FALMOUTH
PERMEABLE REACTIVE BARRIER PLANNING

USING PERMEABLE REACTIVE BARRIERS TO ADDRESS NITROGEN POLLUTION

APRIL 5, 2017

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Science Wares, Inc.

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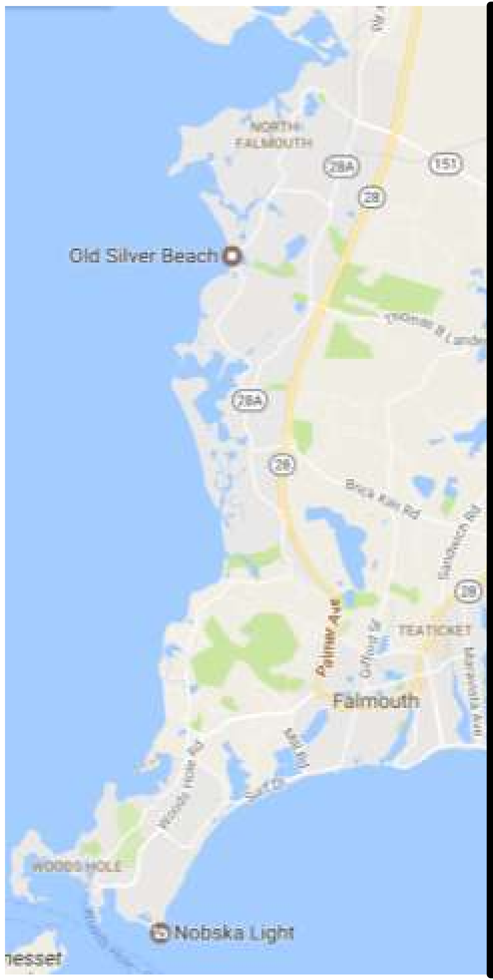
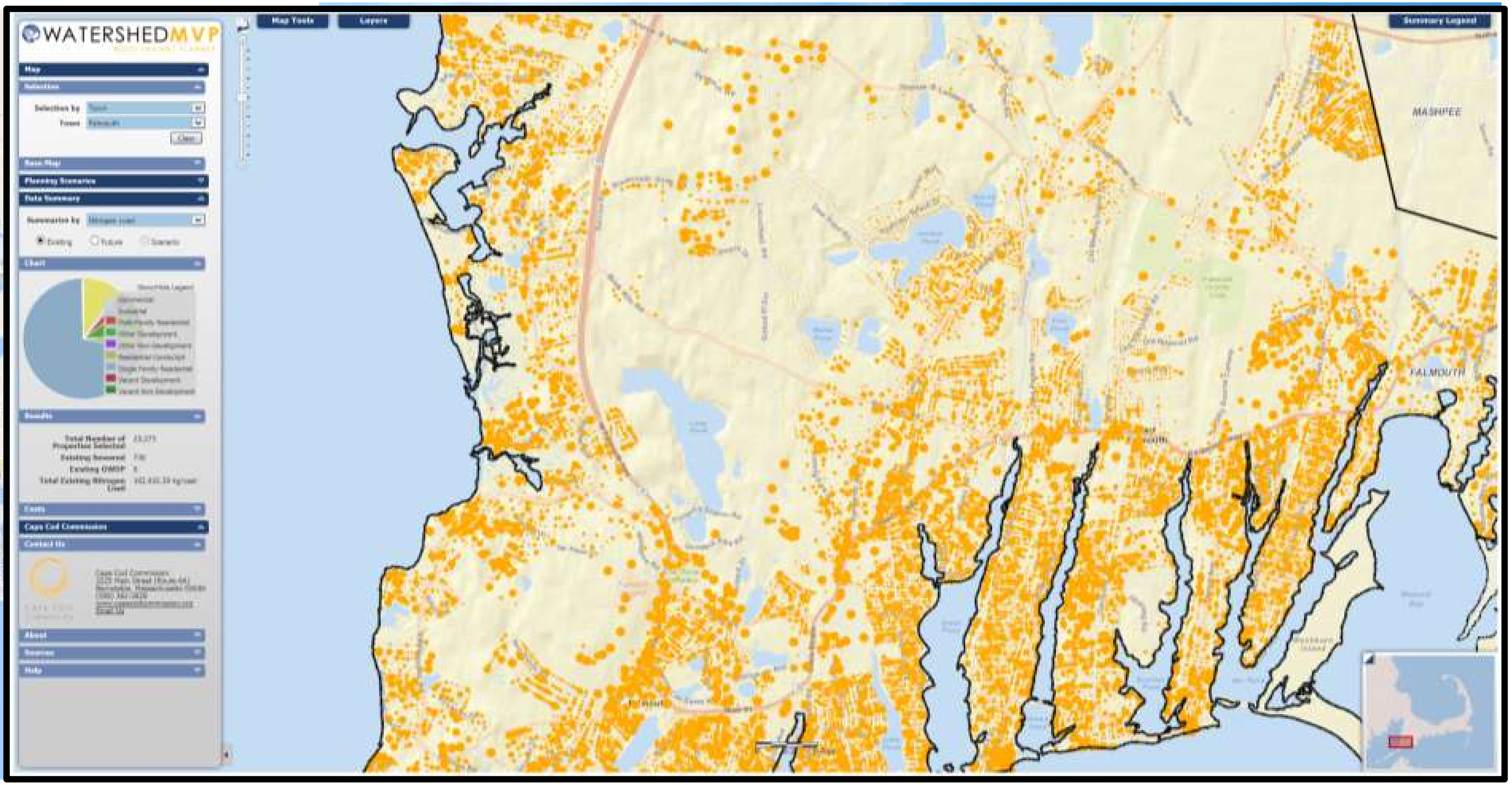
MT Environmental Restoration

