medium sand
- Slight groundwater gradient 0.00014 ft./ft. (groundwater velocity is slow 0.088 ft./day to 0.21 ft./day)
- Variable but mainly low nitrate concentration (<1.5 mg/L) with low flow = low flux of nitrate = **not ideal conditions for a PRB**

NORTH SITE ASSESSMENT

Paper Size ANSI B

0 75 150 300 Feet

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane Massachusetts Mainland FIPS 2001 Feet

N

LEGEND

Monitoring Well

Groundwater Contour (June 2016)

Topography

Falmouth Parcels

GHD

M T Environmental Restoration

Molecular Translations, Inc.

Town of Falmouth, Massachusetts
Acapesket Groundwater Investigation

Job Number	86-18162
Revision	A
Date	31 Mar 2017

LOCATION MAP & GROUNDWATER CONTOURS

Figure 2A

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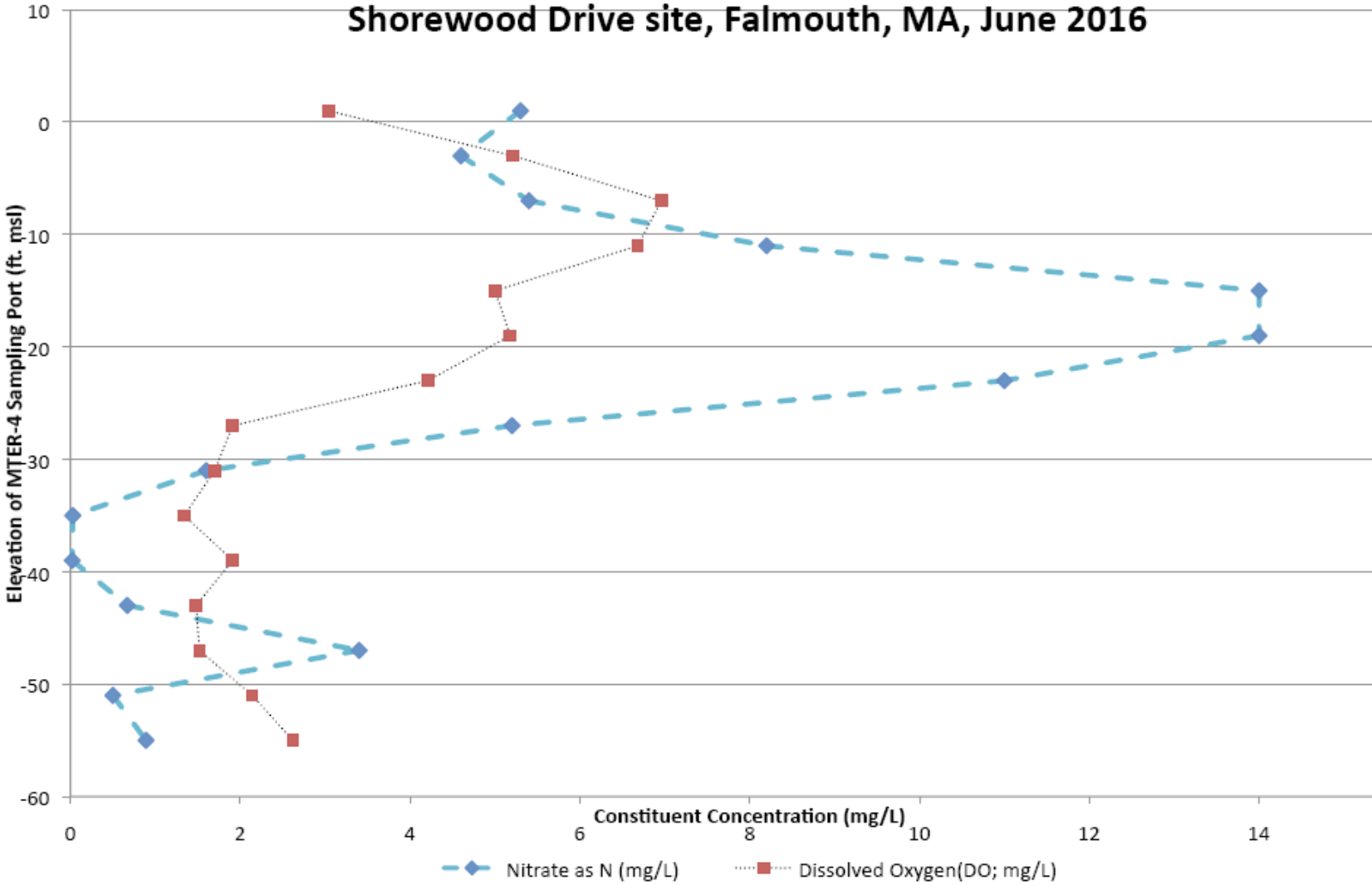
1545 Iyanough Road, Hyannis Massachusetts 02601 USA T: 1 508 362 5680 F: 1 508 362 5684 E: hyannis@ghd.com W: www.ghd.com

