The First In-Situ EVO PRB on Cape Cod: From Concept to Implementation in Orleans

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ISOTEC REMEDIATION TECHNOLOGIES

It takes a village

- MT Environmental Restoration
  - James Begley
- ISOTEC
  - Mike Temple, Tom Musser, Marlon Martinez
- AECOM:
  - Tom Parece, P.E., Julianne Marrion, Betsy Shreve-Gibb
- Terra Systems
  - Michael D. Lee, Ph.D., Richard Raymond, Jr., Ph.D., Frederick Hostrop
- Town of Orleans
- Orleans Water Quality Advisory Board
- Mike Domenica, Water Resources Associates

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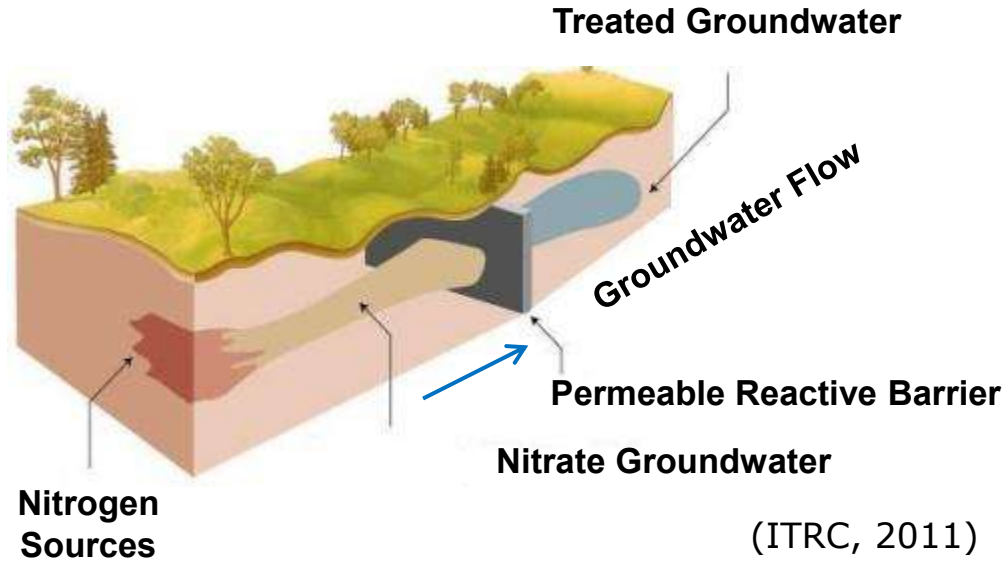
Subsurface PRB

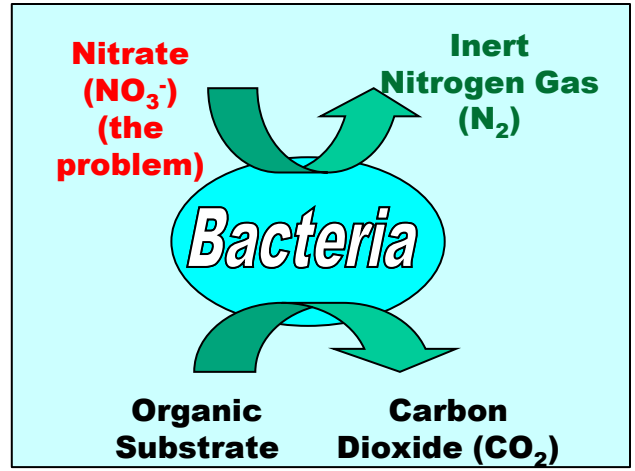
- Permeable
- Reactive
- Barrier



(ITRC, 2011)

(Non) Traditional Technologies

- Objective: minimize area/properties for sewer
- Naturally occurring bacteria convert nitrate to inert nitrogen gas (N_2)
- Denitrifying bacteria are ubiquitous
- Permeable Reactive Barrier
  - Reactive material installed in the path of a plume
  - Reduce nitrate flux into surface water