FALMOUTH'S ESTUARIES





PLANNING HISTORY FOR FALMOUTH

- Water Quality Management Committee established by Town Meeting in 2011 to focus on wastewater planning alternatives. Working Groups consist of 3 members who focus on different alternatives.
- April 2011 Town Meeting unanimously appropriated $2.77 million to proceed with sewer design and alternative demonstration projects. Ballot vote passed by a 2:1 margin. This allocation has leveraged over $500,000 in grant funding.
- January 10, 2014, Certificate of Adequacy issued for Falmouth's Final Comprehensive Wastewater Management Plan (CWMP) that endorsed sewering the Lower Little Pond watershed and gave the Town 5 years to evaluate alternatives. These alternatives include:

  Permeable Reactive Barriers

  Innovative/Alternative (I/A) Septic Systems

  Shellfish Cultivation

  Bournes Pond Bridge Replacement and Inlet Widening

  Nitrogen Control By-Law for Fertilizer

PRB PLANNING (LEARNING) PROCESS

- Starting in 2012, Falmouth Water Quality Management Committee worked with CDM Smith to evaluate potential PRB locations
- Town-wide evaluation at the watershed level
- Evaluation approach driven by installation paradigm
  - Trenching and wood chips
  - Ringing peninsulas

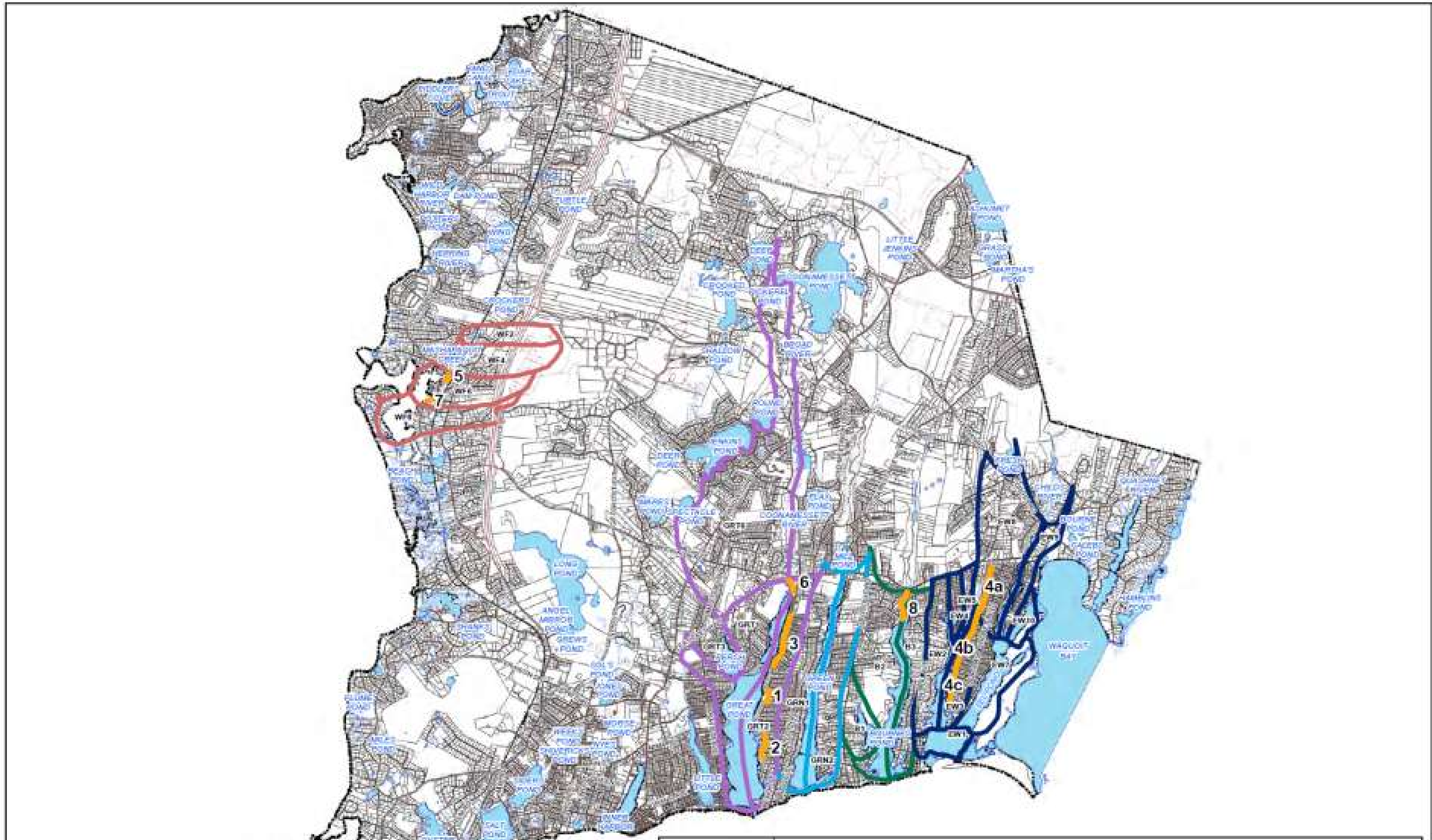
SITE EVALUATIONS

- Important Siting Considerations (CDM Smith Technical Memorandum 1, March 2013)
  - Most relate to characteristics of groundwater and soils
  - Evaluation approach based on information on land use and limited field data
    - High density residential areas
    - Plume from Wastewater Treatment Facility

Design and Siting Considerations for Nitrate PRBs

Criteria	*Significance of Criteria*
Hydrogeological	Understand groundwater flow to properly intercept plume
Geochemical impacts	Account for interactions with the geochemical composition of the aquifer