NORTH ASSESSMENT

- Assessment completed in 2 phases (iterative approach)
  - initial investigation with limited number of monitoring wells
  - continued assessment to fill data gaps
- EPA Southeast New England Program provided an assist with additional data collection as part of the program implementing site characterizations to support the design of PRBs as pilot technologies
- USGS installed and sampled a multi-port research well (MTER-4) with 14 sampling points to profile groundwater chemistry

Figure 5 - Variation in Nitrate-N and Dissolved Oxygen Concentrations with Elevation at MTER-4 Multiport Well, Shorewood Drive site, Falmouth, MA, June 2016



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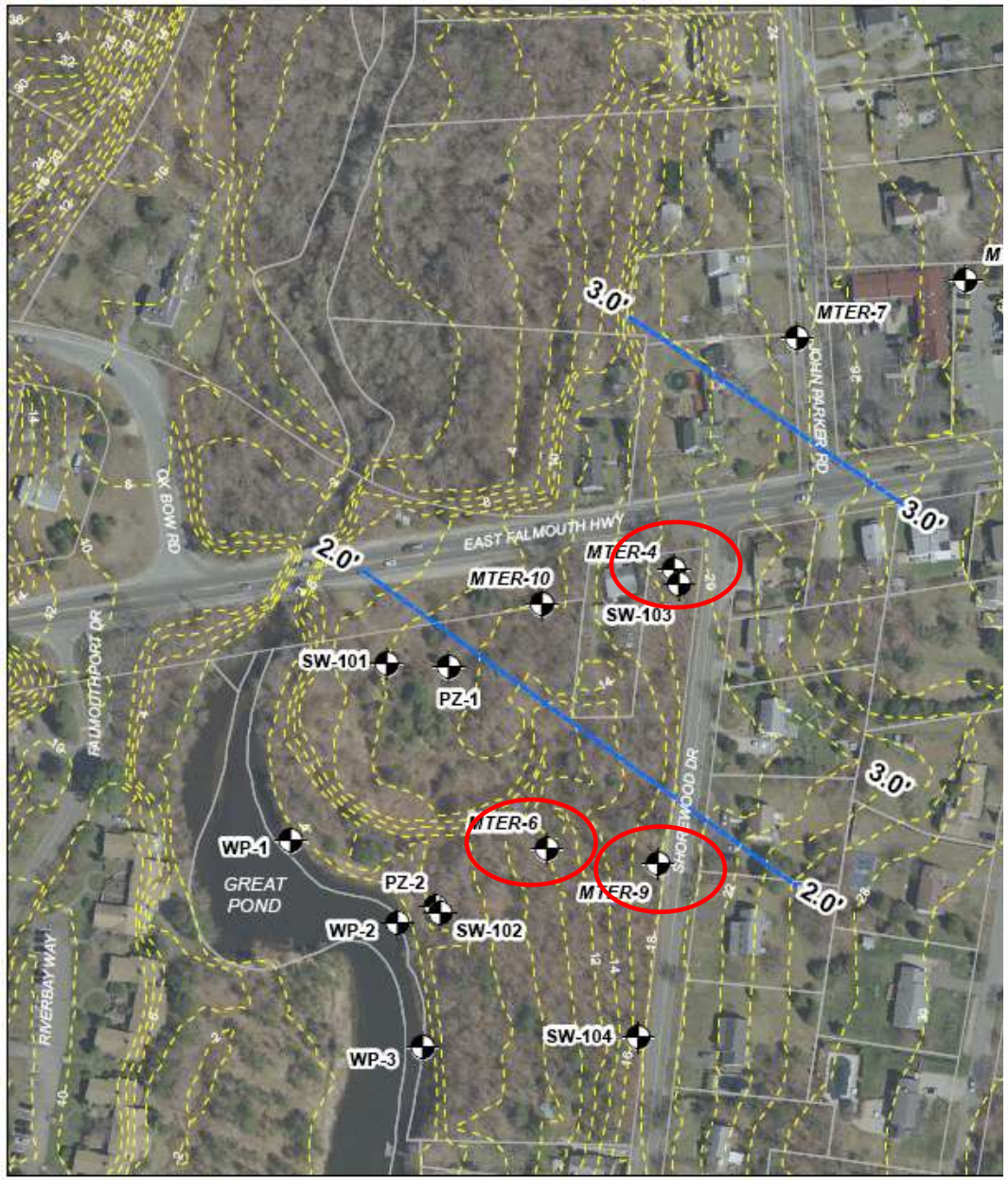