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Objectives Statement

- Demonstration Test
  - Conduct Testing Representative of Full Scale Application
  - Providing Proof of Nitrogen Concentration and Load Reduction (Extrapolate to TMDL Reduction Targets at Full Scale)
  - Obtaining Data for Engineering Evaluations and Full Scale Cost Estimates
  - Confirm Time Frame for Technology Performance
  - Demonstrate Programs for Performance, Compliance Monitoring, and Assessment of Treated Water Quality.
- Full Scale PRB
  - Significantly Reduce Nitrogen Load to Surface Water Resources
  - Implement Cost Effective PRB Design
  - Evaluate Performance Over Time and Replenishment Frequency

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Demo and Full Scale Siting Evaluation Criteria

- Evaluate Sites
  - 4 major criteria (20 sub-criteria)
- Site Suitability
  - Depth to Groundwater
  - Groundwater Nitrogen Profile (concentration/depth)
  - Groundwater Flow Direction and Velocity
- Permitting
  - Potential Regulatory Concerns
  - Site Use
- Project Evaluation
  - PRB Nitrogen Removal Efficiency
  - Accessible Well Locations
- Other/Overriding Considerations
  - Potential for Watershed/Estuary Impacts
  - Potential for Full Scale Implementation

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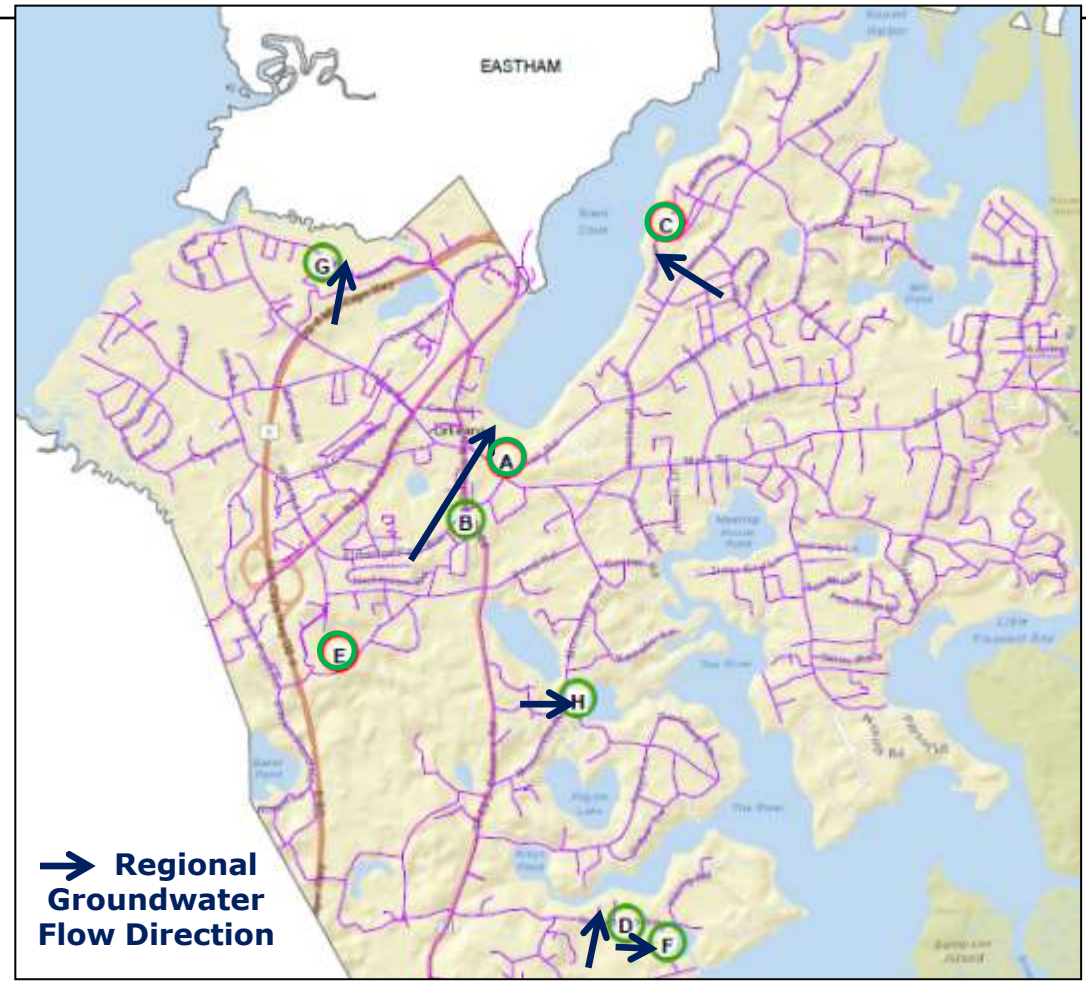
PRB Locations Evaluated