Nitrate concentration	Position PRB to target highest concentrations
Competing contaminants	Important to understand if competing chemicals exist in the aquifer
Appropriate media type	Choose media that will best reduce nitrate concentration at the chosen location
Proximity to tidal area	Salt water intrusion may negatively impact system longevity, increasing ammonia/ammonium and hydrogen sulfide production
Dimensions of plume	Total depth >45 feet to base of contamination is beyond practical depth of trenching or excavation using the one-pass method. May lead to consideration of injection methods[1]
Infrastructure and land use	Buildings or utility lines that cannot be breached may leave gaps in the PRB. May lead to consideration of injection methods[1]
Soil types in aquifer	Will affect permeability, best case is homogeneous soils[1]
Stratigraphy	Best if PRB extends to confining layer of aquifer[1]
Hydraulic conductivity (K)	Important that PRB does not significantly affect the hydraulic conductivity of the aquifer. Best if K of surrounding aquifer is < 1.0 ft/day. Depending on the contaminant flux and reactivity of the media, higher velocities may be accommodated. Multiple sets of PRBs spaced along the axis of the plume could be used to provide greater net residence time.[1]
pH of aquifer	Best if pH is neutral[1]
Dissolved oxygen (DO) concentration	Ideal DO concentration is < 4.0 mg/L[1]
Sulfate concentration	Lower initial concentration is desirable so that ammonia/ammonium production is minimized, also useful life of PRB is lengthened due to less competition for substrate
PRB width	The thickness of the PRB is designed based on the required residence time of the contaminants and the groundwater flow velocity. Simple estimation of thickness is (V)*(t) where V is the groundwater flow velocity and t is the residence time.[1]