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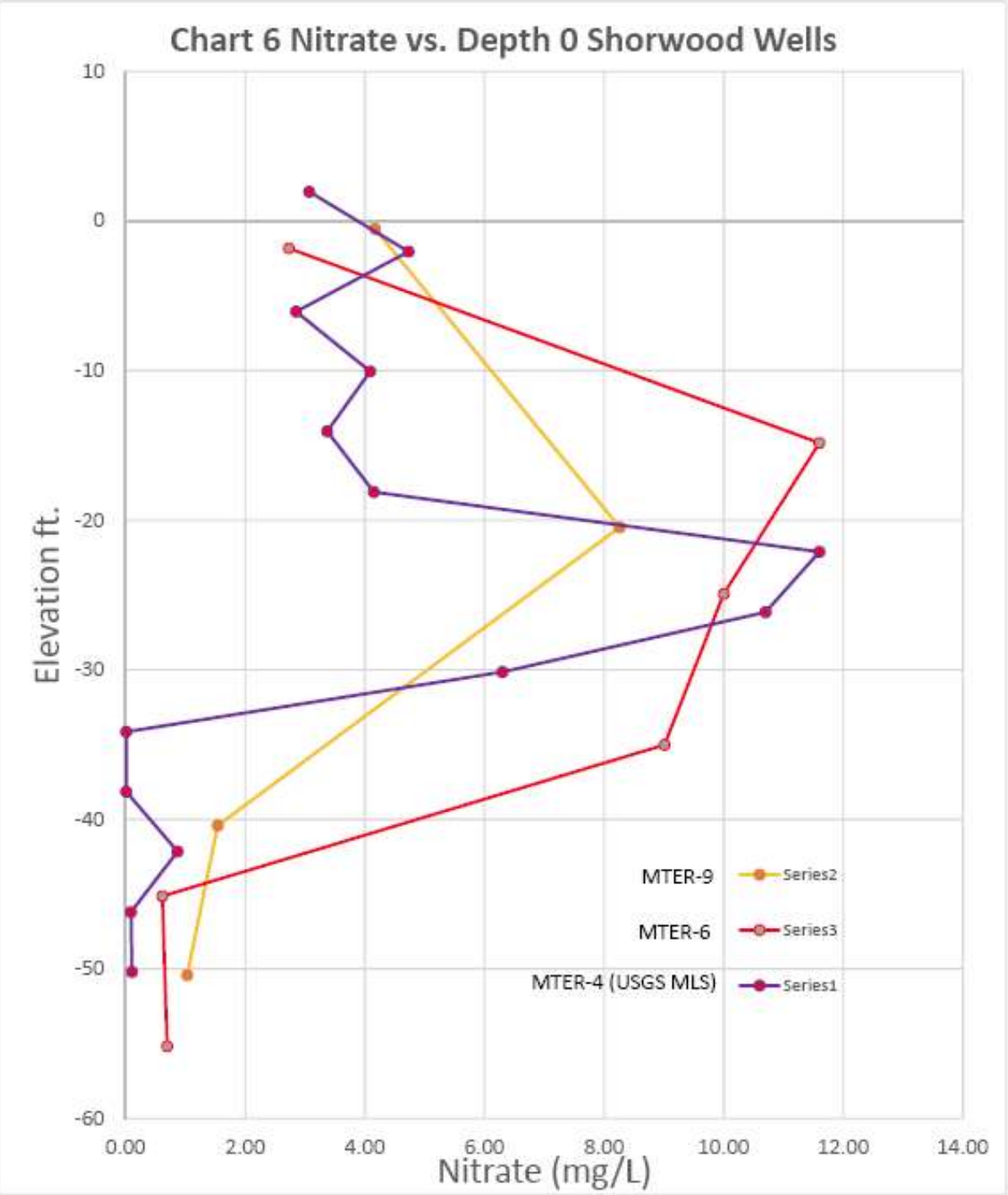