A. Main Street and Tonset Road (Main Street)
B. South Orleans Road at Tonset/Eldredge Parkway (Route 28 site)
C. Town Cove Gibson Road
D. Namequoit Road
E. Town Landfill
F. Paw Wah Pond
G. Rock Harbor Road Area
H. Kescayo Gansett Pond (Lonnie's Pond)



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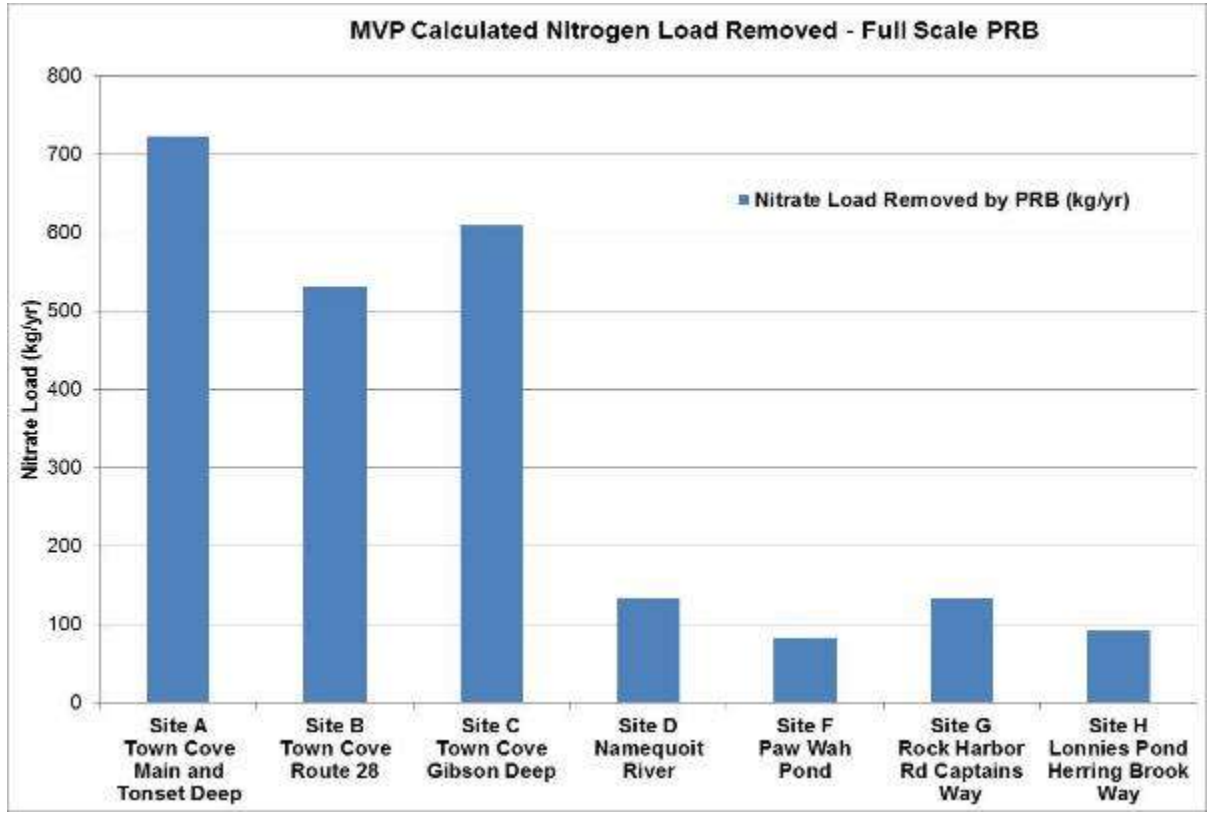
PRB Locations Evaluated – Nitrogen Loads