1. The Interstate Technology & Regulatory Council, 2011



Town of Falmouth, MA

PRB Demonstration Project

PRB Locations to Screen in Next Phase

Figure ES-1
Date: 2/12/2014

Legend

- **PRB Locations to Screen in Next Phase**
- Bournes Pond
- Eel Pond and Waquoit West
- Great Pond
- Green Pond
- West Falmouth Harbour
- Town Boundary
- Lake/Pond
- Stream
- Wetland
- Roads
- Parcel Boundary

0 2,000 4,000 8,000 Feet

1 inch = 5,000 feet

Basemap: Planimetric GIS layers
Sources: Town of Falmouth
Coordinate System:
NAD83 Mass. State Plane Mainland FIPS 2001 (Feet)
Vertical Datum: NGVD 29

Subwatersheds		Locations	
No.	Description	No.	Description
GRT1	Great Pond East Peninsula	1	GRT1 - Mid (Private sand): good location; at water and relatively open; could have good access to upgradient and downgradient monitoring wells. This location is the clubhouse area at Great Harbors. The USGS also has a monitoring station here for the summer. Good open stretch along coastline.
GRT1	Great Pond East Peninsula	2	GRT1 - South: relatively open and flat. Could be paper road going south, possibly owned by Conservation Commission; could be a good site; actually called Shorewood Avenue.
GRT2	Great Pond East Peninsula	3	GRT2 - North (Shorewood Beach Association): Flat, above watertable but not too high where Shorewood Drive dead ends at Edgewood Drive. Shorewood Drive - most likely a privately owned road, which could prove difficult in obtaining permission for PRB installation; southern portion of this location would capture more homes.
EW3	Eel Pond West Lower East Peninsula	4a	EW3 - Edgewater Drive West. Columbus Drive south to Seapine.
EW3	Eel Pond West Lower East Peninsula	4b	EW3 - Varies in elevation frequently but could potentially work. Could capture flow from a number of homes; has "demonstration potential" and also brings in Cape Cod Commission's "shared watershed" interest and also prior work by CCC and Nitrex demo associated with Seacoast Shores.
EW3	Eel Pond West Lower East Peninsula	4c	EW3 - Edgewater Drive West - Knollwood Drive south to Ormond Drive. Close to groundwater divide so likely site for expansion.
WF6	Snug Harbor 1710	5	50 - 75+/- Nashawena Street. Very close to the coastline and thus the WWTF NO_3 plume is shallow there due to the saltwater/freshwater interface. In addition, this site is within Subwatershed WF6, in which the core portion of the plume is located. Site is flat but some big trees.
GRT2	Great Pond East Peninsula	6	Old MRF Site. South side of Route 28 and east side of Coonamessett River. A significant drop-off however it would be an excellent location for treating upgradient, southward flowing groundwater with NO_3 plume. Proponents designed a constructed wetland for this location.
WF6	Snug Harbor 1710	7	Old Dock Road. Only about 30' in length vs. Site No. 5, but town-owned and no wetlands; however, not in core of plume.
B2	Bournes Pond West Peninsula	8	Carter Conservation Parcel. Significantly long strip of town-owned land, downstream of dense development at the headwater of Bourne's Pond.