NORTH SITE RESULTS

- Aquifer is >80 ft. thick (drilling limited by gravel at 70 to 80 ft.)
- Groundwater flow to the southwest with significant gradient (I =0.002 to 0.003 feet/foot)
- Permeable medium to coarse sand - groundwater velocity fast (range 2.0 ft/day to 4.0 ft/day)
- Flow from upland area with multiple sources of nitrogen
- Aerobic redox conditions in shallow groundwater and anoxic conditions in deep groundwater
- Significant nitrate concentration (up to 14 mg/L) with defined vertical extent - high nitrate flux = **good conditions for a PRB**

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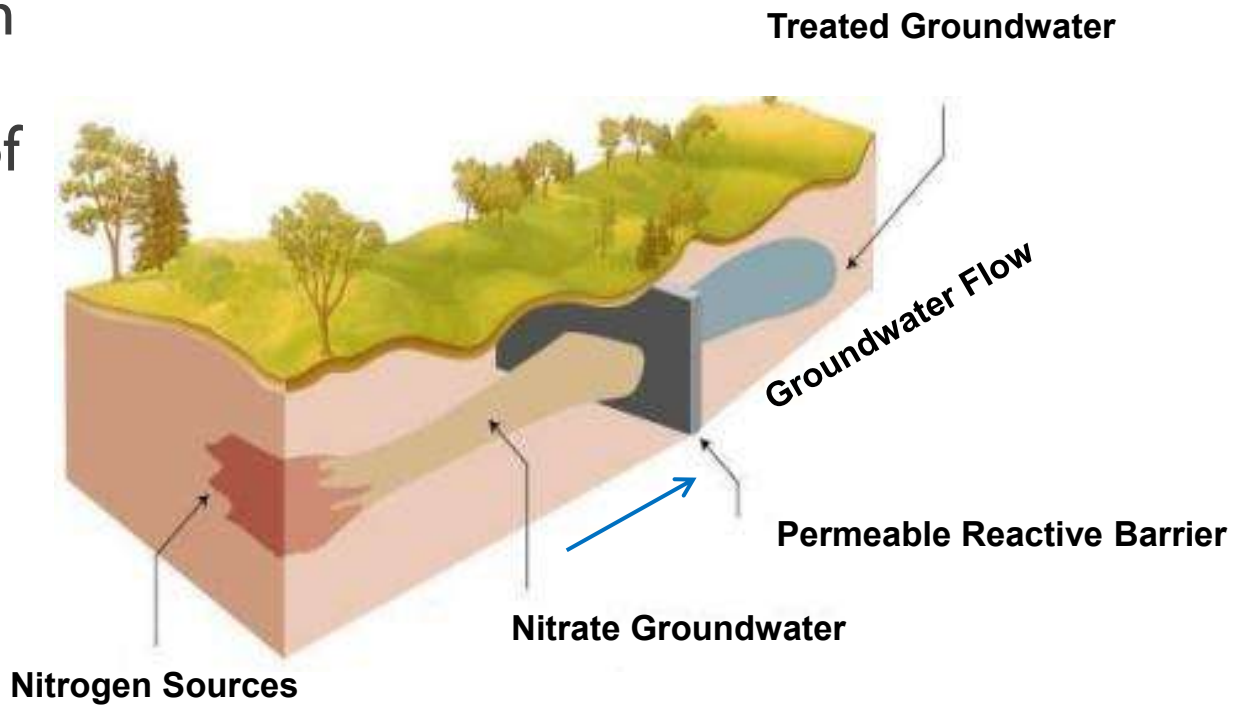
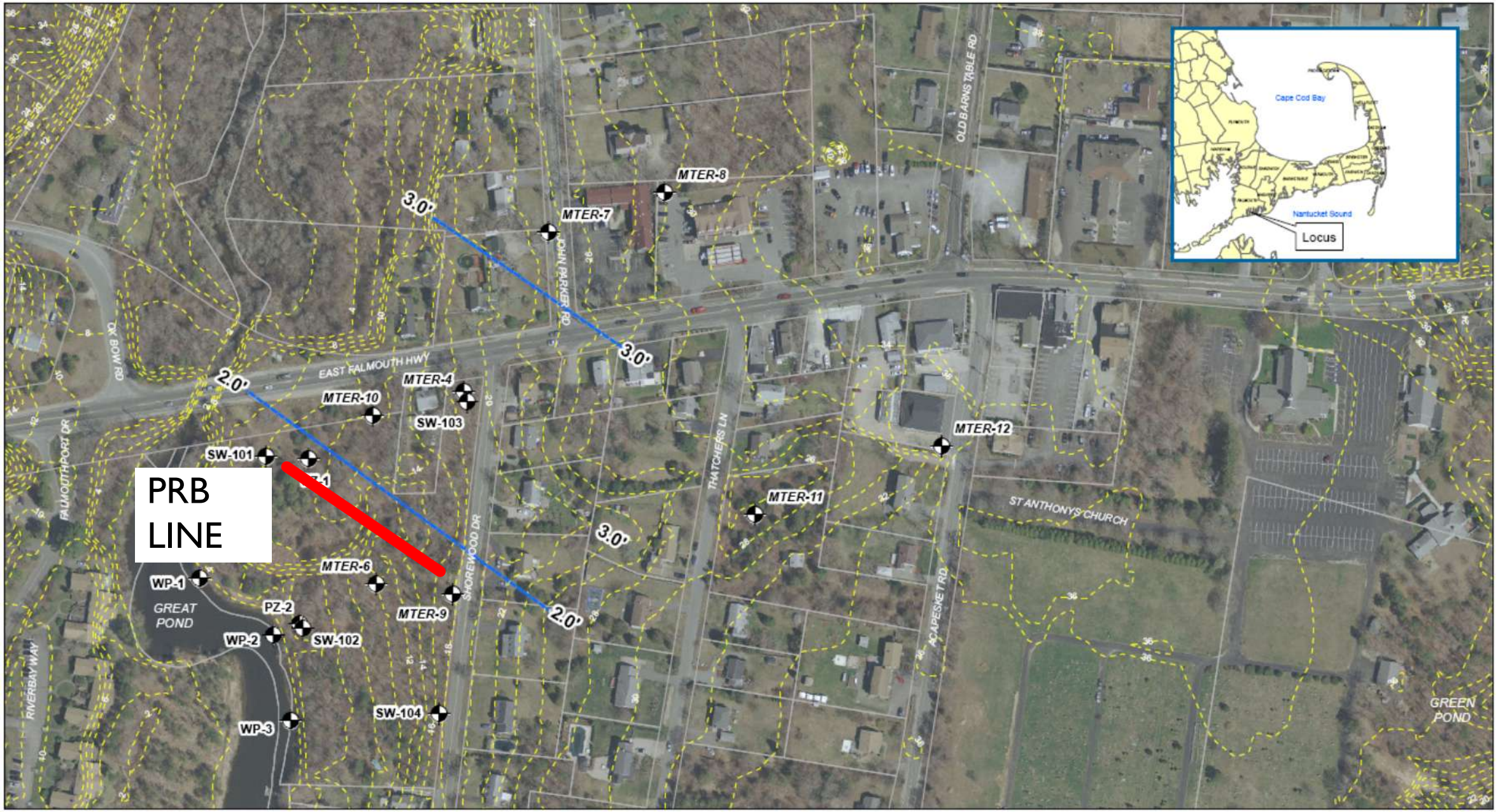
PRB DESIGN

- Select PRB line and target depth
- Determine volume & location of substrate required for optimal system conditions
- Determine optimal substrate emplacement pattern



(ITRC, 2011)



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Questions