- WatershedMVP – Tool Developed by the Cape Cod Commission that Estimates Theoretical Nitrogen Load and Potential Reduction at Each Site
- Landfill Not Evaluated by WatershedMVP - Actual Data Necessary



Planning and Design – Field Investigations

- Collect Soil and Groundwater Samples from 4 Highest Ranked Locations
- New multi-depth wells installed
- Sample existing wells
- Measure Parameters to Support PRB Site Selection and Design
  - Vertical Profile of Nitrate (and ammonia) Concentrations
  - Depth to Groundwater
  - Groundwater Flow Velocity
  - Soil Types
  - Other Groundwater Analytes of Interest Include Total Organic Carbon, Metals, Competing Electron Acceptors

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PRB Application Methods

- Trenching
  - Solid Reactive Media (Mulch) Placed in Excavated Trench
  - Trenches 3 to 4 Feet Wide
  - Requires Large Construction Equipment (excavator, trenchers, and/or other earth moving vehicles)
  - Disturbance to Abutters, Traffic and Utilities
  - Requires Future Rejuvenation (Often by Injection)
- Injection/Soil Boring
  - Liquid Amendments/Solid Amendments Placed in Soil Borings
  - No Limitation on Depth
  - All Pumps and Mixing Tanks Centrally Located
  - Only Hoses and Adaptors at Each Point
  - Hose Ramps Can be Used to Keep Street Open to Traffic, if necessary.
  - Limited Disturbance

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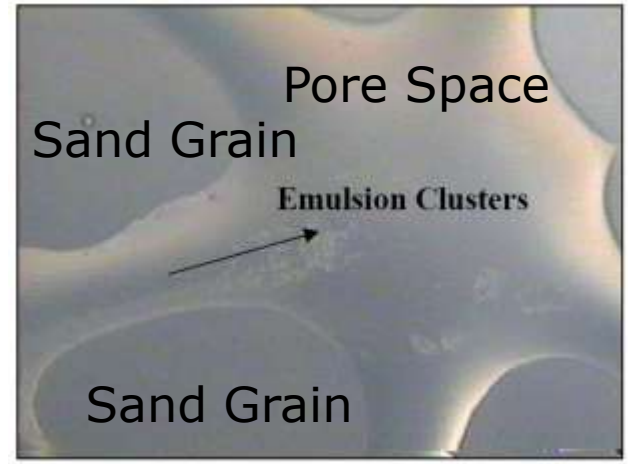
Emulsified Vegetable Oil

- Emulsified Vegetable Oil is a food-grade substrate made with soybean oil (oil-in-water emulsion with consistency similar to soy milk)
- Emulsion slowly releases dissolved organic carbon and provides a long term carbon source for denitrifying bacteria
- Emulsions are designed to be immobile once injected into groundwater
- Commonly used for in-situ treatment
- AECOM experience at 10s of sites – emulsion never travels more than 100 feet (mostly less than 20 feet)



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Denitrification PRB – Challenges