CDM Smith

SITE EVALUATIONS

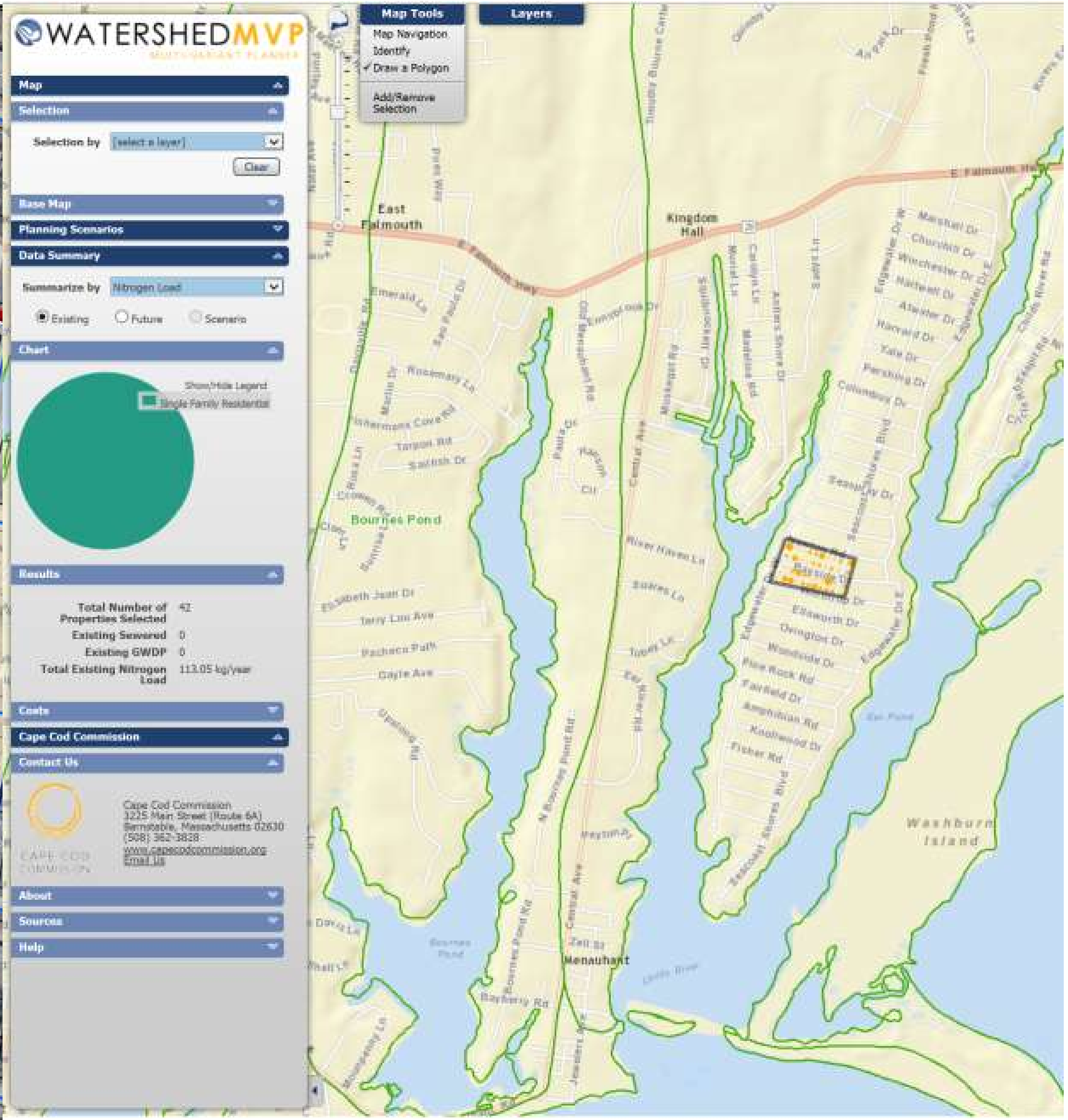
- **Narrowing the possibilities using CDM Smith matrix**
  - **Accessibility**
  - **Replicability**
  - **Ease of monitoring**
  - **Nitrogen-removal and expansion**
  - **Permitting**
  - **Non-starters**

Screening Step	Criteria	Description	
(3a) Refined potential PRB Locations to 3 demonstration sites	(3.1) Site Accessibility	An evaluation of topography, roadway access, and presence of extensive vegetation. Sites that are relatively flat, easily accessibly, and with limited need for vegetation removal will receive a higher score	H M L
	(3.2) Non-Starters	Identification of "non-starters" such as areas within a salt marsh, ACEC, Zone II areas, locations downstream of private drinking water well locations, or other sensitive resources. Locations with any of these restrictions are non-starters	H L
	(3.3a) Applicability to Other Sites	Ability to replicate PRB at other sites in Falmouth. Sites that capture common themes in Falmouth (i.e. housing densities, depth to groundwater, proximity to estuaries, etc.) will be ranked higher. These common themes will emerge through the two screening steps above	H M L
	(3.4) Potential for Utility Conflicts	Locations that pose potential utility conflicts will increase the difficulty of PRB installation, especially one-pass trenching. Sites with no utility conflicts receive a higher score	H M L
	(3.5) Costs/PRB Installation Method	Capital (based on casings vs. one-pass method); higher costs will receive a lower rating	H M L
	(3.6) Ease of Monitoring	Sites that allow relatively easy access for monitoring well and probe installation, periodic monitoring equipment maintenance, and regular data collection will receive a higher score. Additionally sites with town owned land 5-15' up and downgradient and ~50' downgradient will receive a higher score	H M L
	(3.7) Expansion Potential	Sites with adjacent nitrogen plumes and similar site characteristics that allow for ease of expansion will receive a higher score	H M L
	(3.8) Potential TMDL Credit	Based on current zoning information, assumed build out and potential length of PRB for GW capture. Sites located in and around smaller class C zoning areas will receive a higher score because of the denser housing. Additionally sites with expansion potential will also increase the score for this criteria due to greater GW capture	H M L
	(3.9) Permitting Requirements	For the demonstration projects, sites with limited permitting needs will receive higher scores. Sites adjacent to wetlands receive a lower score	H M L

THREE SITES SELECTED

- Detailed analysis for 3 sites
  - Estimated depth to groundwater and thickness of aquifer (no wells)
  - Nitrogen-removal based on upstream septic load for two densely developed residential areas
  - Wastewater Treatment Facility plume was third site evaluated

Ground Elevation: 12ft
Depth of PRB: 47ft
Proposed Length: 525ft
NEWTON RD
Ground Elevation: 18ft
Depth of PRB: 53ft
Potential Nitrogen Capture Zone
Ground Elevation: 15ft
Depth of PRB: 50ft
Potential PRB Location
BAYSIDE DR
Ground Elevation: 12ft
Depth of PRB: 47ft
Total Depth: 36
Water Level: 23
WINTHROP DR
ELLSWORTH DR