- Public concerns
  - Injecting oil?
  - "hazardous waste site"
  - Migration of oil
  - Impacts to surface water
- Design & Implementation Challenges
  - Depth to groundwater: 35–75+ feet bgs in Orleans
  - High groundwater velocity
  - High fluxes of oxygen and nitrate (20-40+ mg/L)
  - Vertical Treatment Interval
  - Highly developed region
  - Persistence/rejuvenation frequency
  - Ability to effectively monitor groundwater
- Cost/Funding

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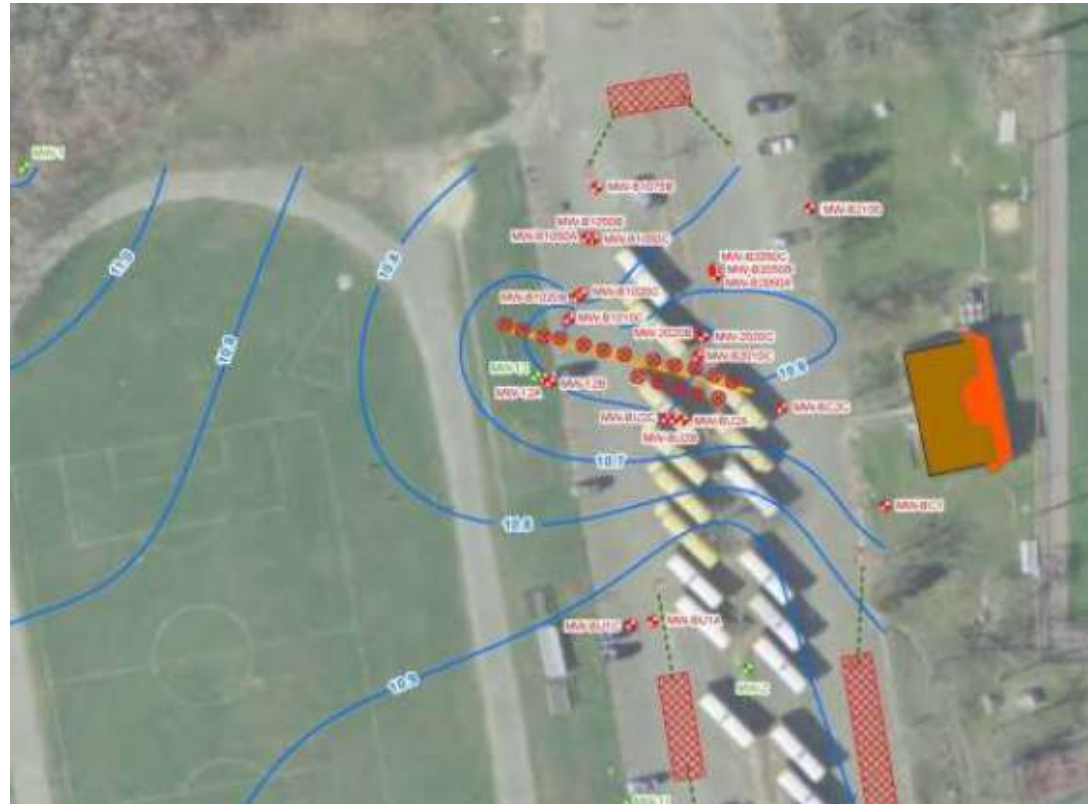
Bench Scale Testing

- Optimal Reagent
  - Long Lasting
  - Slow Release
  - Does Not Migrate
- Can the emulsified vegetable oil be made stickier?
- High Flow Column Tests
- Formulation with anionic surfactant retained on soil matrix better than standard EVO
  - Selected for use for Field Demonstration Test

Field Demonstration Test Site

- Recommended Site = Middle School Parking Lot
  - Access
  - 5 years of GW data
  - DTW ~ 35’ bgs
- Storm water drains and irrigation wells impact flow direction
- Objective
  - 3 year persistence



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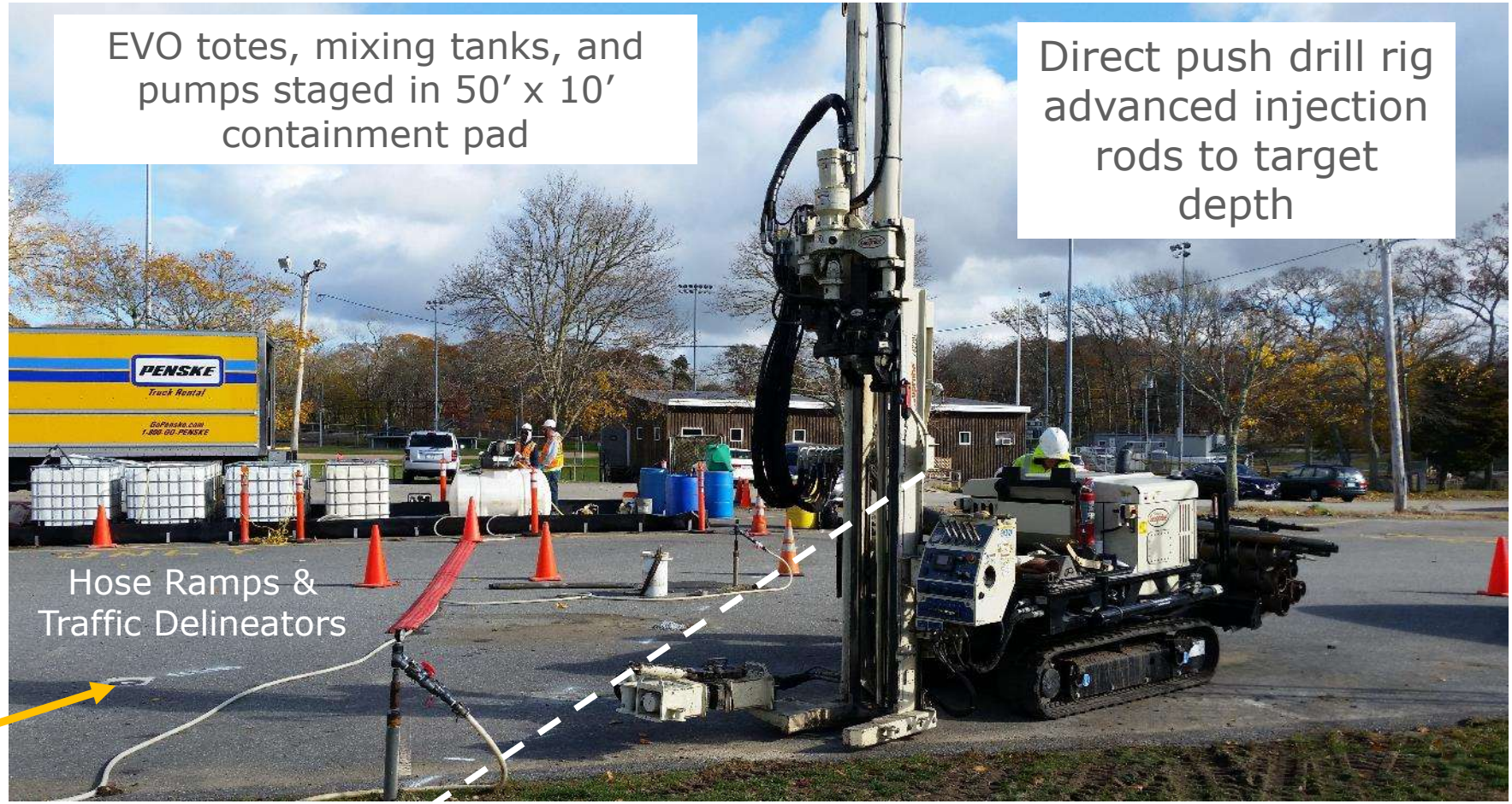
Field Demonstration Test Design