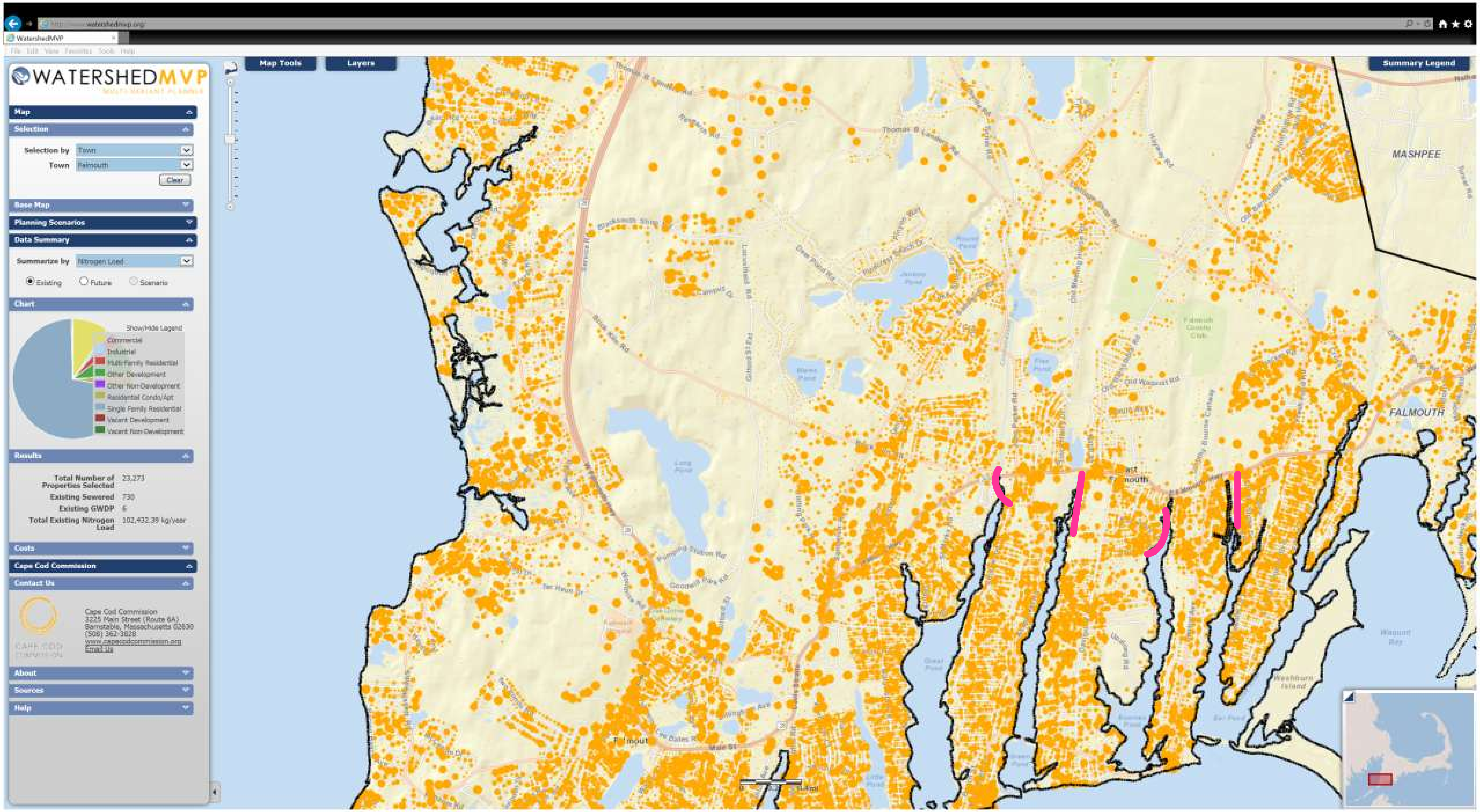
WATERSHED MVP
MULTI-VARIANT PLANNER
Map
Selection
Selection by [select a layer]
Clear
Base Map
Planning Scenarios
Data Summary
Summarize by Nitrogen Load
Existing Future Scenario
Chart
Show/Hide Legend
Single Family Residential
Results
Total Number of Properties Selected 42
Existing Sewered 0
Existing GWDP 0
Total Existing Nitrogen Load 113.05 kg/year
Costs
Cape Cod Commission
Contact Us
Cape Cod Commission
3225 Main Street (Route 6A)
Barnstable, Massachusetts 02630
(508) 362-3828
www.capecodcommission.org
Email Us
About
Sources
Help
Map Tools
Layers
Map Navigation
Identify
Draw a Polygon
Add/Remove Selection
East Falmouth
Kingdom Hall
E Falmouth Hwy
Bournes Pond
Washburn Island
Menauhant

INITIAL RESULTS

- Total depth of PRB over 40 feet in all cases
  - Trenching impractical for required depths and density of development
- Nitrogen removal moderate
- Cost estimates based on:
  - Injection wells
  - PRB installed from ground elevation to saltwater interface
  - Extensive monitoring
- $/kg high

PARADIGM SHIFTS

- 2012
  - Trenching and wood chips
  - Ringing peninsulas
  - Reach saltwater interface
- 2015
  - Injection wells and Emulsified Vegetable Oil (EVO)
  - Areas of high nitrogen concentration and flux
  - Groundwater and soil characterization
  - Not capturing entire cross-section of groundwater to saltwater interface



WATERSHEDMVP
Map Tools
Layers
Summary Legend
Map
Selection
Selection by Town
Town Falmouth
Clear
Base Map
Planning Scenarios
Data Summary
Summarize by Nitrogen Load
Existing
Future
Scenario
Chart
Show/Hide Legend
Commercial
Industrial
Multi-Family Residential
Other Development
Other Non-Development
Residential Condo/Apt
Single Family Residential
Vacant Development
Vacant Non-Development
Results
Total Number of Properties Selected 23,273
Existing Sewered 730
Existing GWDP 6
Total Existing Nitrogen Load 102,432.39 kg/year
Costs
Cape Cod Commission
Contact Us
Cape Cod Commission
3225 Main Street (Route 6A)
Barnstable, Massachusetts 02630
(508) 362-3828
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FROM PLANNING TO IMPLEMENTATION