- 110 foot PRB
- 17 Injection Points
  - 1 and 2 rows of points
  - 10 foot spacing
  - 36 to 68 feet bgs
- Monitoring well network
  - Upgradient
  - Downgradient
  - 10-75 feet from PRB
- 14% pore volume target
- 10,800 gallons injected
- SRS-NR (14%)
  - Diluted 4.3:1 in field

PRB Demonstration Implementation

PRB Injection Completed week of November 14, 2016



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PRB Demonstration Implementation

PRB Injection Completed week of November 14, 2016

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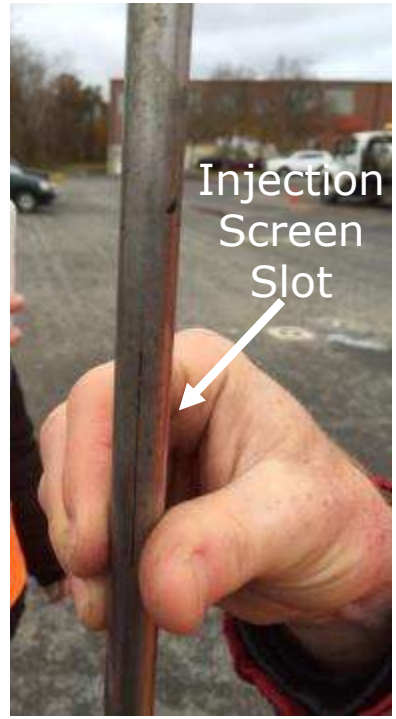
ISOTEC – Delivering Treatment

- Proprietary injection screens
  - Laser-cut stainless steel injection screens
  - Pressurized jet flow with uniform discharge across screen interval
    - small diameter [1 cm] - <0.05 gallon fills the screen
  - Screen lengths 4 and 8 feet used at Orleans
  - Low pressure injections (generally 0-10 psi)



Eldredge Park PRB Groundwater Monitoring

- Prior to injection – baseline sampling
- During injection to monitor distribution
- Initial post-injection sampling in early January 2017
- 1st quarterly sampling round late February 2017

Field Measurements
pH (SU)
Temperature (°C)
Dissolved Oxygen (DO, mg/L)
Redox Potential (ORP; mV)
Specific Conductivity (µS/cm)[c]
Turbidity (NTU)
Laboratory Analyses
Nitrogen
Nitrate as N (mg/L)
Nitrite as N (mg/L)
Ammonia (mg/L)
Total Kjeldahl Nitrogen (TKN) (mg/L)
Total Nitrogen (mg/L)
Anions
Chloride (mg/L)
Sulfate (mg/L)
Elements
Dissolved Iron (mg/L)
Dissolved Manganese (mg/L)
Boron (mg/L)
Other
DOC (mg/L)
Methane (µg/L)
Alkalinity as CaCO3 (mg/L)

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Eldredge Park PRB Monitoring

- Initial testing of PRB monitoring wells - baseline concentrations measured as high as 35 mg/L nitrate-nitrogen
- Wide range of nitrate concentrations at different sampling locations
- No migration of EVO detected during injection (monitoring turbidity and dissolved organic carbon 7, 10, 20, 50 and 100 ft. downgradient)
- Initial monitoring indicates positive developments at some of the downgradient wells

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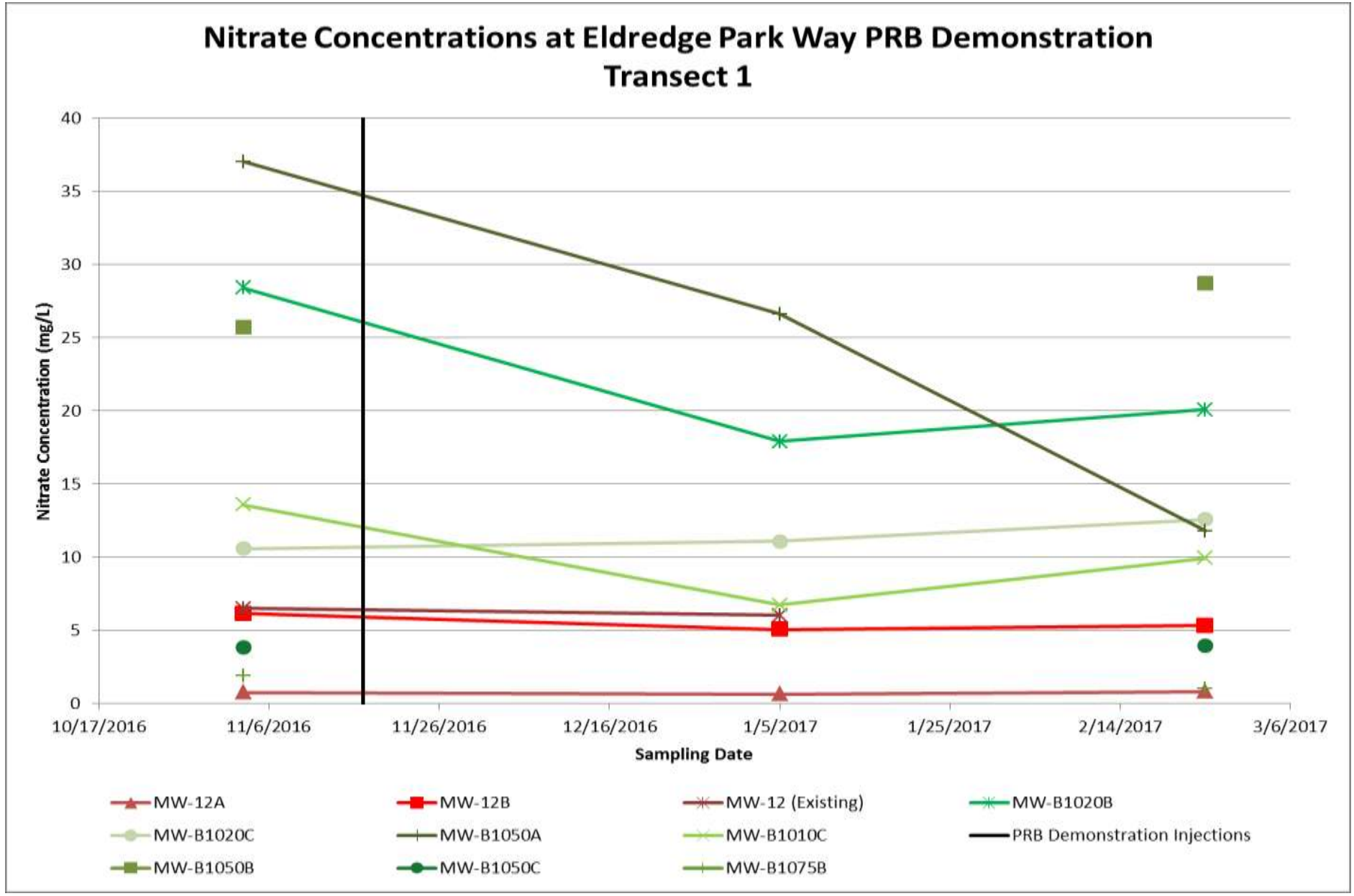
Eldredge Park PRB – Preliminary Data



Costs

- Demonstration Test Injection by ISOTEC = $63,000
- Different Cost Measures
  - Cost per linear foot
  - Cost per kilogram nitrate removed
  - Construction Costs
  - Monitoring Costs
  - Rejuvenation Costs
- 20 year costs
  - Nitrate flux sensitivity
  - Rejuvenation frequency
- Compare non-traditional costs to conventional treatment costs

All Done


Questions?
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